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CARBONATE STRATIGRAPHY AND
PETROLOGY: ROBB LAKE
ZINC-LEAD PROPERTY,
NORTHEASTERN BRITISH COLUMBIA

by

ALBERT HAZEN TAYLOR

A.B., B.Sc.

A thesis submitted to the
Faculty of Graduate Studies and Research
in partial fulfilment of the requirements
for the degree of Master of Science

Department of Geology

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The undersigned recommend to the Faculty
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ABSTRACT

On the Robb Joint Venture Property, northeastern British Columbia, the carbonate rocks lying between the Silurian Nonda Formation and the largely Upper Devonian Besa River Formation can be divided into four stratigraphic units. The major disconformity at the base of this sequence is overlain by about 200 feet of marine shoreline deposits ranging from quartz-sandy dolostone to nearly pure quartz sandstone. A second unit, about 1000 feet of dolostone, was deposited following a regression and probably extended emergence. Bioturbate, probable lagoonal deposits grade upward to alternating thick, medium-crystalline and thin, fine-crystalline beds, deposited in sheltered subtidal and intertidal-supratidal environments, respectively, with subaerial exposure in many cycles. The third unit (about 1100 feet of dolostone) begins with the thin, fine-crystalline beds of a prolonged intertidal-supratidal phase. Interbedded shallow subtidal and intertidal-supratidal beds make up most of Unit 3 but with a less distinctly cyclical pattern than in Unit 2. The dark grey dolostone and microcrystalline limestone composing the thin, fourth unit were deposited on an erosion surface with about 150 feet of relief. Deposition in restricted embayments gave way in time to deposition in more open and widespread subtidal environments. A rapid increase in water depth ended carbonate deposition.

Most, if not all, of the dolostones studied originated as calcareous sediment and were dolomitized and lithified during early

diagenesis, probably by circulating pore waters with low salinity and magnesium/calcium ratio near that of sea water.

The significant zinc-lead mineralization is contained in large bodies of breccia which are cross-cutting on a large scale, although partially stratiform in many cases. The evidence points to formation of these breccias mainly by intrastratal karstification, between the end of Unit 3 deposition and late Unit 4 time. Zinc and lead were introduced later, probably in formational waters issuing from compacting shales after deep burial of the rocks studied.

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INTRODUCTION

GENERAL

This thesis is the product of a stratigraphic and sedimentological study based on measured stratigraphic sections and reconnaissance traverses near Robb Lake in the Rocky Mountains of northeastern British Columbia (N.T.S.: 94 B 13; Lat. $56^{\circ} 57' N.$, Long. $123^{\circ} 42' W.$). This area was selected because the Devonian carbonate rocks exposed there offered the opportunity for both an academically worthwhile study and a project of real, practical value to the companies engaged in exploration for zinc and lead in these rocks.

Initial inspection of the carbonate rocks exposed in the study area shows a relatively monotonous succession of apparently unfossiliferous, uniform dolostones which are well exposed in the steepest and highest parts of an area with more than two thousand feet of relief (Plates 1.1; 1.2).

PURPOSE

This study was designed primarily to attain three successive

objectives: (1) to describe the petrographic characteristics and stratigraphic patterns of the Devonian rocks studied; (2) to reconstruct the local Devonian geologic history on the basis of these observations; (3) to set forth the implications of these findings for mineral exploration in these and similar rocks.

Secondarily, the relationship of the study-area to the regional stratigraphic and paleoenvironmental pattern was to be determined, and it was also hoped that some of the findings of the study would be of general, rather than geographically restricted, significance.

REGIONAL GEOGRAPHIC AND GEOLOGIC SETTING

The study-area is northwest of Fort St. John, at the head of the Halfway River. This is in the first range of the Rocky Mountains, bordering the Foothills Ranges (Fig. 1-1). Although the Mississippian and younger rocks exposed in the western part of the foothills in northeastern British Columbia support rather rugged topography in many places, with considerable relief, there is everywhere a marked increase in relief and amount of exposed rock and bare talus where Devonian and Silurian carbonate rocks come to the surface in the first range of the Rocky Mountains (Plate 1.1-a).

FIGURE 1-1

1-3

Location Map and Physiography of the Robb Lake-
Fort St. John Area (From British Columbia
Department of Lands, Forests and Water Resources
Map No. 1 DL - 1971)

1 OF

126°

127°

123°

122°

FIGURE 1-2: Geological Map of the Thesis Area and Surrounding Region by L.J.W. Irish (Part of Geological Survey of Canada Map No. 1232A).

Scale: 1 inch = 4 miles.
Legend: behind map.

Thesis Area

1-2 Geological Map of the Thesis Area
 bounding Region by F.J.W. Irish (Part of
 Geological Survey of Canada Map No. 1232A).

Scale: 1 inch = 4 miles.

Legend: behind map.

2 of 2

Thesis Area

FIGURE 1-2: Geological Map of the Thesis Area
and Surrounding Region by E.J.W. Irish (Part of
Geological Survey of Canada Map No. 1232A).

1 OF

Scale: 1 inch = 4 miles.

Legend: behind map.

LEGEND

CENOZOIC

QUATERNARY

18

Glacial till, lake silts and clays, gravel, sand, silt

CRETACEOUS

UPPER CRETACEOUS

DUNVEGAN FORMATION sandstone, shale,
conglomerate (marine and non-marine)

LOWER CRETACEOUS

FORT ST. JOHN GROUP

SIKANNI FORMATION shale, siltstone,
sandstone (marine)

BUCKINGHORSE FORMATION shale, siltstone
(marine)

MINNES AND BULLHEAD GROUPS

MONTEITH, BEATTIE PEAKS, MONACH, CADOMIN
and GETHING FORMATIONS quartzite, sandstone,
siltstone, shale, coal (marine and non-marine)

MESOZOIC

JURASSIC

FERNIE GROUP

Shale, siltstone, minor ironstone and sandstone (marine)

TRIASSIC

12

GRAYLING, TOAD, LIARD, PARDONET FORMATIONS
shale, calcareous sandstone, calcareous siltstone,
limestone, dolomite (marine)

PERMIAN

FANTASQUE FORMATION chert (marine)

PERMIAN (?) PENNSYLVANIAN AND MISSISSIPPIAN STODDART GROUP

GOLATA, KISKATINAW, TAYLOR FLAT FORMATIONS
sandstone, siltstone, limestone and shale (marine)

MISSISSIPPIAN (Undivided)

Includes mainly
units 8 and 10

**PERMIAN (2) PENNSYLVANIAN AND MISSISSIPPIAN
STODDART GROUP**

*GULFATA & SKATINAW FORMATION FORMATIONS
sandstone, siltstone, limestone and shale (marine)*

MISSISSIPPIAN Undivided¹

*Includes map 1,
units 8 and 9*

MISSISSIPPIAN

8

*PROPHET FORMATION limestone and shale, heavy
massive limestone, dolomite, chert, lower part of shale
of shale, chert, argillaceous limestone, marble*

DEVONIAN

UPPER DEVONIAN

7

*RESA RIVER FORMATION shale, dolomite, limestone,
marble, limestone, marble*

MIDDLE DEVONIAN

*Limestone, argillaceous limestone, dolomite, silty
dolomite, calcareous shale, sandstone, marble*

SILURIAN

5

*Dolomite, silty dolomite, minor limestone and
quartzitic sandstone, may include some upper
Ordovician beds at the base (marine)*

LOWER PALAEOZOIC Undivided¹

4

*Includes mainly
units 3 and 5*

ORDOVICIAN

3

*Platy argillaceous limestone, nodular limestone
dolomite, minor siltstone and shale, may include at
top the graptolitic shale of northwest corner of
map-area, lower part may include some Upper
Cambrian beds (marine)*

CAMBRIAN

2

*Quartzite, quartzitic sandstone, siltstone, silty
dolomite, dolomite (marine)*

MISINCHINKA GROUP

*Limestone, chlorite schist, phyllite, calcareous
sericite schist, schistose sandstone, white quartz*

Geological boundary (defined, approximate, assumed)

Bedding, tops known (horizontal, inclined, vertical, overturned)

Thrust fault, approximate, assumed, (teeth in direction of dip)

*Thrust fault on cross sections, approximate, assumed,
(arrows indicate relative movement)*

*Basic dykes and sills (cut units 3 and 4 but presumed
older than 5)*

Anticline (approximate)

Syncline (approximate)

Fossil locality

Coal mine

As elsewhere in the eastern part of the Cordillera, the region surrounding the study-area contains many large, approximately parallel, northwest-trending thrust faults with westward dips (Fig. 1-2). On the whole, these faults have brought successively older rocks to the surface, westward. Devonian rocks are exposed in one main thrust "slice" in the study area. They are bordered by Mississippian shales, cherts and carbonate rocks on the east side and by Silurian and Ordovician carbonate rocks and shales on the west side (Fig. 1-2).

The Robb Lake area lies well to the south-southwest of the gas-producing Devonian "reefs" of the Fort Nelson area and northwest of the Peace River Arch, which was a positive tectonic feature during much of the Devonian Period (Douglas, et al., 1970, p. 394-399). The study-area lies approximately on the extrapolated southwest extension of the Middle Devonian Slave Point facies front as shown by Griffin (1967, Fig. 3). Moreover, the buried trace of the McDonald fault zone of the Great Slave Lake area should pass close to, or through, the study-area, if projected southwestward beyond its known extent into the edge of the Cordillera (Douglas, et al., 1970, p. 370: Fig. VIII-2).

PREVIOUS WORK

Williams and Bocock (1932, p. 201) described Devonian carbonate rocks exposed along the Peace River, about 60 miles to the south and on trend with the study area, and Williams (1944, p. 15-19) describes similar rocks along the Alaska Highway, some 120 miles to the north-northwest. Laudon and Chronic (1949, p. 197) correlated the fossiliferous limestones at the top of the Devonian carbonate section along the Alaska Highway with the Ramparts Formation of the MacKenzie Valley. They also tentatively assigned all of the "unfossiliferous" carbonate rocks beneath these limestones and above the fossiliferous Silurian section to the Devonian. Within the unfossiliferous section, they recognized two formations, McConnell and Muncho, at the bottom and included the rest in the Ramparts Formation, although recognizing a lower, sandy member and an upper, white, member. McLearn and Kindle (1950, p. 28-29) summarized the work of these four geologists.

In the course of a regional study of the area between Halfway and Tetza Rivers, supervised by Laudon, Kingston (1956, p. 80-81) measured a stratigraphic section somewhere near Robb Lake. This section was said to include 160 feet of fossiliferous limestones "of Fairholme age" underlain by an unspecified thickness of "the white Ramparts member".

Several fossils from Devonian carbonate rocks in northeastern British Columbia have been described by C.H. Crickmay. These include a new species of Stringocephalus and a new genus, Geranocephalus, both from near Redfern Lake, 30 miles north of the study-area (Crickmay, 1954; 1960).

During the 1950's and early 1960's, Irish mapped the Halfway River Map Area (N.T.S. 94 B). His map, published at a scale of about 4 miles to the inch, outlined the regional structure (Irish, 1969). In the vicinity of the study-area, he recognized an unfossiliferous dolostone unit of Silurian and/or Devonian age overlain by a (mainly middle) Devonian carbonate unit and then the thick, Upper Devonian Besa River shale previously defined farther north (Irish, 1969, p. 27-38). The unfossiliferous dolostone corresponds to Laudon and Chronic's "sandy" and "white" members of the Ramparts Formation and the Middle Devonian carbonate evidently corresponds to Kingston's "Fairholme equivalents". The distribution of these units on Irish's map in the area of this thesis study correlates only very approximately with the actual distribution of the corresponding lithologies, however (compare Fig.'s 1-2 and 2-6).

Griffin (1965, 1967) described the nature and distribution of

Devonian facies in northeastern British Columbia, largely using subsurface data obtained to the east and northeast of the Robb Lake Area. He also attempted a correlation between subsurface units and the Devonian outcrops near the Alaska highway described by Williams, Laudon and Chronic, and later by G.C. Taylor. (See page 2-9.)

Finally, on the basis of fieldwork covering a large area extending southward almost to the study area, G.C. Taylor divided the exposed Devonian carbonate rocks of northeastern British Columbia into four formations and described their relationships to each other and to overlying and underlying strata (Taylor and MacKenzie, 1970). The Devonian carbonate section in the study area correlates with the upper three of these formations (page 2-9).

The work cited above, along with the writer's experience in the region in 1971, formed the information base with which this thesis project was begun. Since the field work, lab work and most of the writing for the thesis were completed, several reports relating directly to the Robb Lake Property and its surroundings have been published. These reports are mainly the result of property inspection visits by government geologists due to the the great interest in the zinc-lead potential of the area following the discovery of the Robb Lake deposit.

Sangster (1973) was the first to publish a report on the Robb Lake Property, followed by Thompson (1973a). Later reports by Taylor (1973), MacQueen and Taylor (1974) and by Taylor, MacQueen and Thompson (1975) also deal with the property or relevant stratigraphic and structural problems. A significant contribution by R.I. Thompson to the structural interpretation of the area is noted elsewhere (page 2-2).

METHODS

Preliminary Preparation

The area to be studied was agreed upon following the author's first, brief reconnaissance of the Robb Lake area in the fall of 1971. Subsequently, aerial photographs and topographic maps of the study area were purchased and a preliminary study of these was made before going into the field. A small number of samples taken during reconnaissance by a Texas Gulf, Inc., party were also studied in hand specimen and thin-section prior to the next field season. Unfortunately, these specimens were of little use at that stage due to lack of accurate knowledge of sample locations and to non-typical, non-distinctive or entirely secondary (breccia) textures.

Field Methods

Two and one half months were spent in the field in the summer of 1972. Work began with reconnaissance traverses aimed at locating the upper and lower limits of the Devonian carbonate section in the study-area, becoming familiar with the gross aspect of the Devonian and other formations in the area of the claim group, and locating mappable

subdivisions of the Devonian carbonate section. Initially, a major part of the writer's efforts was directed toward distinguishing and locating mappable Devonian units so that mapping by Cordilleran Engineering could proceed effectively (Fig. 2-6).

Most of the field season was spent in measuring 8 principal sections (Fig.'s 2-5; 2-6) and several additional, fragmentary sections for comparative purposes. In all, 16 different measured sections or traverse lines on or adjacent to the property and one some distance to the south received varying degrees of detailed study, and six other localities on the property and several outside its boundaries were rapidly measured or inspected.

The principal sections were measured in standard fashion with a 5-foot staff marked in feet and tenths of feet, on the top of which a clinometer had been mounted. An effective logging system was gradually developed which consisted of a graphic log with numerous side notes according to a set pattern. Most of the sections were logged at a graphic scale of 1 inch to 10 feet. Some, particularly in Unit 4, were logged at 1 inch to 5 feet. Figures 3-1 through 3-4 and 3-9, 10, and 11 are essentially refined and edited copies of these field logs.

Seven of the principal sections and several other sections and traverses were sampled in detail. For most of the sections, two forms of sampling were used: regular-interval sampling, mainly by an assistant and without regard to the lithology of the horizons sampled; and selective sampling by the writer of noteworthy lithologic changes, and structural and textural features. The interval used for the regular samples was normally ten feet of stratigraphic thickness, with several samples taken at ten foot lateral intervals along a stratum every forty feet, where exposure permitted, for information concerning local lateral variations. In Unit 4, regular interval samples were taken every five stratigraphic feet. Approximately 1100 specimens, the majority of them oriented with respect to bedding, were shipped to Carleton University for study the following winter.

Laboratory Methods

All of the specimens returned to the laboratory were inspected repeatedly for significant features. A selection of about 400 of them were cut with a diamond saw, generally perpendicular to bedding, and a number of cut samples were polished with 240, 400 or up to 600 grade carborundum grit. However, for most purposes, including the recognition of clastic textures and internal sediments, a sawn surface, when wetted, proved adequate after some familiarity with these rocks had been developed.

Parts of approximately 70 specimens cut or broken perpendicular to bedding were dissolved to yield insoluble residues. Nearly all of these specimens were dolostone and were dissolved in concentrated hydrochloric acid. Several limestone samples were dissolved in less concentrated HCl and a limestone specimen containing phosphatic fossils was dissolved in concentrated acetic acid to yield the fossils intact. Residues were washed, dried at 55°C to a stable dryness and weighed immediately to the nearest thousandth of a gram in a Mettler Balance. It was found, however, that errors due to variation of filter paper weight about the mean weight used and due to variation in water up-take between the drying oven and the balance amounted to about 0.1 gram. Some residues were subsequently ashed to determine amount and nature of organic content; some were separated into heavy and light fractions for further study and a number of argillaceous and silty residues were separated into clay and silt sized samples by settling in water, for x-ray identification of principal constituents.

Both plexiglass and acetate film peels, used successfully by the writer on a previous project, were tried on all kinds of lithologies. However, the peels were of little use except in the case of a few limestone samples. Differential etching of primary particles, except quartz grains, did not occur in the dolostones and the peels revealed

only the secondary crystallinity. Even the latter was not reproduced well enough in the fine part of the crystal size ranges so that the peels could be used for size range counts.

Thin-sections were made from sixty-five specimens in addition to 25 thin-sections made prior to fieldwork from 1971 samples. Most of the thin-sections were stained with potassium ferricyanide to reveal ferrous iron in dolomite and calcite. Many were also stained with alizarin red to show calcite. (See Friedman, 1959.) One litre solutions were used, containing 2 ml. concentrated HCl and either 5 g. potassium ferricyanide or 1 g. Alizarin Red-S. Useful immersion times at 40°C ranged from 1.5 to 4 minutes for Alizarin Red and from 5 to 8 minutes for potassium ferricyanide.

The thin-sections were studied using both a Wilde binocular microscope (in transmitted light mode) and a Leitz research-type polarizing microscope. A number of representative specimens were point-counted to provide grain and crystal size, composition and quartz grain roundness data (Appendix I). These raw data were recorded on a form which grouped the size data logarithmically for computation of phi size distribution statistics by a computer program written for the purpose (Appendix V, Tables 1 and 2). The same program was also used to compute arithmetic statistics such as those for roundness distributions and bed thickness distributions.

Observations of specimens studied in the greatest detail were recorded on a six page form prepared the previous year (Appendix V, Table 3). While this form proved to contain a considerable amount of wasted space, particularly when used for dolostones, it did provide for complete and consistent recording of information.

The recognition of a considerable amount of primary textural detail in thin sections of some dolostone specimens was made possible by the discovery of a simple light-filtering technique which does not seem to have been reported previously. This consists simply of placing a sheet of moderately thin, good quality white paper of uniform texture (not watermarked bond) beneath the thin section to be studied (between it and the light source). At the same time, it is sometimes necessary to increase the intensity of light from the source to provide sufficient illumination. This technique brings about a kind and amount of diffusion of light that results in a great reduction of crystal boundary contrast and of other effects produced by refraction and rotation of light. Thus, secondary crystal textures disappear or become much less prominent and primary particles are revealed due to the inclusion patterns they have left in the replacing dolomite (Plates 3.29-e, f; 3.31-e, f; 3.45-a, b). The technique can be used with both the Wilde binocular microscope and the research-type polarizing microscope. The latter cannot be

used in the "crossed polarizers" mode with the paper filter, of course. It proved most convenient to tape a piece of suitable paper to a square of plexiglass for regular use.

A means of organizing and comparing the abundant data from field and laboratory observations was needed to aid in recognition of valid relationships among the various features of these rocks and to support statements concerning the distribution and relationships of these features. To answer this need, a method of computing matching coefficients was devised, employing a modification of the approach used by Bonham-Carter (1965). This involved systematic coding of data in the form of a number of two-state (presence-absence) variables. Multi-state variables such as colour and crystal size were separated into several presence-absence variables (Appendix V, Table 5). Data were derived mostly from "sampling" at regular stratigraphic intervals of the detailed section logs after the latter had been modified in the light of laboratory work.

A computer program was written to compute matching coefficients ranging in value from minus one to one which show, in fact, the comparison between the number of cases in which at least one of a pair of characteristics is present and the number of cases in

which both of the pair are present (explanation in the program listing: Appendix V, Table 4). As some of the variables used are much less commonly present than others, however, a "one-way" matching coefficient based on the presence of the less common of a pair of characteristics proved more useful in many cases (Appendix V, Table 4). A matrix of less common characters and two "weighting" matrices were also printed to permit effective interpretation of the matching coefficients.

Factor analysis could not be applied, as such semi-quantitative variables are not continuous. In some cases, a form of cluster analysis appears to be valid and useful in application to discrete-state data (Parks, 1967). However, in the present case, further analysis of this kind was rejected due to somewhat questionable validity and lack of sufficient promise of valuable new information to justify the additional work involved.

DEFINITIONS

In this thesis, the meanings of most terms which might be unfamiliar, or the usage of which varies in the literature, are defined by references. However, a few definitions are required at the outset.

Terrigenous Clastics

The use of the word "orthoquartzite" herein is that of Pettijohn (1957, p. 290) and does not refer to a metamorphic rock or a rock that must break across the grains. The grain roundness scale used is that of Powers (1953) with Folk's rho scale superimposed for calculations (Folk, 1968, p. 11). The common size terms (silt, fine sand, etc.) are used according to the well-known Udden-Wentworth scale (e.g., Folk, 1968, p. 25).

Limestone and Dolostone

The term "dolostone" refers to rocks, while the term "dolomite" refers to a mineral. Where classifying terms are used, particularly for limestones, the classifications of Folk (1962) and Dunham (1962) are used interchangeably or according to which seems most useful in each case. The term "biostrome" refers to a layer or bed containing an abundance of organisms fossilized essentially at their places of growth. Such a layer had no positive relief above the surrounding sea floor during deposition. The term "bioherm" refers to a mound or similar structure containing a fossil assemblage like that of a biostrome or one with a more extensive organic framework but which projected

above the level of the surrounding sea floor during deposition and formed a "bulge" rather than a bed or layer of uniform thickness.

The use of these latter two terms corresponds approximately, although not precisely, to that of Krumbein and Sloss (1963, p. 134, 569). The term "reef", on the other hand, refers to a bioherm which contained, during growth, a rigid framework formed by intergrowth of organisms and concurrent filling of interstices with debris and cement.

Where carbonate particle size terms are used (e.g., "silt"), the size scale used for terrigenous clastics applies. Table 1-1 shows the crystal size ranges signified by the crystal-size modifiers used. For field and hand specimen usage, these terms indicate visual estimates of average size which, upon comparison with point-count measurements, were found to represent approximately the mean size ranges shown in Table 1-1. For point-count measurements and thin-section descriptions of limestones, Folk's (1968, p. 153, 168) definitions of micrite, microspar and spar were modified slightly to better fit the natural size-frequency "breaks" in the rocks studied and to allow for the limitations of resolution of the measuring scale used (Table 1-2).

TABLE 1-1

Size Terms Applied to
Carbonate Crystals

Microcrystalline	Less than 0.005 mm.
Fine Crystalline	0.005 mm. to 0.05 mm.
Medium-Fine Crystalline	0.05 mm. to 0.1 mm.
Medium Crystalline	0.1 mm. to 0.4 mm.
Medium-Coarse Crystalline	0.4 mm. to 2.00 mm.
Coarse Crystalline	Larger than 2.00 mm.

TABLE 1-2

Crystal Size Terms for Limestones,
Modified from Folk (1968, p. 153 & 168)

Term	<u>Size Range and Description</u>
Spar	Greater than or equal to 20 microns, largest visible dimension. Generally clear calcite.
Microspar	Greater than or equal to 5 microns but less than 20 microns, largest visible dimension. Generally clearer (more inclusion-free) than micrite.
Micrite	Less than 5 microns, largest dimension. Generally contains numerous submicroscopic inclusions.

Bedding and Lamination

Table 1-3 shows the bed thickness terminology used. The use of the term "lamination" should also be noted. Although it is difficult to define this term to eliminate possible overlap with "thin bedding", in practice the two are distinct. Lamination occurs within a bed. Its presence implies no physical discontinuity (crack) between laminae but it does imply some compositional or textural difference from one lamina to the next. Laminae are less than about 2 cm. thick and lamination referred to as "fine" is on a scale of millimetres.

TABLE 1-3

Bed-Thickness Terminology

Thick-bedded	= Greater than 2 feet (0.7 m.) thick
Medium-bedded	= One foot (0.3 m.) to 2 feet (0.7 m.) thick
Thin-bedded	= Less than 1 foot (0.3 m.) thick

1.1

a. Panorama southeast (left) to south to southwest from the top of Tennessee Mountain. Halfway River valley in middle distance; Halfway Mountain beneath the word "Rocky"; Mt. Robb to right.

b. Panorama northwest (left)-northeast-east from the ridge forming the southwest side of Mississippi Creek Valley: head of Mississippi Valley at left, with location of Texasgulf Breccia marked T.G. (on Texas Ridge); side of Tennessee Mountain in middle to right. Dotted outline marked "L.S." is the limestone outcrop at location AC; other dotted outlines are approximate outlines of major breccia bodies. Also note anomalously dipping (collapsed) bedding adjacent to the upper part of a large breccia (arrow).

c. Panorama west (left) to north (right) from the top of Tennessee Mountain: south side of Texas Ridge, with approximate outline of Texasgulf Breccia shown by dots.

(Names referred to are located on Fig. 2-6.)

a

b

c

1.2

a. Panorama east to south from Texas Ridge: north face of Tennessee Mountain, with approximate outline of limestone exposure dotted. Breccia occurs both to right and to left of this exposure. Top of Unit 3 along southwest wall of Mississippi Valley is shown at right. View looking approximately down plunge of major anticline, at centre.

b. Panoramic view of north side of Texas Ridge from Pine Point Peak, with approximate locations of formation contacts shown.

c. Panorama southwest to west to north from location L on Texas Ridge: view looking down core of major anticline, at right.

a

Unit 1 Unit 2 Unit 3

Silurian

b

Unit 3 Unit 2 Unit 1

Unit 1

c

LOCAL GEOLOGIC FRAMEWORK

STRUCTURE

The principal structural feature of the Robb Lake Property is a large, gently south-southeasterly plunging anticline (Fig. 2-6; Plate 1.2). A smaller syncline borders this anticline on the east and is bounded to the east by a high-angle, west-dipping normal fault along much of its length. Farther east, outside the property boundary, a major thrust fault separates this structural "package" from the adjacent one. The boundary zone appears to be complicated by several high-angle faults parallel to the structural trend.

On the west or southwest, the west limb of the major anticline is partially buried beneath the next thrust "plate" to the west, which caps the higher parts of the ridge southwest of "Mississippi Creek" Valley (Fig. 2-6).

Southward, the central structural unit on the property plunges beneath the overlying, west plate near the bottom of "Halfway Mountain". To the north-northwest, some structural complexity occurs. Some shale, resembling the Upper Devonian Besa River Formation was seen in the

bottom of the valley north of "Texas Ridge" and the writer recognized a dolostone section in a low structural position farther north as belonging to the Devonian sequence. However, the structural relationship between these exposures and the rest of the area was not fully clarified during the 1972 field season. When R.I. Thompson, then with the British Columbia Department of Mines, visited the property, he suggested that the entire anticlinal structure on the property might have been thrust over the Devonian shales. Subsequent work suggested that this interpretation is correct and that the Devonian rocks at the north edge of the property belong to an underlying structural "package" which comes into fuller view in the mountains on trend to the north (Thompson, 1973, a, b).

Thus, while minor faults and rare drag folds do occur on the Robb Lake Property, the structural setting is quite simple on the whole. The thick carbonate rock section was deformed mainly by abundant brittle fracturing (jointing) and broad, large-scale arching.

Measurements of the orientations of planar fracture surfaces on both limbs of the major anticline show two prominent sets of near-vertical fractures, one striking approximately north-south and the other striking approximately east-west (Fig.'s 2-1a and 2-1b). As

Figure 2-1a

Poles to Fractures - Section K
Contoured Equal-Area Stereoplot
(Contours at 2% intervals starting
at zero. N=48)

Measurements by J.M. Chinneck: Field Assistant

Figure 2-1b

Poles to Fractures - Section H
Equal-area stereoplot contoured
at 2% intervals (starting at zero).
N=89

Measurements by J.M. Chinneck: Field Assistant

Figure 2-1c

Poles to Fractures - Section G
Equal-area stereoplot contoured
at 2% intervals (starting at zero).
N=104

Measurements by J.M. Chinnek: Field Assistant

might be expected from the plunge of the major anticline, the north-south fractures differ slightly in orientation on opposite limbs of the fold. On the east limb, they dip steeply westward and the average strike is very nearly north-south (Fig. 2-1a). On the west limb, probably somewhat closer to the axial plane of the fold, the fractures strike a little east of north, on the average, and dip east and west in approximately equal numbers, with the gentlest dips to the east (Fig. 2-1b).

In the core of the anticline, at a locality where many of the fractures measured occur in a major breccia, there is a wider scatter in strike of near-vertical fractures, although a north-northwest orientation is most prominent. A subsidiary set of gently southeast-dipping fractures appears to be present as well, although these may be bedding remnants or bedding-parallel fractures not recognized as such by the measurer (Fig. 2-1c). The scatter of data at this locality is probably due to the structural isotropy of the fully cemented breccia (page 4-8).

FIGURE 2-2

2-7

Devonian Stratigraphic Units
Defined North of the Study Area

(Modified after Taylor and MacKenzie, 1970,
Fig. 9, south end.)

WEST

EAST

SILURIAN AND OLDER

Figure 2-3: Correlation of
Exposed Devonian Formations
With Subsurface Stratigraphy,
Northeastern British Columbia.
(After Griffin, 1967, Fig. 1)

Devonian Stratigraphic Units in the Robb Lake Area
As Defined in This Thesis

(For legend, see Figure 3-13; for regional correlations, see Table 2-1, page 2-11.)

STRATIGRAPHIC UNITS

The Devonian formations recognized by Taylor and Mackenzie (1970) and traced southward to within a few miles of the Robb Lake area are shown in Figure 2-2. The approximate relationship of these formations to those already well established in the subsurface to the east was shown by Griffin (1967: Fig. 2-3, this thesis).

Four stratigraphic units, defined and described herein, can be recognized and mapped within the study area (Figures 2-4, 2-5 and 2-6 and Plates 1.1-b, c; 1.2). The lowest of these units overlies the Nonda Formation (Norford; et al., 1967) which contains Halysites and other Silurian fossils. The uppermost underlies the thick shale section of the Besa River Formation (Kidd, 1962; Irish, 1969, p. 36-38). On the basis of his familiarity with the lithologies and stratigraphic sequence exposed to the north and trending into the study-area, the writer recognized during fieldwork the lithostratigraphic correlations shown in Table 2-1. It will be noticed that these correlations imply large differences in formation thicknesses between the Robb Lake area and localities only a few miles to the north (Figs. 2-2 and 2-4).

TABLE 2-1

Correlation of Units
Robb Lake and Northward

Unit 4	=	Dunedin Formation
Unit 3	}	= Stone Formation
Unit 2		
Unit 1	=	Wokkpash Formation

It is suggested that the oldest Devonian formations of Taylor and Mackenzie (1970) were not deposited at Robb Lake on the sub-Devonian unconformity (Norford, et al., 1967, p. 610), or else they were removed on an overlying unconformity not yet recognized in the region. It should also be noted that the Dunedin Formation has a diachronous upper contact, younger to the south (Taylor and Mackenzie, 1970, p. 15). This thesis presents stratigraphic evidence that the lower contact of this formation is also at least somewhat diachronous, and relatively younger on the Robb Lake Property than farther north. This upper, relatively young part of the Dunedin Formation, found at Robb Lake and to the south, is now correlated with the Pine Point Formation by G.C. Taylor (1973) and others, indicating a closer lithologic and biostratigraphic resemblance to the latter formation than that of Dunedin rocks farther north.

Figure 2-5 is a stratigraphic diagram showing in proper relative

position the 8 principal measured sections with which the writer has defined the stratigraphic sequence and thicknesses in the study-area. Although the relative vertical placement of the measured sections is, for the most part, based directly on measurements, a measured thickness uncertainty of about 200 feet occurs in the top part of Unit 3. At this stratigraphic level, lithologic correlations between measured sections were used to provide a more accurate relative placement of the sections.

123° 45' W

57° 00' N

FIGURE 2-6

Geological Map with
Measured Section and Traverse
Locations, Robb Lake
Property, B.C.

DESCRIPTION AND INTERPRETATION
OF STRATIGRAPHIC UNITS

UNIT 1

Field Characteristics

The lowermost Devonian unit (Unit 1, Fig's. 2-4, 2-5, 3-1) is composed of dolomitic quartz sandstone, non-dolomitic quartz sandstone, and very sandy dolostone. The more dolomitic beds weather buff to light grey but very quartz-rich beds appear dark-grey, brownish-grey, and black, mostly due to the lichens that favour these beds. Where not lichen-covered, non-dolomitic layers have a white weathered surface.

The lowest beds of the unit contain less sand than the rest. Above the basal twenty feet, however, laminae and thin layers of quartz sandstone occur locally, particularly at location F (Fig. 2-6). Approximately the middle third of Unit 1 is thoroughly cross-bedded on a moderately large scale everywhere the unit was seen. Cross-bed sets are on the order of 20 to 50 cm. thick and appear roughly planar. Ripple marks occur on the surfaces of several cross-bedded layers at location F. Once identified, this cross-bedded, dolomitic sandstone and sandy dolostone can generally be recognized from a distance by the distinctive weathering aspect of the cross-beds.

However, care must be exercised in order not to confuse this with a quite similar unit within the upper part of the Nonda Formation, below Unit 1.

Where the unit was measured (Section P), the cross-bedded portion of Unit 1 abruptly gives way upward to about 35 feet of massive, thick-bedded, non-dolomitic orthoquartzite. At location F, this subunit has about the same thickness as in Section P but it can be seen to thin considerably, northeastward, over a distance of about 2,000 feet.

At the top, the orthoquartzite grades to lenses of orthoquartzite in quartz-sandy dolostone, over a few inches, and the rest of Unit 1 consists of sandy dolostone with a few large (up to five feet thick) and small lenses of non-dolomitic orthoquartzite.

Petrography

Mineral and Particle Composition

Dolomite

Except for the non-dolomitic orthoquartzite beds (Plates 3.1-c, d; 3.2-b,e), dolomite forms from forty or less to more than seventy volume-percent of the rocks of this unit (Plate 3.1-a, e, f, g, h; etc.). In a specimen from the cross-bedded subunit, crystal sizes range from less than five microns to 0.4 millimetres or more, not including coarse dolomite "spar" filling fractures (the distribution of crystal sizes in this specimen is shown in Appendix I, Table 1). In the bulk of the rocks, dolomite crystals are mostly roughly equant and consist of a mixture of irregular, interlocking shapes and (generally smaller) partly idiomorphic crystals, forming a tight-looking mass that appears non-porous in thin-section (Plates 3.1-g, h; 3.2-d, f, g).

The specimen shown in Plate 3.1-a is cut by a fracture about 4 millimetres wide, largely filled with zoned dolomite "spar" in the following pattern: (1) from the walls of the fracture, coarse

dolomite crystals with abundant submicroscopic inclusions extend into the former cavity; (2) the number of inclusions decreases abruptly along a former set of idiomorphic crystal faces and relatively clear overgrowths extend farther into the fracture; (3) a thin, mostly opaque coating of densely massed bitumen, pyrite, "limonite" and unidentified inclusions occurs near the inner edge of this clearer phase; (4) a strong concentration of iron (identified by staining) occurs in the dolomite immediately surrounding this band of opaques and there is a thick layer of lesser, but significant, iron concentration adjacent to it on the side towards the centre of the vein; (5) beyond this layer, clear and iron-free dolomite overgrowths fill the remaining spaces or terminate in idiomorphic facets facing into vugs (Plate 3.1-b).

Quartz

Quartz forms from nearly 100% of the rock in parts of ortho-quartzite layers to less than 30% in some beds in the upper and lowermost parts of the unit. It consists mainly of rounded, detrital grains with variable amounts of authigenic overgrowth (for roundness distributions, see Appendix I, Tables 7 and 8). In a representative

non-dolomitic specimen from a lens at the top of the unit, there is a gradational variation, on a scale of a centimetre or less, between patches with almost no overgrowths and areas where overgrowths fill all space between quartz grains and have formed planar boundaries that meet in "triple-points" (Spry, 1969, pp. 39 et seq.; Plate 3.1-d, this thesis). An inverse relationship exists between abundance of clay matrix and extent of quartz overgrowths, with little, or no, clay where overgrowths are most extensive. In intermediate areas, small amounts of clay are commonly included in overgrowths. Were it not for the presence of more than 15% clays in some places, this rock would be classified as an orthoquartzite (according to Pettijohn, 1957, p. 291). The apparent compositional-textural anomaly and the patchy distribution of the clays are possibly best explained by the washing of clay minerals into the interstices of this lens of very mature sand soon after it was deposited.

In a representative thin-section from the cross-bedded part of the unit, small, partial, quartz overgrowths are common and extend, locally, into faceted protuberances against rational dolomite faces, evidently having grown to fill voids (Plates 3.1-f, h; 3.2-f).

There are also some deeply embayed quartz grains in this sample and there is minor replacement by small dolomite euhedra penetrating the edges of rounded quartz grains (Plate 3.1-f).

In each of these two samples there are small concavo-convex contacts between quartz grains (Plate 3.1-f) and in some clay-free parts of the "orthoquartzite" there is truncation of large segments of rounded outlines by parts of other grains.

Both of these samples contain a great number of grains showing undulatory extinction (Plate 3.1-d, f; 3.2-b). In the dolostone, there are also occasional polycrystalline quartz grains with each crystal showing undulatory extinction (Plate 3.1-g) and in the "orthoquartzite", a few semicomposite grains are present. The dolostone contains a trace of coarser crystalline chert grains and there are a few rutilated quartz grains in the orthoquartzite.

Quartz grain sizes range from silt to greater than one millimetre, with only moderate sorting. Appendix I, Tables 2 to 4 show data for a representative cross-bedded sample.

Quartz also fills microfractures in orthoquartzite (page 3-15).

Clays

A representative non-dolomitic specimen contains from zero to about 25% clay matrix in different parts of a thin-section (Plates 3.1-d; 3.2-a, b, e). The average clay content is 14% for this thin-section (Appendix I, Table 6), but the average for the rock as a whole is likely to be lower. In one or two places, the clays seem to fill clastic "ghosts" which may have been feldspar grains (Plate 3.2-a and b). Elsewhere, clay minerals are generally oriented parallel to adjacent quartz grain boundaries and, where most abundant, they fill all space not occupied by detrital grains. At some grain borders there are complex intergrowths of clays and quartz overgrowths but overgrowths do not penetrate the densest masses of clays.

In the cross-bedded dolostone, probable clay minerals can be seen only in occasional, scattered "ghosts" where they are generally

at least partly oriented along crystallographic planes of the replaced grains as shown by other alteration products and probable feldspar (?) remnants. Some of these "clays" may actually be fine sericite (Plate 3.2-c and d).

Muscovite

Trace amounts of muscovite occur scattered in the matrix of the "orthoquartzite" (Plate 3.2-c). The largest grain seen is 0.15 mm. long in section and is probably detrital in origin, being slightly bent. Muscovite was seen in the dolomitic sandstone only as an inclusion in a quartz grain (aside from possible sericite, as mentioned under "Clays", above).

Hematite (and "Limonite")

Small, patchy aggregates of red-brown and deep red crystals are present in trace amounts. The approximately equant crystals are mostly less than 0.01 mm. in diameter. In the dolostone, a

yellowish stain between dolomite crystals is associated with hematite crystals which are commonly located in or near relict grain outlines (see "Clays", and below). In the "orthoquartzite", hematite aggregates are scattered in the matrix (Plate 3.2-a).

Tourmaline

The most common trace mineral in the "orthoquartzite" is tourmaline (probably schorlite), in very small (0.07 mm. and less) rounded grains. The grains are dull, dark green and yellowish-green and exhibit varying degrees of pleochroism. One similar grain was seen in the sandy dolostone (Plate 3.2-f).

Zircon

A few very small (0.06 mm.), rounded and subrounded grains of zircon are also scattered in the matrix of the orthoquartzite. None were seen in the dolostone.

Feldspar

One partly altered, untwinned feldspar grain was identified in the dolostone (Plate 3.2-d). Also, see "Ghosts" below.

Unidentified Trace Minerals

The matrix of the orthoquartzite also contains scattered minute patches of a greyish-white opaque mineral (possibly leucoxene) and very fine specks of a metallic mineral (possibly pyrite).

"Ghosts"

The occurrence of a few mineral grain relicts was mentioned under "Clays", above. In both specimens studied in thin-section, some of these shapes contain mostly clays and no opaques, suggesting replacement of mafic minerals (see also Plate 3.2-c).

Carbonate Clasts

The intact framework of the dolomitic sandstone specimen studied is formed by a mixture of quartz grains and rounded carbonate clasts which are now represented only by vague concentrations of fine inclusions and finer-than-average crystal size in the interlocking dolomite mosaic with which they have been replaced (Plate 3.2-g). These clasts are mostly about 0.2 to 0.3 mm. in diameter (Appendix I, Table 5). Recognizable carbonate clasts make up about 7% by volume of the specimen studied. They are scattered randomly among the quartz grains but are most abundant in layers where the maximum quartz grain size is smallest (see "Fabric and Textural Features", below).

Two or three carbonate clasts are larger and have regularly curved shapes in part, suggesting fossil fragments. Also, some of the smaller clasts have more angular shapes than would be expected of pellets. It is uncertain whether these clasts were intraclasts or well-worn fossil fragments.

Textural and Structural Features

Inhomogeneity

Alternating planar layers of relatively coarse and fine sand grains (mean sizes of about 1.3 ϕ and 2.2 ϕ , respectively) make up a representative sample from the cross-bedded dolostone.* (Grain size statistics are listed in Appendix I, Tables 2-4.) The layers are two to six millimeters thick and grade into each other with no discontinuity. Each layer contains only a small percentage of grains of the predominant size mode of the adjacent layers (Plate 3.2-g and Appendix I, Tables 3 and 4). Layers with the finer quartz mode contain more carbonate clasts than coarse layers. Similar layering on about the same scale is present in a specimen from lower down in the unit, where it is parallel to normal bedding.

The inhomogeneous distribution of clay minerals (and correspondingly of overgrowths) in the "orthoquartzite" sample is the only small-scale inhomogeneity observed in that rock.

* Statistical size data from point counts are stated in phi units to facilitate comparison with the results of other studies.

Porosity

There is no visible porosity in a thin-section of the cross-bedded dolostone except for small remnant vugs in dolomite-filled fractures. Field observations and examination of hand specimens indicate no visible porosity in the rest of the unit except where clays have been leached from non-dolomitic orthoquartzites after growth of quartz overgrowths. The "orthoquartzite" thin-section studied shows porosity ranging from nil to 3% or more locally. This specimen is from a thick lens at the top of the unit and may have undergone more leaching than the main orthoquartzite stratum, below.

In dolomitic beds (most of the unit) some submicroscopic inter-crystalline porosity may be present, since the dolomite mosaic often contains semi-sucrosic patches and areas.

Packing

Many grain borders in the "orthoquartzite" are slightly modified by solution, allowing a closer packing and resulting in a slightly

condensed framework (Plates 3.1-d, f; 3.2-e). However, extensive overgrowths obscure grain boundaries in many places, making solution effects difficult to detect. In some grains strain is indicated by radiating extinction patterns fanning from points of contact with other grains. Also, the clay matrix crystals are mostly oriented parallel to grain boundaries. In a few places, however, a fibrous intergrowth of clays and quartz is oriented perpendicular to grain boundaries as if extended between two grains being pulled apart. These matrix patterns probably reflect varied local strain patterns which developed around the framework grains.

In the thin-section from the cross-bedded dolostone, an intact, uncondensed framework is formed by quartz grains and carbonate clasts, together. Quartz grains, viewed alone, appear loosely dispersed in the dolomite in many places (Plates 3.1-g, h; 3.2-d, g).

Fractures

Several dolomite-filled fractures, intersecting each other at small angles, cut the specimen described from the cross-bedded subunit

(Plate 3.1-a). In thin-section, the fracture fillings can be seen to be zoned as described on pages 3-3 to 3-4. In the largest fracture in this specimen a little residual, vuggy porosity remains along the middle of the vein. Quartz overgrowths form part of the "first-phase" dolomite filling and locally extend entirely across a smaller fracture (Plate 3.1-h) but none are found in or associated with the later dolomite phases of the largest veins.

There are few fractures in the orthoquartzites (except large scale, open jointing). One microfracture 0.02 mm. wide was seen. It cuts through both quartz grains and matrix and is entirely filled by quartz overgrowths.

Interpretations

Source of Terrigenous Constituents

The mineral assemblage and quartz types observed in Unit 1 are not diagnostic of a particular type of source-rock. However, the

presence of a trace of coarse chert and of a grain which appears to have a rounded overgrowth favour derivation of at least part of the sand from a previous quartzose sandstone. (One grain of elongate, undulose, complexly interlocking, polycrystalline quartz may be of low-grade meta-siltstone origin (Plate 3.1-g).) The relatively pure quartzose composition of the terrigenous clasts, and the high roundness, may thus be due to recycling. Supporting this: only the most resistant heavy minerals are present (zircon, tourmaline) and these are invariably very small and rounded.

According to what is known of the paleogeography of North-eastern British Columbia and adjacent Alberta, the most likely sources of terrigenous sand for this unit are the Cambrian and older clastics which must have been exposed at this time in the vicinity of the Peace River Arch and perhaps northward from it (Douglas, et al., 1970, p. 393, Fig. VIII-13). There is also a very quartz-sandy unit of about the same thickness as Unit 1, within the underlying Nonda Formation (Fig. 2-5).

Environment of Deposition

As well as the predominantly arenitic grain size range, the presence of moderately large cross-bedding, lenticular orthoquartzite beds, occasional ripple marks, and planar layering formed by gradational change in grain size, all indicate an environment of relatively high physical energy. Trough and festoon cross-beds are not present, nor are narrow, obviously incised channels. In view of this, and of the compositional and textural maturity of the terrigenous components and the abundance of carbonate clasts, a fluvial environment can be eliminated from consideration.

The cross-bed sets are commonly continuous and of relatively constant thickness over some distance laterally and, although they are fairly thick, they are not as thick as the large-scale cross-beds typical of aeolian deposits. These facts, added to the stratigraphic position of the unit and its very broad, regional extent beyond the study area, with the same or similar lithologies, favour deposition of Unit 1 in water of variable, but shallow, depth along an exposed, marine shoreline. Figure 3-1 shows a tentative explanation of the sequence of the depositional features

observed moving upward in the section, admittedly based on somewhat scanty evidence. (This unit was given little attention during the field study because it is relatively remote geographically and stratigraphically from the loci of economic interest.) The depositional history suggested consists essentially of a gentle transgression of the sea, eventually resulting in formation of a belt of offshore shoals in the study area. This may then have been followed by a lowering of sea level and a decrease in current activity, perhaps in an increasingly sheltered area landward of increasingly extensive shoals. The orthoquartzite lenses near the top of the unit may represent storm deposits in an otherwise lower-energy area.

Unconformity

A prolonged period of subaerial exposure after the deposition of Unit 1 is suggested by the patchy distribution of abundant clay minerals in what would otherwise be a very pure orthoquartzite lens at the top of the unit (page 3-5). The very extensive diagenetic silicification in the same lens (page 3-5) can perhaps also be best

explained as a result of prolonged subaerial exposure. In addition, a significant stratigraphic "break" is suggested by the very abrupt change from relatively massive beds of sandy dolostone with sandstone lenses, at the top of Unit 1, to a thin layer of laminated, slightly silty, thin-bedded, fine-crystalline dolostone, here placed at the bottom of Unit 2 (page 3-20). The writer observed no angular discordance between the two units, however.

The Wokkpash Formation, which is evidently the regional correlative of Unit 1 (page 2-11), is reported to have an unconformable upper contact which is a paraconformity in most places and on which little erosion seems to have occurred (Taylor and MacKenzie, 1970, p. 9).

- a. Very quartz-sandy dolostone from the cross-bedded sub-unit of Unit 1. Note crude grain-size layering and veinlets of white dolomite containing minor residual porosity. (Approx. X 1.)
- b. Zoning in the larger veinlet in (a). Wall of fracture at right. (Plane polarized light; thin-section stained with potassium ferricyanide; scale bar shows 1 mm.)
- c. Well cemented quartz sandstone with streaks of argillaceous matrix: Unit 1.
- d. Variations in microfabric of specimen in (c). Note interlocking overgrowths in upper part; clay matrix in part of lower half. Some quartz grains show undulatory extinction. (Thin-section; X-nicols; scale bar shows 1 mm.)
- e. Fine, dolomitic quartz sandstone: Unit 1, location F.
- f. Quartz overgrowths, embayments and minor penetration of dolomite into quartz grains. Possible pressure-solution of quartz. Also note inclusion trails in quartz grains and undulatory-to-semi-composite extinction. Same specimen as (a). (Thin-section; X-nicols; scale bar shows 1 mm.)
- g. Polycrystalline quartz grain showing undulatory extinction in several crystals. (Meta-siltstone or coarse meta-chert?) Also note several highly rounded grains where overgrowths are minor. Same specimen as (a). (Thin-section; X-nicols; scale bar shows 1 mm.)
- h. Dolomite-filled fracture also containing overgrowths from quartz grains along walls. Same specimen as (a). (Thin-section; plane light; scale bar shows 1 mm.)

a

b

c

d

e

f

g

h

PLATE 3-1

- a. Clay-rich portion of specimen in 3.1-c: fractured quartz grains; scattered hematite specks; clay-filled grain outlines. (Thin-section; plane light; scale bar shows 1 mm.)
- b. Same view as (a) but X-nicols. Note abundant clay minerals, some filling clast outlines (former feldspar? — arrow). Also probable broken quartz grain near bottom.
- c. Partial outline of altered grain in specimen in 3.1-a. Clay minerals or fine sericite, with hematite, in grain outline (centre). (Thin-section; crossed nicols; scale shows 0.5 mm. between cross bars.)
- d. Rounded, partly altered, untwinned feldspar grain in specimen shown in 3.1-a. Flecks of sericite or clay mineral in feldspar. (Thin-section; crossed nicols; scale bar shows 1 mm.)
- e. Muscovite crystal at centre, adjacent to probably broken, rounded quartz grain. From a moderately argillaceous streak in specimen shown in 3.1-c. (Thin-section; crossed nicols; scale bar shows 1 mm.)
- f. Overgrowths and slight embayments of quartz in sandy dolomite; broken (?) tourmaline grain (dark) near bottom. Specimen shown in 3.1-a. (Thin-section; plane light; scale bar shows 1 mm.)
- g. Carbonate clasts visible as concentrations of inclusions. Also note vague grain-size layering; dolomite-filled fracture at left. Specimen shown in 3.1-a. (Thin-section; plane light; scale bar shows 1 mm.)

PLATE 3-2

UNIT 2

Field Characteristics

The second Devonian unit consists mostly of thick and medium beds of light-coloured, buff and light grey-weathering dolostone, monotonous and uniform in appearance at first glance (Plates 3.3-a; 1.2). Although Unit 2 lies on Unit 1 without noticeable angular discordance, there is evidence, both locally and regionally, for a disconformity (paraconformity) between the two units (page 3-18).

In Section P, where the unit was measured in its entirety, there are a few inches of fissile, thin-bedded, micro-crystalline, thinly laminated dolostone at the base, followed upward by thick-bedded micro-crystalline dolostone with layers rich in quartz sand. Above this, most beds in the bottom 230 feet of the unit contain readily noticeable amounts of quartz sand. Some (most ?) of these beds consist of fine and micro-crystalline dolostone, although at first glance the rough, pitted weathered surfaces may suggest coarser crystallinity. At location F (Fig. 2-6), where the lowest two-to-three hundred feet of Unit 2 occur in the core of a syncline, no sand was noted in outcrop or hand specimen and the thin, laminated

section at the base was not seen. Otherwise, the dense, micro-crystalline dolostone of the first thirty feet or so of the unit is similar in the two localities. However, above this there is a change at location F to repeated interbedding of fine-crystalline dolostone and a variety of medium-crystalline beds some of which have a large amount of intercrystalline (sucrosic) or vuggy porosity and others of which have a marbled, "pseudobreccia" texture (page 3-65) or contain vague traces of fossils (probably mainly amphiporids).

At location P, there is an abrupt transition at about 230 feet from the bottom of the unit, from beds with abundant quartz sand, below, to essentially quartz-free dolostone, above. In the rest of the unit, quartz grains appear only in a very few thin, widely separated interbeds. Upward in the section, the bedding pattern and lithologies soon closely resemble those of the upper 400 feet of the unit, which were logged and sampled in detail. Here, what first appears as a monotonous and uniform succession (Plates 1.2 ; 3.3-a) is seen on closer inspection to consist essentially of a cyclic repetition of:

- a) sets of one or more uniform, light-coloured, generally thick beds;
- b) one or more thin, generally darker grey, layers which commonly weather recessively and may easily be overlooked (Fig's. 2-5, 3-1). The thicker beds are composed predominantly of medium-

crystalline dolomite with moulds of large brachiopod shells displayed on many weathered surfaces (Plate 3.4-d and page 3-39). These fossils were seen as low as 800 feet below the top of the unit but they are very common above 255 feet from the top of the unit. Apparently, these large brachiopods are restricted to Unit 2. Patches and bands of "zebra structure" (page 3.57) are also very common in these beds.

The thin beds are fine-crystalline or micro-crystalline dolostone and many of them contain small blebs of white dolomite. Some beds are finely laminated (page 3-46).

The cyclical pattern is broken by several thicker-than-average sections of thin beds. The thickest, 350 to 390 feet below the top of the unit, includes argillaceous dolostone and some shale, with quartz-sandy dolostone and beds with white blebs ("fenestrae": page 3-47), at the top.

The uppermost one to two hundred feet of the unit is particularly thick-bedded (Plate 3.1-a) and often forms a major cliff in steep exposures (Plate 1.1-b). In two places on the property, parts of

this upper section consist of thick-bedded-to-massive limestone, passing laterally and vertically into the typical thick dolostone beds (Plates 1.1-b; 1.2-a; 3.17; 3.18). These limestone exposures stand out as sheer cliffs beside the less resistant, laterally equivalent dolostone. In certain horizons, they contain brachiopod casts of the same shape and size as those common in the dolostone beds (Plates 3.16-g; 3.17-c).

The contact between Units 2 and 3 is poorly exposed nearly everywhere as a result of the recessive nature of the basal beds of Unit 3 (page 3-138) and the rubbly-weathering tendency of the top few beds of Unit 2. One of the best exposures of the contact is in Section P, where the first "wormy" bioturbate beds of Unit 3 (q.v.) lies on the somewhat uneven surface of the uppermost of several relatively thin but mainly medium-crystalline beds showing signs of extensive diagenetic alteration (Fig. 3-1). The first thick bed with brachiopod moulds is a few feet lower in the section (Plate 3.3-b). A closely similar stratigraphic pattern, although incompletely exposed, was observed at Sections V, Y and G (Figures 3-2, 3-3, and 3-4, respectively).

Insoluble Residues - Unit 2:
Percentages Contained and Descriptions

Specimen No.	Weight % Insol. Res.	Description of Residue
LITHOTYPE I		
V-1	2.4	Clay and some silt; minor hematite after pyrite.
P-41.8	2.2	Clay, silt, some fine quartz sand, finely divided bitumen.
P-68	1.6	Clay, minor quartz sand and sand-sized, pyritomorphic hematite aggregates.
P-31.5	1.3	Subequal weights of clay and silt, and quartz sand and pyritomorphic hematite.
G-18	1.2	Clay (and minor silt?), minor pyritomorphic hematite.
P-44.6	1.0	Clay, minor silt and fine sand? Bituminous.
P-20.6	0.85	Clay, bitumen, minor pyritomorphic hematite. 86% of residue is finer than sand.
P-24.5	0.62	Clay, lesser silt and fine quartz sand, minor pyritomorphic hematite. (Not perfectly typical Lithotype I - some vugs.)
P-31	0.44	Quartz sand, lesser silt, tr. clay and bitumen. Minor pyritomorphic hematite and a rutile (leucoxene?) grain. (Non-typical specimen, with small vugs.)
P-56.1	0.39	Clay, minor pyritomorphic hematite and tr. bitumen.
LITHOTYPE II (Brachiopod Beds)		
P-60	0.40	Weighed after ashing of large pyrobitumen component. Pyritomorphic hematite.
P-42	0.23	Hematite, tr. quartz sand and bitumen.
P-50	0.20	Secondary quartz crystals, tr. hematite and bitumen. (Tr. quartz silt?)
P-31.4	0.18	Quartz silt and rounded quartz sand, minor bitumen and pyritomorphic hematite.
P-19.9	0.16	Dipyramidal, authigenic quartz crystals, pyritomorphic hematite, tr. quartz sand.
P-44.5	0.12	Silt, secondary quartz, hematite, bitumen
P-30	0.09	Quartz sand, pyritomorphic hematite.
P-34	0.06	Quartz sand to silt, bitumen pyritomorphic hematite, unidentified grains.
UNASSIGNED BEDS (Most like Lithotype II) - Random Selection		
V-9	0.77	Clay (x-ray shows mineralogically muscovite). (Specimen is intraclastic.)
P-24	0.53	Quartz crystals, pyritomorphic hematite, quartz silt?, tr. bitumen, clays? (Considerable internal sediment in specimen.)
P-44	0.22	?
P-55	0.22	?
P-44	0.21	?
P-21	0.13	? (Zebra dolostone.)
OTHERS		
AC-1	0.15	? (Micritic matrix of brachiopod-bearing limestone.)
P-830	13.4	Mainly quartz sand. (Top bed of lower, sandy section of Unit 2.)
AC-6	1.6	? (Laminated, intraclastic, peloid limestone.)
AD-T.2.	12.1	Largely quartz and lesser pyrite. (Matrix of large breccia.)

Petrography (Dolostones)

Minerals

Dolomite

Aside from the two limestone remnants mentioned on the previous page, nearly every bed in Unit 2 is properly called dolostone. Compositions range from nearly 100% dolomite in many of the thick beds to 90% or less in sandy beds in the lower 200 feet of the unit and probably considerably less in a few thick, argillaceous beds about 370 feet below the top of the unit. There is a marked difference in percentage of insoluble material between the two major types of beds (page 3-85 and Table 3-1). Staining and examination of thin sections indicate that the soluble fraction is entirely dolomite.

Dolomite crystal size is correlated with bed thickness, colour and other characteristics, in the upper part of the unit (page 3-85 and Appendix II, Table 1). The variation of crystal size up the section as observed in the field is shown in the detailed logs of Sections P, V and H (Figures 3-1, 3-2 and 3-5, respectively). Approximate crystal size ranges indicated by the terms used on the logs are given in Table 1-1.

A representative specimen from a thick bed containing brachiopod casts and also internal sediments (Plate 3.8-f) has a wide range of crystal sizes but a mean size in the "medium" range (Appendix I, Table 9). The crystal size distribution for a specimen representative of beds which have undergone particularly extensive diagenetic alteration (page 3-111 to 3-112, and Plate 3.11-a) is similar but lacks the coarsest sizes (Appendix I, Table 10). A representative specimen of the "zebra" lithology which is common in the thick beds (page 3-57 and Plate 3.11-h) can be separated into medium-coarse, white dolomite and finer-crystalline, grey dolomite, the latter typical of the relatively uniform rock outside the pockets of zebra structure. When both types of dolomite are point-counted together, a size distribution not unlike that of the previously described two samples results (Appendix I, Table 11). However, distinctly different, medium-crystalline and medium-coarse-crystalline distributions result when the two types are counted separately (Appendix I, Tables 12 and 13).

In thin sections representing all major lithologies in the upper 420 feet of the unit and the lowermost beds of the unit, a mosaic of relatively equant, interlocking crystals predominates (granoblastic-to-idiotopic: Spry, 1969, p. 6, 160-161, partly

after Friedman, 1965). (See Plates 3.4-a; 3.5-g; 3.6-f.) The exception to this is in cavity fillings. There, dolomite is generally coarse spar, commonly visibly zoned with respect to iron and inclusions (page 3-135; Table 3-2; Plates 3.3-c, 3.5-f, 3.8-d). The zoning outlines partial rhombic shapes facing vugs or facing former cavities, where further growth has caused an irregular interlocking between crystals growing from the two sides. Such cavity-filling crystals are commonly elongate perpendicular to cavity walls. (See also "Porosity", page 3-69, and "Diagenetic History", page 3-115.)

In internal sediments of dolomite silt (page 3-54), the crystals are blocky and granular-looking (Plates 3.4-a; 3.9-g, h; 3.10-b).

Quartz

As already noted, quartz sand is abundant in the lowest 230 feet of the unit in Section P, but it is present only in a few thin layers in the upper part of the unit. In the basal, laminated layer, where quartz amounts to less than 1% of the specimen studied (Plates 3.5-h; 3.6-a), the mean size is in the silt range (50- Appendix I, Table 16) and the largest grains are very fine sand (Specimen No. P-1065: Fig. 2-5,

-1045 feet). However, immediately above, in massive, thick-bedded dolostone, the mean size in a layer with 13% quartz is medium sand (1.7 ϕ) and the range is from very fine sand through coarse sand (Appendix I, Table 17 and Plates 3.3-e; 3.8-h: Specimen No. P-1060, Fig. 2-5, -1040 feet). A specimen from the topmost bed of the sandy lower part of the section appears to have a similar grain size distribution (Plate 3.7-a: Specimen #P-830, Fig. 2-5, -810 feet). This size range is probably fairly characteristic of the lower part of the unit, inasmuch as large amounts of coarser (granule) sizes would have been noted and fine and very fine sand alone, would have been largely overlooked in the rapid traverse of this part of the section, whereas most of the section was recorded as being "quite sandy".

In the upper 400 feet of Unit 2, no quartz is visible in hand specimens or at the outcrop except at 360 feet below the top of the unit (Fig. 3-1, -360 feet). Here several thin beds contain dispersed medium and fine quartz sand, probably bimodally distributed with subequal medium and fine modes.

Study of insoluble residues of representative specimens of the lithotypes in the upper 400 feet of Unit 2 indicates that

these beds contain less than 2½% insoluble residue, with quartz sand forming from zero to less than half of the residue (Table 3-1).

Sand-sized quartz grains in Unit 2 are mostly rounded-to-well-rounded, although overgrowths and embayments sometimes make roundness determinations difficult. There seems to be a decrease in roundness in the finest sizes and the quartz silt in the lowest bed appears angular. Several broken rounds were seen in the lowest thick dolostone bed (Plate 3.3-d). A wide range of sphericities occurs, with a moderate-to-high average sphericity and a decrease in average sphericity with decrease in size, in the one thin-section and several hand specimens inspected microscopically.

Small overgrowths are prevalent in a sample from near the bottom of the unit and many grains are penetrated by angular "embayments" of dolomite (Plates 3.3-d, e). In the topmost bed of the sandy lower section, however, there are few or no overgrowths or embayments and virtually all grains have a roundness of 4 to 5. (See "Definitions".) Overgrowths are difficult to identify in a hand specimen from the sandy layer in the upper half of the unit (Fig. 3-1: -360 feet) but superficial roundness is less than lower in the unit (subrounded-to-rounded?) and a few embayments seem to be present. ,

In a few places in Unit 2, quartz crystals are found in vugs as the last, or nearly the last, mineral precipitated (Plate 3.3-c). One specimen contains isolated dolomite crystals on quartz prisms but bitumen in the same specimen appears to predate the quartz. The quartz crystals are typically transparent, well-formed, elongate prisms with idiomorphic terminations and they range from a few millimetres long to two or three centimetres. They occur at approximately -130, -175 and -370 feet in Section P (Fig. 3-1), and at -256 feet in Section G (Fig. 3-4).

Bitumen

Bitumen is a common accessory throughout the upper part of Unit 2 and fills intercrystalline porosity in some of the porous, non-sandy beds which occur in the lower 200 feet of the unit at Location F. In the upper 400 feet or more of the unit, bitumen is characteristically the last component emplaced in voids, either as a complete filling or simply as a lining in vugs. In this "habit", it occurs in "zebra" structure, in breccia fillings, in voids caused by leaching of fossils, in fractures cutting intact dolostone, and in other cavities of indeterminate origin but invariably first lined and mostly filled with dolomite. Bitumen,

or what appears the same as the more readily identified vug-fillings, is also found as a stain along crystal contacts or as fine streaks between crystals in the homogeneous dolomite mosaic of some specimens. Similar black non-crystalline material occurs along stylolites in a few cases.

In hand specimen, the larger accumulations of bitumen in vugs have very shiny surfaces when fresh or broken, but cut and weathered surfaces are dull black. The bitumen often has curving or bubble-shaped surfaces against open cavities and in many specimens, curving pieces of bitumen are "stuck" in various orientations in the dolomite lining the cavities, juxtaposed in such a way that they clearly formed bubble-like or botryoidal surfaces which were subsequently broken (whether by inward collapse or by shrinkage is uncertain; Plate 3.8-g).

Most bitumen is harder than a fingernail but can be easily crushed by a knife, producing a carbonaceous-looking powder. Samples tested for fusibility did not melt but retained their form even after decomposition in an oven at 600°C , i.e., they are pyrobitumen (Abraham, 1966, p. 56).

Calcite

Aside from the two limestone cliffs discussed on page 3-72, calcite is rare in Unit 2 and was found only as a last filling in voids. In a thin-section from 220 feet below the top of the unit in Section P (Fig. 3-1), calcite is associated with bitumen and appears to have crystallized after deposition of the bitumen. Calcite was seen in outcrop at about 210 feet below the top of Unit 2, in Section P, and at about 250 and about 300 feet below the top of the unit in Section G. The colour of the calcite ranges from transparent to (mostly) milky white.

Pyrite

Pyrite was identified in hand specimen only at 370 feet below the top of the unit, where it occurs in a relatively pure, very fine-crystalline dolostone beds just below some argillaceous layers. The pyrite is finely disseminated, scattered along healed hairline fractures, and in small patchy aggregates of microscopically small crystals scattered in the dense dolostone.

In several thin-sections, other iron minerals with distribution

patterns similar to that just described, locally exhibit typical pyrite cross-sections (see below). Mineralized major breccias are not included in this description. They contain some pyrite in Unit 2, although pyrite is by no means always associated with the ore minerals.

Hematite-Goethite-"Limonite"

Secondary iron oxides are very common accessory minerals throughout the sampled parts of the unit, in all types of dolostone lithology. Insoluble residues from the upper 400 feet of Unit 2 almost all contain some brownish, opaque, heavy grains, framboidal or pyritomorphic in many cases, which x-ray analysis shows to be composed of hematite (Table 3-1). In nearly every thin-section from the dolostones of this unit, fine crystals and aggregates of brownish-red, reddish-brown and brown opaques can be seen scattered between dolomite crystals and/or along stylolites. Although these opaques are generally not uniformly distributed, neither is a systematic pattern of distribution evident, except that opaques are frequently more abundant within internal sediments than in the "host" rock. Pyrite-like cross-sections in a number of specimens indicate that these oxides replace pyrite (Plate 3.4-b). While the present composition of these opaques could not be determined with confidence

in thin-section (hematite v.s. goethite, etc.), they are presumed to be largely hematite by comparison with apparently identical material in insoluble residues, identified by x-ray diffraction.

Sphalerite

In the sections logged in Unit 2, sphalerite was encountered only within the large-scale breccia crossed in Section G. Here it occurs as a few small patches surrounded by the normal white dolomite breccia filling, generally in thin veinlets of white dolomite between closely spaced fragments.

The stratigraphic distribution of the major zinc-lead showings is discussed in Part IV of this thesis.

Feldspars and Muscovite

A few sand-sized twinned plagioclase grains and a trace of microcline and untwinned feldspar are present in the specimen studied from the lowest thick bed of Unit 2 (Plate 3.3-d, f, g). Muscovite, in trace amounts, occurs in the same thin-section (Plate 3.3-h) and also in the laminated basal layer at Section P

and in a sample from a bed near the bottom of the unit in Section F. In the latter sample, the muscovite is restricted to patches of finer-than-average crystallinity which also contain a little quartz silt (probably internal sediment - Plate 3.4-a). In all these samples, the muscovite is mainly in the silt size range and is intercrystalline to the dolomite.

Muscovite (identified by x-ray diffraction and possibly including illite) is the most abundant constituent of the insoluble residues of most fine-crystalline beds (Table 3-1).

Allochems

Intraclasts and Pellets

(Intraclasts and pellets are treated together, since they could not be distinguished in these rocks.)

Small intraclasts are scattered in most of the fine-to-microcrystalline, medium and dark grey layers containing white dolomite flecks. In these "fenestral" beds (page 3-45) the intraclasts are composed of the same material as their surroundings

2

and in a sample from a bed near the bottom of the unit in Section F. In the latter sample, the muscovite is restricted to patches of finer-than-average crystallinity which also contain a little quartz silt (probably internal sediment - Plate 3.4-a). In all these samples, the muscovite is mainly in the silt size range and is intercrystalline to the dolomite.

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(presumably originally micrite but now microcrystalline dolomite mosaic). They are clearly visible only where located in a lamina of slightly different colour or where partly surrounded by white, diagenetic dolomite (Plate 3.7-f, h). Care must also be taken not to confuse them with internal sediments, when viewed in a polished hand specimen. For these reasons, it is difficult to estimate the percentage of intraclasts in these beds but they appear to be present in amounts varying from one to ten percent, from a survey of several cut specimens. The intraclasts are even more difficult to distinguish from their surroundings in thin-section than in hand specimen.

These intraclasts are rounded, generally with sub-spherical or oval cross-sections and their size generally ranges from about 2 mm. to 0.1 mm. or less, although one specimen contains several large (9 mm.) irregularly shaped intraclasts which were clearly not transported far from the original location (Plate 3.7-h). In these beds, there is no obvious preferred orientation of the few relatively elongate intraclasts seen.

Intraclasts are also present in a few specimens from light and medium-light grey beds. Each of the specimens studied (Plates 3.7-b, c, d, e; 3.4-c) was taken within 9 inches of a bedding surface. Two

of them were found at the tops of thick, light-grey, medium and medium-fine crystalline beds and two were found at the bottoms of similar beds (none of these beds contain brachiopod casts). The specimens are mainly fine-crystalline and some contain very small open vugs. All contain a few irregular patches of white dolomite on the same scale as in the more typical "L-F" beds (page 3-47) and two contain internal sediments. Intraclasts recognizable on polished surfaces form a dispersed framework and amount to 15% to 35% of the rock (Appendix-I, Table 18). A fifth example is from a five-inch bed below a thick bed with large brachiopods and above a typical "L-F" bed (Fig. 3-1, -233 feet). The bottom portion of the specimen is a dark, "L-F" lithology but this is truncated and covered by a thick layer composed mostly of dark grey (and some light grey) intraclasts. This lithology grades upward to a lighter-coloured rock with smaller, dispersed intraclasts, much like the other four samples (Plate 3.4-c).

The intraclasts are composed wholly of uniform, micro-to-fine-crystalline dolomite with colours varying from dark to light grey, but with colours darker than the "matrix" predominating. Few intraclasts are larger than 3 mm. in apparent longest dimension

and most are larger than 0.5 mm. However, in two specimens a few light-grey intraclasts up to 1.5 cm. long are present (Plate 3.7-b, c).

The normal (small) intraclasts invariably have rounded outlines and most of them are oval or spherical. The most elongate, "tabular" cross-sections have a crude preferred orientation sub-parallel to bedding. A less regular and less rounded shape is characteristic of the larger intraclasts, although none exhibit sharp corners.

In a typical "zebra rock" sample (page 3-57 and Plate 3.8-d; 3.10-f; 3.11-h) from a thick, light-grey, medium-crystalline bed near the top of the unit, very vague concentrations are inclusions crossing crystal boundaries in the "host" phase may represent a primary pelleted sediment, although the size of the concentrations seems a little larger than the normal pellet range in Robb Lake limestones (normally about 0.1 to 0.15 or 0.2 mm.). A few vague, rounded concentrations of inclusions in a thin-section from a fenestral bed are also only slightly larger than normal pellets. In general, there is often a continuous distribution of particle sizes from normal pellet sizes to several millimetres. It is possible that a large percentage of the clasts are of fecal origin, although the largest and least spherical are undoubtedly non-biogenic, locally derived mudclasts.

Fossils

As well as the large brachiopods which characterize the upper half or more of the unit, there are large gastropods associated with the brachiopods in some beds. In addition, lenses rich in probable amphiporids were found in two places and a few small, delicate fragments of bivalves and unidentified (other?) fossils can be seen in thin-sections or polished surfaces from several fine-crystalline or microcrystalline beds.

Two different size ranges of brachiopods (possibly different kinds of brachiopods) are found, sometimes together but often in different layers. The larger and more common type is the better (although still very poorly) preserved. Most cross-sections of these are 5 to 10 cm. long and the very few nearly entire casts that could be obtained are about 10 to 14 cm. in longest dimension. Cross-sections of the smaller size range in outcrops are mostly less than 2 cm. long. These are present only as vague, curving traces, apparently intact and occasionally with valves in natural opposition to each other.

The larger brachiopods are clearly intact and in most beds some

naturally opposed valves, apparently still articulated, are present (Plate 3.4-d). A variety of orientations is common in each bed, with some valves elongate horizontally, or nearly so, and as many oriented more nearly vertically. This applies to both opposed and separate valves.

In most cases, only an imperfect cast is preserved. It consists of a former cavity, produced by leaching of the fossil, filled with white "sparry" dolomite or with an internal sediment of silt-sized dolomite crystals, or with a combination of the two fillings. In one specimen, dolomitization or recrystallization to a stable form preceded leaching. Here the cavity between the valves was filled with internal sediment after some inward crystal growth from the shell (Plate 3.4-e, g, h). The dolomite replacing the shell shows vague relict prismatic structure (Plate 3.4-f). The best preserved specimens occur in the limestone exposures in the upper part of the unit. A detailed description of the best specimen is given on page 3-80 and in Appendix III and Plates 3.15-g, h; 3.16-a, b, c.

The brachiopods are restricted to one or more ill-defined "horizons" of varying thickness in the very thick beds but they are abundant throughout several beds only three or four feet thick.

Different individuals are in contact locally but as a rule the shells are evenly dispersed and isolated from each other in the dolostone.

Most beds containing brachiopods also contain "zebra structure" (page 3-57). The brachiopods are occasionally found in the edge of areas of "zebra" banding (Plate 3.11-d) and are often found a few centimetres laterally from such areas. Zebra structure is far more plentiful than are brachiopods, however, and there is no apparent correlation between the locations of the two features in beds which contain both.

Gastropod casts were observed in a number of beds in Section P (Fig. 3-1). They have approximately the same size range as the larger bivalves and are distributed similarly in parts of beds, although they are never present in as great an abundance as the brachiopods commonly are. In most cases they are found with brachiopods (Fig. 3-1).

The gastropods are more poorly preserved than the brachiopods, perhaps due to their morphology and thinner shells. However, various outcrop cross-sections indicate that coiling is advolute and

planispiral, or nearly so, with a circular or near-circular whorl cross-section. Like the brachiopods, the gastropods do not appear broken or worn.

At location Y (Fig. 2-6), in a single thin, lenticular, dark-coloured horizon approximately 35 feet below the top of Unit 2, one large high-spined gastropod was found (Plate 3.5-a) along with brachiopod moulds similar to those found elsewhere in this unit (Plate 3.5-b). Although the specimens shown are more or less intact, this layer contains numerous small fossil fragments, and appears to represent a mostly transported assemblage, unlike any layers in Unit 2 in other places studied.

At about 335 feet below the top of the unit in Section P and about 90 feet below the top of the unit in Section H, thin, lenticular beds contain abundant very poorly preserved fossils with the same size, shape and distribution as recognizable amphiporids in Unit 2 limestones. A sample from the Section P locality is composed of white, curving, cylindrical fossils, apparently replaced by a fine-to-coarse dolomite mosaic, partly or wholly surrounded by light grey, medium-crystalline dolomite which has been reduced to very irregularly shaped "patches" engulfed by dark grey, microcrystalline internal

sediments which penetrate the rock in interconnecting former cavities that compose 40-50% of the rock volume (Plate 3.5-c).

Finally, a thin-section of a medium and dark grey, fine and microcrystalline bed contains a few scattered, fine fragments of small and probably delicate bivalves (possibly including ostracods). The largest of these are less than 3 mm. long in cross-section and they are visible only due to a slightly larger crystal size and slightly fewer inclusions than the surrounding dolomite. In one thin-section, one or two fragments were partly bordered by faint inclusion trains suggesting micrite envelopes. In the same thin-section one pair of probable (small) brachiopod valves occurs naturally opposed and only slightly disarticulated. These beds also contain occasional traces of unidentified fragments suggesting possible algal plates, small gastropods and perhaps other forms (Plate 3.5-d).

Quartz-sandy, microcrystalline dolostone from near the bottom of the unit contains more fine fossil fragments, though still less than 1%. Here, very thin, nearly intact, disarticulated, probable ostracod valves are most abundant and are up to 4 mm. long in cross-section. Fragments of thicker shells mostly small and worn are also present (Plates 3.3-e; 3.5-e).

Textural and Structural Features

Lamination

Normal sedimentary lamination is seen only in some "fenestral" layers (page 3-47) and in a few other thin, usually fine or micro-crystalline beds. There is some evidence that it may have been more prevalent before diagenesis (see zebra structure and ~~limestones~~ below). In addition, very fine lamination is common in internal sediments.

The fissile, lowermost layer of Unit 2 in Section P is made up of faintly visible laminae $\frac{1}{2}$ to 2 mm. thick which are produced mainly by differences in crystal size of the dolomite, presumably reflecting differences in crystal (grain) size of an original dolomite or calcareous silt. The laminae are grossly planar, but slightly undulatory on a fine scale and thickening and thinning slightly, laterally (Plates 3.5-h; 3.6-a).

A different type of lamination was found only in a thin-bedded interval at 210 feet below the top of the unit (Fig. 3-1). Here, the lamination consists of fining-upward, graded laminae of light-

to-medium grey, fine-to-microcrystalline dolostone and a lesser volume of thinner, dark grey, microcrystalline laminae (Plate 3.6-b). The thinner, darker beds appear to be crudely concentrated into groups about 1.5 cm. apart. Most of them are abruptly truncated laterally in places, as if segments had been removed, and they tend to have sharp upper contacts but generally grade downward into lighter coloured layers.

Graded laminae were also noted in a sample of dark grey dolostone taken from the lower part of a large-scale breccia body in Section G (Fig. 3-4). This specimen consists wholly of a series of fining-upward, light-to-dark coloured laminae, each about 2 mm. thick. Very small flame structures are visible on the surface of one lamina (Plate 3.6-c). These laminae are penetrated by a vertical "tube" filled with a homogeneous mixture of dolomite crystals which appear to have the same size range as in the rest of the rock. The laminae are markedly depressed around this tube and the dark, fine portion of each layer appears to have behaved more cohesively during this deformation than the light portion (Plate 3.6-d).

Where this specimen was taken at about 260 feet below the top of Unit 2, an outcrop surface about four feet square is occupied by

fragments of this lithology but no similar fragments could be seen laterally or vertically outside this area. It is not known whether this occurrence of micro-graded carbonate represents a local quiet-water depression in the depositional surface or an internal sediment deposit filling a large cavity.

In the fenestral beds (page 3-47 and Plates 3.6-g; 3.7-f, g, h), lamination is seldom as distinct and continuous as described above but it is nevertheless common. It occurs as a few darker-than-average layers commonly only a few tenths of a millimetre thick in a rock otherwise not visibly laminated. These thin laminae have a finer crystal size than the rest of the rock and contain minute, dull, dark brown opaques scattered at crystal contacts (Plate 3.6-e, f). The dark laminae are usually gently undulatory on a scale of a centimetre or two and they have very uneven surfaces on a scale of tenths of a millimetre. In at least one particularly clearly laminated specimen, this small-scale surface roughness seems to be due in part to the presence of relatively coarse, clastic-looking particles scattered on the laminae surfaces and in part to a through-going "wrinkling" of the laminae.

In many cases, these thin, dark laminae are continuous across

a hand sample but in some cases they contain gaps, as if pulled apart, and in other places they are simply a crudely aligned layer of separated "plates". In thin-section, an irregular, discontinuous appearance is characteristic (Plate 3.6-e).

In the most strongly laminated examples, groups of dark laminae and intercalated material are locally dislocated and overlapped as units, suggesting that a physically significant layering on a scale of 2 to 4 mm. also existed at one time (Plate 3.6-g).

Several thin, light-coloured, medium-crystalline beds near the bottom of the logged section (352 to 356 feet below the top of the unit) exhibit discontinuous thin, dark laminae which may be primary or may be due to internal sedimentation along horizontal cracks (Plate 3.6-h).

Fenestral Fabric

A "fenestra" has been defined by Tebbutt, et. al., (1963, p. 4) as, "a primary or penecontemporaneous gap in rock framework, larger than grain-supported interstices". The fenestral fabrics described

by these authors are identical or closely similar to most of what has been described as "birdseye" structure" (e.g. Shinn, 1968; Ham, 1954) and to A.G. Fischer's "loferites" (Fischer, 1964, p. 119; also Tebbutt, et. al., op. cit., p. 3). The term "fenestral fabric" is used in this thesis because a particular mode of genesis is not associated with the term, "fenestral", itself, although the fabric undoubtedly has environmental significance.

Fenestral fabrics are very common, although not universal, in fine-crystalline layers in the logged portion of Unit 2 (Fig.'s 3-1, 5). In nearly all cases, enough fenestrae are elongate parallel to bedding so that they define a crude layering indicating the bedding orientation. This "laminoid-fenestral" fabric is generally of the more vaguely layered, "Type B" (Tebbutt, et. al., op. cit., pp. 6-7; this thesis, Plate 3.6-g; 3.7-f, g, h). In some specimens with only a few fenestrae, the preferred direction of elongation is very ill-defined. A number of specimens with laminoid-fenestral fabric also contain fine laminations as already noted (page 3-44). However, fenestrae within finely laminated layers tend to be very small and some may actually be grain-supported (Plate 3.6-g). Intraclasts are common in beds with fenestral fabric, as already noted. Regardless

of the fact that both the "host" rock and the fenestral fillings are dolomite, the borders of the fenestrae are generally quite sharp. Most fenestrae are filled with coarse, white dolomite, often with a thin greyish-white layer next to the edge of the former cavity. In thin-section, these dolomite fillings can be seen to be composed of elongate or irregular dolomite crystals, in some cases zoned with respect to iron content and concentration of inclusions in euhedral patterns along their cavity-ward sides (Plate 3.5-f). In most cases, these dolomite crystals meet in an irregularly interlocking mosaic closing the fenestra. However, a few fenestrae in some specimens contain internal sediment, apparently emplaced at different stages in precipitation of the cavity lining in different cases (Plate 3.10-a, b, c). Traces of black opaques are common along last-formed crystal contacts at the centres of fenestrae and one specimen contains readily identifiable amounts of a black bitumen surrounding rhombic dolomite faces and filling the cores of some fenestrae. Excepting the white fillings of fenestrae, the average fresh-surface colour of most specimens containing fenestral fabric is medium or medium-dark grey (G.S.A. colour chart, 1963). However, fenestral fabric does occur in a few thin, light-grey beds and a few distinctive layers within thick beds. Here, it is not as well-developed as in the darker beds. All five of the light-coloured intraclastic samples

mentioned under "Intraclasts" (page 3-36) contain a few vaguely laminoid fenestrae filled with white dolomite and/or internal sediments and in one of them the fabric is fairly well-developed (Plate 3.7-e). Most of these five samples contain some porosity in pin-head-sized vugs. However, these voids are commonly within clast outlines and have only a slight lining of white dolomite, while outlines that do not seem to have been produced by leaching of clasts (true fenestrae) in the same specimens are entirely filled. However, cavities formed secondarily, by solution, cannot always be distinguished by their relationship to clasts from very weakly laminated fenestrae.

Typical laminoid-fenestral (L-F) fabric is not visible in the medium-and-coarse crystalline dolostone that makes up most of the unit. Early-formed voids certainly existed in many beds, since internal sediments are common, but the origin of many of these voids is probably different from that of the L-F fabric (see below). Borders of white dolomite and/or sediment fillings are seldom as sharp and distinct in these coarser beds. The shapes, sizes and distributions of white-dolomite-filled former voids are extremely varied, and there is an apparent gradation from roughly equidimensional "blebs" to zebra texture and even local breccia fillings (see "Zebra Structure", p. 3-57).

Nevertheless, certain relatively thin layers from parts of the section showing a particularly extensive diagenetic overprint (page 3-119) contain former voids which do show a laminoid orientation, albeit modified by leaching (Plates 3.8-c; 3.9-b; 3.11-a; 3.12-h). It is possible that these are diagenetically altered fenestral beds.

Intraformational Conglomerates

Except for one truncated laminoid-fenestral surface covered by a dense concentration of intraclasts (Plate 3.4-c), "ripped up" and locally re-sedimented material is conspicuous by its absence. Specimen number P-76.8, from 385 feet below the top of the unit (Fig. 3-1) resembles intraformational conglomerate due to slumping (moved only a little out of place), but its matrix is typical, fine, "internal" sediment and its fabric appears to have been produced diagenetically (Plate 3.9-c). Specimen No.G-24a, collected within a disrupted zone involved in large-scale brecciation (Fig. 3-4, -265 feet), exhibits small-scale disruption of layering that clearly occurred earlier than the brecciation (Plate 3.9-d). The extremely bituminous layers in this specimen suggest an organic-rich sediment. The curling and separation of layering that has occurred is probably

FIGURE 3-6

Distribution of grains of dyed sand within the sediment after a year of bioturbation. All grains originally were at the sediment-water interface.

(Redrawn after Clifton and Hunter, 1973, p. 261, Fig. 5.)

largely a result of desiccation and early partial lithification of an algal-rich sediment rather than being produced by hydraulic forces.

Mudcracks

In Unit 2, mudcracks were found only in the thin-bedded, partly argillaceous interval near the bottom of the logged portion of the Unit (Fig. 3-1, -362 feet). There, small mudcracks occur in argillaceous partings in a fissile, shaly dolostone layer and, lower down, faint, poorly preserved, large mudcracks are visible on a thin bedded dolostone layer (Plate 3.9-e).

Bioturbation and Burrows

9

All specimens from fine-to-microcrystalline, sandy beds, both in the lower part of the unit and in the one sandy layer in the upper 400 feet, display a "patchy" distribution of sand grains that can best be explained as a result of burrowing (Plate 3.7-a; 3.8-h). (For comparison, Fig. 3-6 shows a diagrammatic section

across a Recent bioturbated layer in carbonate sand.) In the light coloured specimens from near the bottom of the unit, patchily distributed, diffuse concentrations of brown, "limonitic" stain are associated with the burrowed sand. Comparison with bioturbate horizons in Unit 3 (page 3-173) indicates that these stains are probably also due to organic activity.

As well as the bioturbation within sandy layers, two non-sandy specimens exhibit vertically oriented tubes filled with dark sediment, probably representing burrows. One of these specimens was taken about three inches from the top of a thick, light-coloured bed with bivalve casts in its lower part (Fig. 3-1, -166 feet). The other (Plate 3.6-h) is from a thick, weakly laminated bed with discontinuous, thinner bedding planes located just above the thin-bedded, fissile interval about 360 feet below the top of the unit in Section P. A poorly developed bedding surface occurs an inch or two above the sample location.

Internal Sediments

Fine sediment introduced into cavities in previously deposited sediment or rock is very common in Unit 2. The internal sediment

invariably now consists of silt-sized dolomite crystals, sometimes with scattered traces of hematite and/or goethite (Plates 3.9-g, h; 3.10-b) and sometimes with some interstitial bituminous material. One thin-section from 420 feet below the top of Unit 2 in Section P (Fig. 3-1), contains internal sediments (partly altered by aggrading recrystallization) with up to 1% silt-sized muscovite (Plate 3.9-g).

Internal sediments are associated with virtually every combination of crystal size, colour and bed thickness. In beds with fenestral fabric, the sediments are generally confined to a few fenestrae, most cavities being filled entirely by white dolomite (page 3-49 and Plates 3.7-f, g, h; 3.10-a, b). (One possible exception to this is discussed under "Fenestral Fabric", p. 3-47.) Some thin, fine-crystalline beds contain interspersed voids filled with internal sediment and voids filled with white dolomite. Plate 3.8-a (Fig. 3-1, -187 feet) is an example of this but the specimen contains one void filled partly by internal sediment and then by white dolomite, suggesting that the bulk of the white dolomite fillings post-dates the internal sediments. Such a fabric might result from formation of different cavities at different times or from the lack of large enough pores for penetration of silt-laden water into some cavities.

Larger "pockets" of internal sediment are common in many medium- and coarse-crystalline beds, particularly in certain parts of the section (Fig. 3-1). Many brachiopod moulds were filled wholly or partly with internal sediment. Internal sediments fill solution-cavities varying from isolated, irregular cross-cutting shapes to interconnected networks surrounding remnants of the earlier rock and forming up to 50% or more of the specimen volume (Plates 3.5-c; 3.8-d, f; 3.11-a, d; 3.12-a, b, d, h). "Pockets" of internal sediment are also common in samples in which few or no vestiges of primary texture can be distinguished. In the last case, the internal sediments are recognizable by colour, texture, shape, distribution, relationship to other parts of the rock, and by resemblances to sediments in better-preserved layers. These internal sediments occur in a variety of irregular shapes but they often have a crude preferred elongation parallel to bedding (Plates 3.8-f; 3.11-a). Two specimens with probable burrow fillings of internal sediment have already been mentioned (page 3-54) and several specimens contain fractures along which internal sediments have been deposited (Plates 3.8-b; 3.9-a).

In some hand specimens and thin-sections, pseudomorphs of elongate crystals, now a dolomite mosaic, project into the sediment from former

cavity walls. These forms are narrower and more elongate than the dolomite rhombs which commonly project into present voids. They appear to represent an early lining of calcite scalenohedra or other forms (Plates 3.4-e, f, g, h; 3.8-e). They sometimes extend directly from the host rock and sometimes from a layer of white dolomite which lines the upper part or all of the cavity. Many sediment-filled cavities in all lithologies have distinct, relatively smooth borders against the containing rock, however, and some others, particularly in thoroughly re-crystallized specimens are bordered partly by stylolites (Plate 3.9-f; 3.11-a)

Colour differences and relationships with white dolomite fillings and fractures indicate that more than one phase of internal sedimentation took place in a number of specimens (Plates 3.4-h; 3.12-a, d).

Zebra Structure

One of the most striking features of Unit 2 and the two above is the layered dolomite pattern here called "zebra structure"

or simply "zebra". This term is not a new one. It has been used by A.G. Fischer (1964, pp. 115, 135, Fig.'s 15, 17, etc.) to describe parallel sets of planar "sheet cracks" occurring mostly in "neptunian dykes" of lime mudstone. Some of Fischer's illustrations show somewhat similar features to the Robb Lake structure.

The term, "zebra" is also commonly used, at least informally, to describe structures similar to those at Robb Lake which are found in carbonates associated with the lead-zinc deposits of the Mississippi Valley area, according to several geologists familiar with that area.

The zebra structure common in Unit 2 consist of thin dolostone layers identical to, and connecting with, the surrounding homogeneous, grey rock but separated from each other by coarser-crystalline, white dolomite layers or, in some cases, by voids of the same shape as the white layers or by a black bitumen, or by a combination of the three (Plates 3.10-d, e, f; 3.11-c, d, h). The layering is invariably oriented parallel to bedding except where disrupted by brecciation.

In well-developed, typical zebra structure, the white layers always vary more widely in thickness than the darker layers, ranging

from several times thicker than the thickest dark layer to pinch-outs between adjacent dark layers.

Under a low-powered microscope, many borders between light and dark layers appear quite irregular and few of them are perfectly sharply defined (Plate 3.10-f). In thin-section, the dark-light layering can be seen to be due mainly to differences in crystal size (Appendix I, Tables 12, 13) but also partly to lack of inclusions in the cores of the white layers (Plate 3.8-d). The dark layers are composed of a relatively fine, fairly equant, tight-fitting crystal mosaic identical to homogeneous dolostone adjacent to the zebra structure. Projecting from the dark layers are larger crystals showing a strong preferred orientation perpendicular to the layering. These crystals are zoned with respect to concentrations of inclusions (Plate 3.8-d) and with respect to iron content of the dolomite, as shown by staining tests. The zones form successive idiomorphic (rhombic) overgrowths on the sides of the crystals facing the centres of the white layers. Where open cavities are present in the middles of the white layers, the crystals end in the cavities in rhombic faces, sometimes coated with bitumen. Elsewhere, the dolomite crystals extending from adjacent dark layers meet at irregular, tightly interlocking contacts (Plate 3.8-d).

In at least one specimen, a few faint, subvertical fractures composed of the light-coloured type of dolomite cut across, or into, dark layers. They generally wedge out downward or branch into thinner fractures which pinch out in dark dolomite.

In many cases, zebra structure is cut by planar fractures at high angles to the layering. A few of these are open and clean but there are commonly also fractures obviously formed earlier than the open ones. These earlier fractures are entirely filled with white dolomite or occasionally very fine, dark dolomite in part (Plates 3.10-d, e; 3.11-c, d, g). In several specimens, one or more of these filled fractures cuts others, showing that more than one stage of fracturing and filling occurred. The fillings of the earliest fractures appear to be continuous with the later phases (central parts) of the white layers of the zebra which they cut (Plate 3.10-e). The zebra layering pattern generally does not match on the two sides of these fractures (Plates 3.10-d, e; 3.11-c). In some cases, this is due to a simple offset but in others there are a larger number of more closely spaced layers on one side than on the other. In several specimens, the upper side of these early fractures is bordered by a continuous, or nearly continuous, band of dark dolomite that seems to be formed by thickening and joining of the ends of the dark zebra layers (Plate 3.10-e).

In one case, a pocket of zebra structure ends abruptly against a somewhat different fracture (lacking a white dolomite filling), (Plate 3.11-d). Since the same fractures cut a fossil mould filled with internal sediment, without offsetting it noticeably, the abrupt change to a homogeneous grey rock cannot be explained as an offset.

Zebra structure was never found to extend continuously either vertically or laterally, for more than a foot or so (usually less). At its borders it grades into apparently homogeneous, structurally isotropic dolostone without white dolomite, as shown on a small scale on the left side of Plate 3.11-d. (See also Plate 3.11-g, h.) In rare cases, zebra grades instead to a finely laminated dolostone (Plate 3.11-c). Zebra structure is poorly exposed on weathered and lichen-covered surfaces, so that good outcrop photos are hard to obtain. Plate 3.18-c shows small zebra pockets in a relatively well-exposed surface adjacent to the largest limestone exposure.

Some zebra "pockets" contain local breccias consisting of fragments of dark zebra layers "floating" in white dolomite coextensive with the white layers of adjacent zebra structure (Plate 3.11-g). These breccias range from about one to several hundred square centimetres in cross-sectional area and seem to

have a very irregular three-dimensional shape.

Internal sediments (q.v.) are occasionally found in zebra rock but none were identified within the actual white zebra layers. Rather, they form cross-cutting bodies surrounded partly by zebra structure. Plate 3.11-d shows internal sediments filling a brachiopod cast and irregular cavities. Here, the zebra structure and its fillings (white dolomite) evidently post-date the internal sediments.

As well as the "typical" zebra structure described and illustrated above, there are a number of examples of similar, but less uniform and well-defined patterns (Plates 3.11-b, f). In all cases, elongate streaks or layers of white dolomite separate a darker "host" dolostone into at least a crude layering, oriented approximately parallel to bedding. In these "borderline cases" white layers are less continuous than in typical zebra and they are commonly thinner than adjacent dark layers. While typical zebra structure in Unit 2 is restricted to relatively light-coloured, generally medium crystalline dolostone, "borderline" examples do occur in somewhat darker and finer-crystalline lithologies.

Figures 3-1, 2, 4 and 5 show the locations of zebra structure in logged sections of Unit 2. Clearly, this feature occurs almost wholly in thick beds with medium-fine-to-medium-coarse average crystal size. It is usually present in beds containing brachiopod casts but is also common in non-fossiliferous beds. Although zebra structure within some thick beds seems to be limited to certain ill-defined layers, it is not restricted to any particular level with respect to bedding planes. Zebra structure is not found in typical laminoid-fenestral beds or in similarly dark-coloured and fine-to-microcrystalline, thin beds.

Fractures

In all sections, open fractures are very common, ranging from three or four to ten or so per square foot, in most places. These are evidently related to tectonic activity long after lithification and undoubtedly vary in orientation in various parts of the large-scale structural features of the area (see "Structure", page 2-1). However, most are at a high angle to bedding. They are planar or subplanar and cut across all other structures.

Dolomite-filled, planar-to-irregular fractures are also common

throughout the unit, and all sections, although they are less abundant and less uniformly distributed than the open ones. These filled fractures or white dolomite veinlets are particularly common in and near large breccia zones. There is a gradation from planar, cross-cutting fractures within a part of a bed, to the discontinuous planar fractures described in zebra rock (q.v.) and to very irregularly shaped fractures which pinch out in short distances within a hand specimen. Cross-cutting relationships of fractures in many samples indicate more than one time of formation and filling (Plates 3.4-h; 3.8-b; 3.10-g; 3.12-a).

All thin-sections from the upper 400 feet of Unit 2 contain at least one "generation" of filled fractures, mostly less than 0.5 mm. thick. Most of the fillings are zoned with respect to iron in the dolomite and with respect to inclusions, as are the zebra white layers (see discussion of zoning under "Diagenesis", page 3-135). A thin-section from within a large brecciated zone contains at least three "generations" of dolomite-filled fractures and one of open hairline fractures en echelon.

In some hand specimens and thin-sections, internal sediments are clearly cut by dolomite-filled fractures (Plates 3.4-e, g, h;

3.10-a; 3.11-a; 3.12-a). However, internal sediments emplaced along fractures are also found in a few fine crystalline samples (Plates 3.8-b; 3.9-a).

Stylolites

Stylolites are not abundant in Unit 2 but they are common in the more thoroughly diagenetically altered samples and in areas of large-scale brecciation. In the former, the borders of internal sediments are often partly stylolitic (Plates 3.9-f; 3.11-a) and any traces of layering may be stylolitized (Plate 3.10-h). In the large breccias, stylolites sometimes border breccia fragments.

Stylolites are uncommon in fine-crystalline, dense beds such as the typical laminoid-fenestral beds.

Local Breccia and "Pseudobreccia"

Except where through-going, large scale brecciation occurs near or in the sections measured (Section G, upper 250 feet of

Unit 2; Section V, lesser) breccias are mainly confined within beds, in Unit 2. The following discussion applies only to these breccias. They often grade laterally and vertically to both non-brecciated dolostone and "marbled"-looking lithologies identical to the "pseudobrecciated" and related textures described by Griffin (1965, p. 24 and Plates XIV, XV and XVI). Of the six terms coined by Griffin to describe a very similar textural spectrum in Slave Point dolostones, three ("clotted", "nebulous", and "pseudo-brecciated") are so intimately mingled and continuously gradational, one to another, in Robb Lake outcrops that it does not seem meaningful or practical to distinguish them in descriptions (Plates 3.11-e; 3.12-a, b, c, g). A mixture of the three will here be implied by the term "pseudobreccia". Griffin's "banded" texture, on the other hand, appears to be equivalent to zebra structure. The latter also grades to local breccia in some cases. (See "Zebra Structure", page 3-57.) Finally, Griffin's "microinclusion" and "macroinclusion" textures do not seem to be present in Unit 2.

With rare exceptions, breccia "pockets" or "zones" consist of relatively dark (medium and light grey) "fragments" identical to laterally adjacent non-brecciated dolostone, and a coarse-crystalline white dolomite filling surrounding the fragments (Plates 3.11-e, g;

3.12-a). "Normal" breccia, with sharply angular, often equant fragments and distinct fragment borders, is very uncommon. "Local breccia" specimens collected from Unit 2 have fragments (remnants?) without sharp corners. Also, abrupt, distinct borders between dark and light phases are uncommon. Fragments are quite commonly elongate and oriented parallel to bedding. Distinctness of borders and corners varies continuously from something approaching a "normal" breccia to the pseudobrecciated textures just mentioned. (Compare Plates 3.11-e, g; 3.12-a, b, c, g to "true" breccias from Unit 3 (Plates 3.25-f; 4.2-f, h).) The pseudobreccias often contain much internal sediment (e.g. Plate 3.12-a) and they grade to the thoroughly recrystallized but relatively homogeneous textures bearing internal sediments, which are common in some parts of the unit (Plates 3.11-a; 3.12-h).

This overall assemblage of diagenetic textures (pages 3-84; 3-119 is well-developed at certain levels in Unit 2. Different levels may be affected in different parts of the study area but lateral control is not sufficient to confirm this. Several parts of the longest detailed section (Section P: Fig. 3-1) consist entirely of various mixtures of the lithologies in this assemblage, ranging from "local breccia" to relatively homogeneous recrystallized textures associated

with abundant internal sediments. The largest such stratigraphic interval is from 300 to 420 (or more) feet below the top of the unit, separated into two parts by ten feet of mudcracked argillaceous dolostone, shale and microcrystalline dolostone at about -360 to -370 feet on Figure 3-1. A similar but smaller interval occurs at 122 to 138 feet below the top of the unit. The top few beds of the unit also exhibit at least part of this textural spectrum whenever they were seen, e.g., Plate 3.12-b, d. In addition, "zones" of internal sedimentation, abundant white dolomite, and commonly coarsely recrystallized textures and patterns approaching pseudobreccia, occur at a number of places, within thick dolostone beds, (e.g., Plate 3.8-f). In some cases, these zones are adjacent to discontinuous bedding surfaces but they may be anywhere in a bed. Pockets of "local breccia" (as described above) occur in some of these zones and also in association with zebra structure and/or concentrations of brachiopod casts.

At Section V, where only the top 100 feet of Unit 2 are exposed, breccia and pseudobreccia-like textures are common in many beds. However, here, through-going fracture systems with associated brecciation also cut the section, crossing the Unit 2-Unit 3 boundary, and large-scale brecciation occurs nearby.

In Section H, "zones" similar to those in beds in Section P occur at several places in the upper 130 feet of Unit 2 (Fig. 3-5).

As well as the textural assemblage already described, parts of several beds in the large, extensively diagenetically altered interval below -300 feet in Section P (Fig. 3-1) exhibit an unusual texture consisting of fine or microcrystalline, light grey "fragments" in a dark-grey-to-black "matrix" of coarse crystals and very fine material. In places, the light-coloured "fragments" are arranged in a crude "criss-cross" pattern (Plate 3.12-e), or occur in clusters in which the pieces are separated only by fine, dark fracture fillings (Plate 3.12-f).

Porosity

Present porosity is highly variable, both vertically and laterally in Unit 2. Moreover, there has been a complicated history of porosity development and modification in these rocks (page 3-119).

The most obvious and widespread type of porosity consists of vugs ranging from the size of a pin head to more than 5 centimetres

in longest dimension. Vugs are common in at least parts of the relatively thick, medium-crystalline beds which form the bulk of the unit. However, they are typically widely scattered and therefore produce only a low or moderate overall megascopic porosity. No porosity is visible in hand specimen in any of the typical laminoid-fenestral beds or in most other medium or dark grey, fine or micro-crystalline beds. Neither is any porosity visible in thin-section in a typical laminoid-fenestral bed.

Some vuggy beds contain the full range of vug sizes but more common are layers containing only small vugs and other layers containing predominantly moderate-to-large-sized ones. A few beds show a vertical gradation from one vug size to another.

In most cases, at least a thin coating of white dolomite lines the vugs. Commonly, a partial filling has reduced original vug size considerably (Plate 3.3-c). In fact, in some beds there is either a lateral or a vertical gradation, or both, from clean vugs to complete fillings of white dolomite and bitumen in former vugs over a distance of less than two feet.

Vugs occur within some brachiopod moulds; they are common in

zebra structure (Plates 3.10-d, e; 3.11-c) and in "pockets" of local breccia (Plate 3.11-g), where they occur in the white filling, and they are usually present in "pseudobrecciated" and coarsely recrystallized textures (Plates 3.8-f; 3.12-a, g). In a few samples, vugs are probably moldic after small fossils. However, many small and moderate-sized vugs cannot be assigned to any of these categories. Among the unassignable vugs, a prominent preferred elongation of vugs parallel to bedding and often a somewhat lenticular shape is found in a great number of beds. Beds with apparently randomly shaped, oriented and distributed vugs are also common, however.

The importance of intercrystalline porosity is more difficult to assess. It is certainly significant in a few beds or parts of beds, where a somewhat sucrosic texture occurs (Plate 3.12-h). However, even coarsely re-crystallized and pseudobrecciated textures lack much visible intercrystalline porosity in most cases (Plates 3.8-f; 3.9-f; 3.4-b; 3.11-a -- hand specimens and corresponding thin-sections). Such porosity is very seldom visible in other lithologies.

Bedding surfaces and numerous open fractures at some localities appear to create significant amounts of porosity.

Petrography (Limestones)

The limestones of Unit 2 consist wholly of essentially microcrystalline rocks ranging from biopelmicrites (or "biopelmicrosparites") to slightly fossiliferous pelmicrites (or "pelmicrosparites"), following Folk's classification (1968, pp. 153-168).

Minerals.

Calcite

Within the two known exposures of limestone in Unit 2, calcite makes up nearly 100% of the rock, except near the edges of the limestone bodies. Crystal sizes range from nearly one millimetre to less than 5 microns, but micrite sizes (less than 5 microns) are most abundant except where fossils form a large percentage of the rock volume (e.g., Appendix I, Table 19). Three other crystal sizes and types are common: 1. microspar (5 to 20 microns and clearer than micrite); 2. spar (larger than 20 microns and containing few inclusions); and 3. internal sediment of calcite

silt. Microspar occurs in relatively equant crystals in patches scattered in the micrite between pellet and fossil outlines and sometimes projecting into pellet borders (Plates 3.14-a, f, etc.). It locally makes up most of the non-clastic portion of the rock.

Typical sparry calcite occurs in patches and irregular patterns of interlocking crystals, usually clearly filling former cavities (Plate 3.13-a, f; 3.14-f, g, etc.) or (?) replacing fossils (page 3-77). Some former cavities are partly filled with equant, granular-looking, silt-sized calcite evidently emplaced as an internal sediment (Plate 3.13-a, f; 3.16-d). Note the order of cavity filling in the examples illustrated: first calcite silt (internal sediment) which blends with the inter-pellet matrix at the bottom of cavities, then a lining of fine, partly radiaxial spar on the near-planar surfaces of the crystal silt and to a lesser extent on other walls of the cavity, and finally coarse spar filling the remaining space.

Dolomite

Dolomite occurs as an internal sediment in a few places and

it occupies part or all of former brachiopod shell volume and fills planar and irregular fractures in some parts of the outcrops (probably only near the transition to dolostone)-(Plates 3.13-b, c; 3.18-a). Isolated dolomite crystals or small clusters occur near some dolomite-filled fractures (Plate 3.13-c). Except for internal sediments, dolomite crystals are medium-to-coarse and interlocking (Plates 3.13-b; 3.16-e).

Quartz

Of four thin-sectioned samples from the limestone cliff at Location AC, only one contained any quartz. In that sample, probably from near the transition to dolostone (taken from a boulder, just below outcrop), a brachiopod mould is filled with dolomite and a few scattered, silt-sized grains of quartz occur in the dolomite (Plate 3.13-b). Other evidence (page 3-83) indicates that the dolomite replaces pre-existing calcite rather than filling a former void. The presence of quartz silt may indicate that the former calcite filled a void (mould) rather than representing original shell material. However, it is possible that the few quartz grains seen were deposited in the internal cavity of the fossil, which cannot now be distinguished from the shell.

Opagues

Traces of an unidentified white, opaque substance (amorphous?) occur along hairline fractures and occasionally scattered in spar and microspar areas. In one sample, apparent crystals about 0.03 mm in longest dimension of section were observed.

Hematite(?) is finely disseminated in parts of a dolomite-filled fossil mould containing quartz. (See above.) In the same sample a few spots of a brownish, opaque stain occur in the limestone. By comparison with other samples, it is probably an organic substance.

Allochems.

Pellets

Pellets are the most abundant clastic constituent of all samples studied. For the most part, the pellets are typical, purely micritic ovoids or spheres. Parts of a laminated sample seem to contain a larger percentage of unusually elongate or relatively angular

"peloids" (Bathurst, 1971, p. 84-86) than the other samples. (Compare Plates 3.14-a and b.) Size analysis of one sample shows an average size of about 0.07 mm (3.8 phi) and moderate-to-good sorting (Appendix I, Table 20). The other samples appear to contain closely similar size distributions.

Although they generally appear to form an intact framework, pellets are largely surrounded by microspar and/or a slightly more transparent micrite than that composing the pellets. Pellet borders vary from very indistinct to quite sharp, depending mostly upon the nature of the surrounding matrix (Plates 3.14 and 3.15).

Pellet sizes are commonly homogeneously distributed but in some cases variation in average pellet size appears to contribute to a crude lamination. (See page 3-82 and compare Plates 3.13-f and 3.14-c with Plates 3.15-b, c, f.)

Intraclasts

Some layers contain a few irregularly shaped or elongate micrite intraclasts up to 2 mm or more in length, mostly visibly

pelleted and resembling the surrounding pelmicrite. In the vaguely laminated specimen shown in Plate 3.13-d, a micrite clast more than 5 mm long was seen (Plate 3.13-e). In the same specimen is an intraclast 7 mm long in section, formed partly of pellets and partly of probably amphiporid pieces (Plate 3.13-g). It also includes a void lined with coarse, radiaxial calcite and filled with dolomite silt. The filling is cut off at the edge of the clast, showing that it was already coherent when the clast was formed (Plate 3.13-h).

Fossils

Trilobites, ostracods, calcispheres and unidentified fragments

Much of the thickness of the limestone exposures is very sparsely fossiliferous (Plates 3.13-e, f; 3.14). Only scattered, fine fragments of thin and apparently delicate fossils are found. Many curving shell fragments are impossible to identify but a few trilobite fragments and ostracods shells are recognizable (Plate 3.14-c, d, e). Other fragments resemble gastropod parts but could also belong to other molluscs or brachiopods. A few calcispheres can also be seen in all thin-sections (Plate 3.14-a) and several

probable foraminifera tests are visible (Plates 3.14-f, g).

Plates 3.14-d, h and 3.15-a show several unidentified fossils and fossil fragments.

The ostracods and trilobite fragments retain a finely prismatic crystal structure perpendicular to shell surfaces but the other shell fragments have been leached and are filled with spar, sometimes with slight radiaxial linings (Plates 3.14-f). Thin micrite envelopes can be seen on some fragments (Plate 3.14-f, g, h).

Amphiporids

Amphiporids are present in abundance at several levels in the AC exposure (Fig. 2-6). They appear to be restricted to relatively thin layers within thick beds. The axial canals are nearly all spar-filled and quite distinct (Plate 3.15-b, c, d) but the "network" structure of the skeleton is clearly visible only in a few cases (Plate 3.15-b, d). More inclusions and finer and more equant crystals in the skeletons than in the adjacent spar indicate that the former have been replaced (or recrystallized?) rather than leached. Thin micrite envelopes coat amphiporids in many cases (Plate 3.15-b, c, e).

Amphiporid skeletons are 2 to 3 mm in diameter and up to 1.5 cm or more long. Most of them are oriented with long axes parallel to bedding but no alignment within the bedding plane is apparent. In some places, an intact framework of amphiporids occurs but elsewhere they are somewhat dispersed in the pelmicrite.

Skeletons show no evidence of wear or fragmentation before burial. In one specimen, parts of several skeletons are cut off against spar-filled cavities evidently formed by leaching (Plate 3.15-e).

Brachiopods

Less common, but still occurring at several horizons in both limestone exposures, are large brachiopods of the same size and shape as the larger, more common type described from the dolostones at the same stratigraphic level (page 3-39). Most brachiopod-bearing limestone layers contain numerous amphiporids, as well (Plates 3.13-c; 3.15-b, f).

Although poorly preserved, brachiopod specimens from the limestones are in somewhat better condition than those from the dolostones. It is on the basis of one nearly complete external cast and several partial specimens from the limestones that these fossils are recognized as brachiopods, almost certainly belonging to the order, Terebratulida, and probably either to the family, Centronellidae, or to the family Stringocephalidae. On the basis of external morphology, these fossils appear to be distinct from all genera described in the Treatise on Invertebrate Paleontology (Muir-Wood, et al., 1965, p. H740-H748), however. Plates 3.13-c; 3.15-g, h; 3.16-a, b, c illustrate specimens collected and a detailed description can be found in Appendix III. It should be pointed out that these fossils are distinctly different in shape from Stringocephalus, reported from farther north in the Devonian outcrop belt (Crickmay, 1954, 1960). Stringocephalus is more nearly spherical in shape and has a prominent beak which these fossils lack.

The brachiopods are found mostly with valves opposed as in life but in some cases slightly displaced from the articulated position. Individuals occur at a variety of orientations, with sub-vertical and sub-horizontal ones apparently equally common (Plate 3.16-g; 3.17-c). Separate valves are also present in some places.

Dolomite replaces the fossil (or its calcareous cast) in some cases (Plate 3.13-c) but most specimens are replaced by coarse-crystalline, white calcite (Plate 3.17-c).

The interior cavities in specimens occurring in limestone are filled largely with former lime mud, apparently similar to that surrounding the fossils (Plates 3.16-g; 3.17-c). Internal sediments of calcite silt were not seen in hand specimens of the cavity fill. No thin-sections were made of these fillings.

Textural and Structural Features.

Homogeneity and Layering

Limestone outcrops appear quite massive and uniform in the field (Plate 3.17-a), although a close inspection reveals vaguely defined, amphiporid-rich layers and brachiopod-bearing horizons. In hand specimens and thin-sections, a gradual vertical variation in concentration of the various fossil constituents can be seen

and in one specimen there is a distinct lamination due to a combination of varying concentration of intraclasts, varying amount of microspar v.s. micrite between pellets, and probably varying average pellet size (Plates 3.13-d, f; 3.14-b, c). Otherwise, a relatively homogeneous "pellet mud" prevails.

Porosity

No porosity was detected in any limestone samples, except in occasional, thin, open fractures. Early porosity is represented by spar-filled and internal sediment-filled areas often occurring around or beneath (supported by) fossils and other large clasts (Plates 3.13-a, f; 3.16-d).

Penecontemporaneous Deformation

The laminated limestone sample studied contains a few dislocated layers (Plate 3.13-d). These predate the entire sequence of cavity fillings, since all three types of fillings occur in cavities formed beneath disrupted layers (Plate 3.13-f).

Stylolites

A few low amplitude stylolites and incipient stylolites are noticeable in thin-section. They are approximately parallel to bedding and extend only for a centimetre or two.

Fractures

Three types of fractures occur in the limestone specimens. The first are very thin, vertical or near-vertical, fairly planar fractures entirely filled with clear calcite. These cut all clasts and internal sediment, and probably(?) cavity-filled spar. However, they predate the dolomite in partially dolomitized specimens. In the dolomite replacing a fossil (or replacing a calcareous cast), one of these fractures remains as a trail of calcite and submicroscopic opaques, included in the dolomite crystals (Plate 3.16-e). Taken together with the geopetal calcite and probable ghosts of radial layers along the bottom part of the same fossil (Plate 3.16-f), this fracture trace supports the contention that the dolomite formed by replacement of a sparry calcite filling and not directly as a cavity filling.

Dolomite-filled fractures continuous with dolomite replacing fossils, occur in several specimens (Plates 3.13-c; 3.15-f; 3.16-f). In one case a part of one of these fractures is filled mostly with calcite. This type of fracture is somewhat wider than the first type but is also subvertical in orientation. The relative times of origin of the two types are unknown.

Finally, in some samples, extremely thin, somewhat irregular fractures occur which are open or partly filled with extremely fine opaque material. These fractures vary widely in orientation.

Lithotypes and Cyclical Patterns

In the upper 400 feet of Unit 2, there is a repeated alternation of two major lithologies, although volumetrically one type is far more abundant than the other. There is also a repeated occurrence of horizons with internal sediments and coarsely recrystallized or pseudobrecciated textures rather than a uniform or random distribution of these features throughout the section or a restriction of them to one part of the section (see "Petrography" and Fig. 3-1).

The repetitive or alternating differences in lithology and bedding character observed in Unit 2 are not always perfectly clearcut. However, two principal types of lithology can be distinguished. They are defined by the presence or absence of most of a set of characteristics. As well as the field characteristics already briefly outlined (page 3-20), this set of distinguishing characteristics includes the content and composition of insoluble residues. The two kinds of dolostone, described more completely below, will hereafter be called Lithotypes I and II.

Lithotype I is characterized by fine or microcrystalline crystal size, except in cavity fillings; by a medium or dark grey colour on fresh surfaces; very commonly (but less universally) by at least partially developed laminoid-fenestral fabric; and sometimes by the presence of intraclasts and/or fine lamination. Beds consisting wholly of Lithotype I are generally less than one foot thick but the other characteristics of this lithotype can also be found in distinct layers within the bottoms or tops of thicker beds. (Appendix IV shows bed thickness distributions.) Insoluble residues are between 0.4% and about 2.5% by weight, in ten samples bearing most or all of these characteristics (Table 3-1). Moreover, in the 9 of these samples

best matching the other defining characteristics, clay and fine silt sizes comprise more than 25% of the residues, and generally 75% to 100%, the remainder being in some cases a little sand and in others entirely authigenic and secondary minerals. Lithotype I also invariably lacks megafossils and it nearly always lacks open vugs and anything approaching zebra structure.

Lithotype II is characteristically medium-light-to-very-light grey or buff-coloured on fresh surfaces. Except in cavity fillings, a medium-crystalline mosaic texture predominates and nearly all samples have crystal sizes between medium-fine and medium-coarse. Vugs of widely varying sizes and zebra structure are very common, although not found in every sample or even in every bed. Casts of large brachiopods are common and large gastropods casts occur less commonly. Insoluble residues comprise less than 0.3% by weight of eight characteristic specimens taken from beds containing large brachiopod casts (Table 3-1). In addition, these residues consist mostly of authigenic and secondary minerals such as hematite (after idiomorphic pyrite), plus fine sand grains. Lithotype II also lacks laminoid-fenestral fabric and fine lamination. Intraclasts are uncommon and occur only in non-typical, "border-line" examples restricted to small parts of beds (Fig. 3-1).

In most cases, the two lithotypes are separated by bedding surfaces of varying distinctness (Fig. 3-1). Although there is a continuous, and not strikingly bimodal, distribution of bed thicknesses in the upper 400 feet of the unit, there is a significant difference in bed thicknesses between typical examples of the two lithotypes just described (Appendix VI). Where Lithotypes I and II grade, one to the other, within a single bed, the proportions of the two lithotypes approximate the ratio of mean bed thicknesses of the two types. A little less than half (46% by volume) of the logged part of Section P can be readily assigned to one of these lithotypes or the other on the basis of field notes. Of the rest, all but a few beds bear the field or hand-specimen characteristics of Lithotype II except that they lack brachiopods (Fig. 3-1). Insoluble residues of four specimens selected at random from these unassigned beds all comprise less than 0.3% of sample weight (Table 3-1).

Out of the twenty-three separate occurrences of Lithotype I logged in Section P, there are thirteen cases where Lithotypes I and II grade one to the other without a distinct, continuous bedding surface between them (Fig. 3-1). In eight of these cases, Lithotype I grades upward into Lithotype II; in only three places this order is reversed, and in two more, there is an upward, rapid gradation from II to I and back to II.

FIGURE 3-7
Ideal Cycle - Upper Unit 2

Thus, there is more commonly a small-scale disconformity at the base of a section of Lithotype I than at the top of such a section. For this reason, it seems appropriate to view the repeated pattern (cycle) present in Unit 2 as beginning with Lithotype I, followed directly by Lithotype II in the ideal case (often with a bedding plane between, in fact) and then ending, almost invariably, with a disconformity. This is followed, ideally, by a repetition of the same sequence (Fig. 3-7). In fact, there are commonly several distinctly separate beds of one lithotype succeeding each other before the other re-appears (Fig. 3-1).

The maximum thickness of type II lithology without intervening type I beds is about 50 feet, whereas the maximum thickness of continuous Lithotype I is only six or seven feet, except in the non-typical, partly mudcracked segment at about 350 feet below the top of the unit in Section P, where 20 feet or more of rocks resembling type I more than type II are present. Apart from these maximum limits on thickness, there is no evidence of a regular rhythm in the cyclical repetition of lithotypes. The cycle is not normally completed within one bed, nor does either of the two members of the cycle consistently occur as single separate beds.

Indeed, it is very difficult to determine where one cycle (perhaps incomplete) ends and the next begins, and thus, how many cycles are actually present in a given segment of the section. The distinctness and morphology of bedding surfaces and the nature of the adjacent few centimetres of rock become very important because they form the basis for estimating the degree of disconformability represented by the surfaces. Some such information was recorded, mostly in diagrammatic form, in all sections logged but the detailed examination of every surface, that could be performed in a study of much smaller physical scope, was not feasible in this project. In addition to direct evidence, interpretations of environmental patterns, from petrologic as well as stratigraphic data, have influenced the subdivision of the logged section into cycles in Figure 3-1. Some of the cyclical divisions shown are thus tentative and somewhat subjective. It is evident from the distribution of lithotypes, however, that the presence of cyclicity in the section cannot be denied (Fig. 3-1).

Superficial field observations suggest that cyclicity cannot be distinguished more than 600 or 700 feet below the top of the unit, at least in the area of Section P. Certainly there is a change at Section P to predominantly fine or micro-crystalline,

sandy, light-coloured dolomite below 800 feet beneath the top of the unit. Information is not sufficient to properly characterize the stratigraphy in detail below the top 400 feet of the unit, however.

Although the sections cannot be matched, bed-by-bed, the pattern described in the upper part of the unit in Section P is certainly present at Sections H and V and everywhere else that the same stratigraphic interval could be viewed closely enough in the study area.

Information from the two isolated limestone exposures*, which are relatively inaccessible and difficult to sample, is insufficient to determine whether or not the calcareous equivalents of Lithotypes I and II can be recognized there.

* Location AC and the north side of Tennessee Mountain near Section G (Fig. 2-6; Plates 1.1-b and 1.2-a).

TABLE 3-2

Dolomite Zoning Patterns - Unit 2

Specimen:	P-21	P-53.5	P-80	P-6
P-34.2				
<u>Ferroan</u> microcrystal- line mosaic. (Host)	<u>Ferroan</u> with numerous inclusions. mosaic (Host)	<u>Sl. ferroan</u> (patchy); irreg. shaped crystals. (Host in part)	<u>Sl. ferroan</u> numerous inclusions. Equant mosaic. (Host?)	<u>Sl. ferroan</u> moderate no. of inclusions (Host)
<u>Ferroan</u> First cavity lining; partly replaces calcite spar	<u>Ferroan</u> with numerous inclusions. First cavity lining. Rhombic borders toward cavity.	<u>Ferroan</u> with some inclusions First cavity lining. Iron content increases to- ward cavity.	<u>Sl. ferroan</u> sl. fewer (a inclusions than above. First cavity filling.	<u>Sl. ferroan</u> (as above) sl. fewer inclusions. Rhombic bor- ders toward cavity.
	<u>Thin band of</u> <u>fewer inclu-</u> <u>sions at</u> <u>outer edge.</u>		<u>Diffuse fer-</u> <u>roan zone.</u>	
			<u>Thin band of</u> <u>very few in-</u> <u>clusions</u> (partly in previous zone)	<u>Thin, highly</u> <u>ferroan band</u> <u>in outer edge</u> <u>of previous</u> <u>zone.</u>
				<u>Distinct band</u> <u>of numerous</u> <u>submicroscopic</u> <u>inclusions.</u>
<u>Non-ferroan</u> overgrowth. (clear band then more in- clusions, then clear, in part	<u>Non-ferroan</u> overgrowth. very numerous inclusions.	<u>Distinct,</u> <u>non-ferroan</u> <u>band with</u> <u>very few</u> <u>inclusions.</u>	<u>Non-ferroan</u> with more inclusions than previous band.	<u>Non-ferroan</u> with extremely few inclusions (clear).
	<u>Clear over-</u> <u>growth, sl.</u> <u>ferroan</u> probably with local non- ferroan final rim.			
<u>Very thin,</u> <u>highly ferroan</u> <u>band in core</u> <u>of cavity</u>		<u>Highly ferroan</u> final, thin layer		
<u>Opaque</u> along crystal contacts after or with pre- vious band.	<u>Bitumen and</u> <u>other opaque</u> <u>as a last</u> <u>filling</u>	<u>Bitumen</u>		

Diagenetic Sequence

Tables 3-3 and 3-4 show the principal features of diagenetic origin in Unit 2 limestones and dolostones, respectively, that can be arranged in relative chronologic order on the basis of evidence described in the foregoing pages (and indicated in the tables).

Certain of the diagenetic features noted in the limestones appear to correspond to equivalent or identical features in the dolostones. Cavities formed by leaching, and internal sediment composed of crystal silt are examples. However, other features can be recognized only in either limestone or dolostone so that an effective chronological compilation of data from the two rock-types is not possible.

TABLE 3-3-

Diagenetic Sequence in Limestones - Unit 2

Diagenetic Feature	Evidence for Position in Sequence	Illustration (Plate No.)
1. Dislocated laminae.	Cavities formed by dislocation show enlargement by leaching and contain crystal silt and later fillings.	3.13-d, f
2. Recrystallized or replaced amphiporid skeletons and fossil fragments.	(Most likely position: could be later.) Leached cavities cut across these and spar grew on them.	3.15-c, d, e, f,
3. Cavities formed by leaching.	Modification of shell-supported cavities; anhedral spar in some fossil outlines (evident void-filling). Amphiporid skeletons partly removed along with adjacent matrix. Brachiopod shell leached out, with minor geopetal calcite and tr. quartz silt accumulation.	3.13-c; 3.15-c, d, e; 3.16-d, f.
4. Crystal silt internal sediment (calcite).	Found in cavities formed or enlarged by leaching.	3.16-d
5. Weakly radiaxial, fine calcite spar-to-micro-spar: microlayer lining cavities, often incompletely.	Grew from (4) and lines cavities filled with (6).	3.13-a; 3.14-f
6. Anhedral spar filling formed cavities.	In former skeletal cavities and cavities containing (4) and/or (5).	3.13-a, f; 3.14-a, f, g, h; 3.15-d, e
7. First brittle fractures	(Many may have formed earlier than this.) Cut all clasts and (4); probably also cut (6). Anhedral sparry calcite fillings similar to (6).	3.14-d; 3.15-d; 3.16-a
8. Later, dolomite-filled brittle fractures.	Relatively wide; dolomite fillings continuous with dolomite replacing fossil fillings.	3.13-c; 3.15-f; 3.16-f
9. White dolomite filling fractures and replacing or partially replacing certain constituents.	Fills (8); largely replaces (7) locally, along with surroundings; replaces spar filling of a fossil mold; minor replacement of matrix and skeletal material along amphiporid boundaries (presumably where some permeability existed along fossil surfaces).	As previous plus 3.16-e

TABLE 3-4

Diagenetic Sequence in Dolostones - Unit 2

Diagenetic Feature	Evidence for Position in Sequence	Illustration (Plate No.)
1. Bioturbation and mudcracks.	Obviously penecontemporaneous. Position relative to fenestrae uncertain.	3.3-e; 3.6-h; 3.7-a; 3.8-h; 3.9-e
2. Fenestrae	Never cross-cut any features listed. Cut or filled by features listed immediately below. Lobate, irregular outlines elongate parallel to bedding.	3.6-g; 3.7-f, g, h; 3.10-a, b, c
3. Cavities formed or enlarged by leaching.	These include molds of brachiopod shells.	3.4-d; 3.5-c; 3.12-a7, d7, h
4. Radial calcite spar. Relatively coarse; lines former voids; subsequently dolomitized.	Scalenohedral shapes now consisting of anhedral dolomite patchwork. Covered by crystal silt. Line fenestrae in some cases. May be partly before (3).	3.4-g, h; 3.8-e; 3.10-a, b, c
5. Crystal silt internal sediment (now dolomite).	Covers (4) and fills (2) and (3).	As previous plus 3.5-c; 3.12-a; etc.
6. Early fractures.	Cut (5) but also contain it. Cut fossils with surrounding material. Visible in dolostone only as clear line or else have zoned fillings.	3.4-h; 3.8-b; 3.9-a; 3.12-a
7. Pseudobreccia and local breccia.	Interpretation of other data indicates disruption prior to (8) and probably after (2), with white dolomite added during (8) thru (9) or (10).	3.11-a, e; 3.12-a, b, c, d, g
8. Zebra structure and replacement dolomite.	Zebra developed in soft sediment (pg.) and clearly formed as voids, yet (5) never found in it. See pg. Zebra found only in replacement dolomite. See pg.	3.11-c, d, g, h
9. First void-filling dolomite.	Lines zebra cavities. Same iron content as replacement dolomite. See pg.	As previous, etc.
10. Successive overgrowth of zoned dolospar.	On (9) and all covered by (11) and (12).	3.5-f; 3.8-g; 3.10-d; etc.
11. Pyrobitumin in vugs.	Covers (10). Not seen on (12).	3.8-g; 3.10-d
12. Quartz crystals in vugs.	Cover (10). Pyrobitumin not seen on quartz crystals.	3.3-c
13. Open, hairline fractures and joints.	Not filled. Cut (10). Relationship to (12) uncertain.	3.4-e

Interpretations

Environments.

Two major lithotypes as different as those forming much of Unit 2, must represent significantly different environments of deposition, and their alternation, an alternation between two depositional environments. As discussed below, the evidence from this study indicates that the upper half or more of Unit 2 was produced by repetition of deposition in intertidal-supratidal (Lithotype I) and then shallow subtidal (Lithotype II) environments, apparently followed most commonly by subaerial exposure and at least a short period without deposition or less commonly by a return to intertidal conditions. The "muddy" nature of the rocks of Unit 2 as a whole and the occurrence of delicate fossil fragments or intact fossils of benthonic epifaunal organisms indicate that environments of low physical energy prevailed throughout the deposition of the unit (i.e., mudflats and their subtidal equivalent). This suggests protection of the area from waves and current action by some kind of barrier.

An intertidal-to-lower supratidal mudflat environment is

considered to be indicated by the laminoid-fenestral fabric (L-F) common in Lithotype I (Tebbutt, et al., 1965; Fischer, 1964, p. 129-130). "Birdseye structure" is evidently equivalent in most cases to fenestral fabric (page 3-48 and is also ascribed to an intertidal-to-supratidal environment of deposition (Shinn, 1968).

On algae-covered tidal flats at Shark Bay, Australia, a sequence of fenestral fabrics has been recognized with fine laminoid-fenestral fabric formed in the lower intertidal zone, irregular fenestral fabrics formed in the middle and upper intertidal zone and a "tubular fenestral fabric" associated with plant roots in the upper intertidal to supratidal zones (Read, 1973, p. 51).

The mode of formation of the fenestrae has not been firmly established. They are commonly associated with algal mats or stromatolites in Recent sediments and rocks (Bathurst, 1971, p. 90). Tebbutt, et al., (1965) suggest that algal mats are responsible for fenestrae either directly, leaving voids representing concentrations of organic material, or indirectly, producing gas-filled cavities due to decay of nearby organic material. However, they note that desiccation of the sediment may also play a part. Shinn cites

desiccation shrinkage and the formation of gas bubbles as causes on Andros Island, Bahamas (Shinn, 1968). Fischer (1964, p. 119) believes that fenestrae are simply caused by shrinkage in sediment desiccating beneath a subaerially exposed surface, although he also points out their association with algal sediments as does Ham (1954).

Other evidence favoring the deposition of Lithotype I in the intertidal-to-lower supratidal zones includes the common presence of occasional fine, dark laminae, sometimes dislocated, and of small intraclasts resembling the surrounding rock and in some cases scarcely transported at all; the lack of fossils with the exception of a few small, thin fragments, and the thin bedding of this lithotype. The common occurrence of internal sediments and evidence of leaching in these beds indicates early diagenesis near an emergent surface, precluding formation in deep water (the other common depositional locale for thin-bedded calcilutites).

Insoluble residues show that Lithotype I contains a larger percentage of clay and silt (presumably windblown) than the rest of the section (page 3-85; Table 3-1). This also seems to favour intertidal to supratidal deposition because it suggests a relatively

low rate of sedimentation of the main (marine) constituents. Although intertidal algal sediments can accumulate rapidly through sediment-trapping and precipitation by the algae, erosion and solution by rain (Gebelein and Hoffman, 1968) and restriction of algal growth by variations in moisture, amount of current or wave action, amount of sunlight and amount of wind-blown sediment (Kendall and Skipwith, 1968) are counter-acting forces. In the oversimplified case in which these other factors have an unimportant net influence, intertidal lime muds would be expected to be thicker than supratidal ones and thinner than corresponding quiet-water subtidal ones, simply on the basis of sediment supply. Most of the calcilutite which forms the bulk of the primary sediment settles out of suspension in sea water, at least in the supratidal and intertidal zones. This water overlies intertidal mudflats only during part of the tidal cycle and overlies supratidal flats only during a short period each year, while it is continuously providing sediment to subtidal areas. Of course, the influences of current and wave action, etc., are not constant across the three environments or in different parts of any one of them. However, it may be that, in an overall view of sediment accumulation to form a bedded sequence, supply of sediment is the only factor of major significance in these environments.

The dark colour of Lithotype I is probably due to finely divided, intercrystalline bituminous material which may be the result both of high original concentration of organic material within the sediment and of subsequent conditions particularly suitable for the preservation of organic material within the sediment. Both might be expected in an intertidal environment where abundant algal material is likely to be present, the decay of which could readily maintain a reducing environment until the sediment surface was removed from exposure to oxygen by burial beneath thick, subtidal sediments (in the most common form of the cyclical pattern).

Fine details of microstructures are vaguely and imperfectly preserved in Lithotype I and the occasional fossil fragments are only faint traces merging with the surrounding dolomite micro-mosaic (page 3-43). Thus, the prevailing fine crystal size probably does not indicate primary dolomite. On the other hand, the relatively good preservation of fine structure, as compared to many other recrystallized and replaced rocks, the presence of intracrysts (page 3-35) and dislocated layers (page 3-47) similar in shape and coloration to those in micritic or pelmicritic limestones, and even the association with fenestral fabric, indicate that the fine-crystalline dolomite represents an original micritic sediment, coarsened only a little in the process of dolomitization.

No scoured beds, channels or intraformational conglomerate layers were seen in Lithotype I except one small-scale eroded surface transitional to Lithotype II (Plate 3.4-c). Thus, physical energy in the depositional environment appears to have been uniformly quite low and tidal range may also have been low.

A particularly thick section of thin beds 350 to 390 feet below the top of the unit at Section P (page 3-22 and 3-84) has typical Lithotype I beds at the top but also includes very thin-bedded argillaceous dolostone and shale with mudcracked films on bedding surfaces, plus a little quartz-sandy dolostone. This unusually thick and diverse thin-bedded zone may represent a particularly prolonged period of intertidal-supratidal deposition. The portion with mudcracks and very thin, partly-to-wholly terrigenous beds probably indicates upper supratidal to terrestrial deposition, nearly-to-entirely above the elevations affected by marine water.

Evidence for the subtidal deposition of Lithotype II consists mainly of the common occurrence of intact, articulated, large brachiopods and less commonly large gastropods, plus the much larger average bed thickness than for Lithotype I and the wide

range of bed thicknesses. That the brachiopods lived on, rather than in, the sediment is suggested by the variety of orientations in which they are found. Moreover, in the limestone exposures in the upper part of the unit, the brachiopods can be seen to be surrounded by a former pelleted lime-mud, often with abundant intact amphiporids. There is no disruption of the surrounding fabric adjacent to brachiopods, to indicate burrowing or movement, and the amphiporids invariably lie with long axes approximately parallel to bedding, generally forming an interwoven "mesh" of individuals lying one on another. Some disarticulated brachiopod valves are also present in both limestone and dolostone outcrops.

Amphiporids are present only at certain horizons in the limestones and they have been recognized in only one bed (and then only tentatively) in the dolostones. Hence, they may not be typical of Lithotype II beds throughout the unit. It seems likely however, that the pelleted lime-mud predominant in all limestone samples is the primary equivalent of the laterally adjacent Type II dolostone as well, and by extension, the principal or sole original sediment now represented by Lithotype II.

Both the large size and the lack of diversity of the Lithotype II

fauna are striking. These characteristics are well known to be typical of extreme or highly variable or "restricted" environments. Salinity is the environmental variable most likely to reach extremes or vary widely in sheltered, coastal environments such as that of Unit 2, although temperature and other variables can also be important. Because there is no evidence of the formation of gypsum or other evaporites in the sediments of Unit 2, while there is considerable evidence of the availability of fresh water during very early diagenesis (page 3-118-to 3-121), it seems likely that the restricted fauna of Lithotype II indicates a brackish or periodically brackish environment rather than a steadily hypersaline one. The association of Amphipora with the brachiopods in limestone outcrops also favours a restricted environment as Amphipora is characteristically found in restricted, shallow-water, "lagoonal" rocks (e.g., McGillivray and Mountjoy, 1976, p. 758 and 781; Jamieson, 1967, p. 166).

With respect to bed thicknesses, as in other respects, there is a remarkably close resemblance between the Unit 2 cyclical sequence and the "Lofer Cycles" of the Alpine Triassic as described by Fischer (1964). The subtidal beds of the Lofer Cycles are thick and massive like Lithotype II beds (see page 3-110).

The light colour of Lithotype II indicates a relatively well-aerated depositional environment or a lack of deposited organic material or oxidation of the sediment and removal of organic material after deposition, or a combination of these factors. Certainly oxidation occurred after burial because most residues from this rock-type contain a few framboids and pyritohedra now composed invariably of hematite. On the other hand, apparently equivalent limestones are also relatively light-coloured, although not as light as Lithotype II, and they lack many fine opaques, in thin-section. Limestones and dolostones of similar composition in Unit 4 that seem to have undergone similar fresh-water diagenesis are generally darker in colour. Therefore, the writer is inclined to think that a relatively well-aerated depositional environment plays a major part in causing the light colour of Lithotype II.

The extremely low content of terrigenous insoluble residue in Lithotype II, and the lack of fine silt and clay in residues, can be explained as a result of a fairly high rate of carbonate deposition which diluted terrigenous supplies, sufficient water circulation to remove or disperse very fine, wind-blown material, and separation from landward sources by an expanse of intertidal and probably supratidal sediments. As the intertidal-supratidal

beds of upper Unit 2 lack terrigenous sand, it seems likely that the traces of quartz sand common in Lithotype II residues have a seaward source, probably in a high-energy zone along the seaward side of a system of islands or shoals sheltering the study area. However, the lack of worn fossil fragments and the extremely small amount of sand suggest the depositional environment was effectively isolated from higher-energy environments. The only evidence for locally moderately high energy conditions is the presence of a few intraclastic horizons, which by their position and characteristics seem to represent a transition between Lithotypes I and II (page 3-36). Typical Lithotype II deposition, then, probably took place in an environment of very little wave development.

The prevailing medium-crystalline, dolomite mosaic of Lithotype II bears no obvious textural relationship to the pelleted limestones evidently equivalent to it. Dolostone specimens 3 or 4 feet laterally from limestone exhibit the same sort of mosaic as other parts of the unit (page 3-26). This uniform, "aggrading" replacement resulted in preservation of the large fossils only as very crude molds. It probably erased small thin fragments such as can be seen in the limestones. Certainly no definite pellets or small fossil fragments can be identified in any typical Lithotype II

samples, although vague concentrations of inclusions which may represent pellets can be seen in a few cases (page 3-38).

In spite of scanty data for the lower half of Unit 2, it is clear that the predominant quartz-sandy, fine-crystalline dolostone represents a different depositional environment from those of Lithotypes I and II (page 3-89). Where cut surfaces or thin-sections are available, evidence of thorough bioturbation can be seen (page 3-53). Occasional traces of delicate, small fossil fragments do occur, at least at the bottom of the unit (Plate 3.3-e) but it appears that any indigenous fossilizable fauna must have been very scanty. Deposition in a subtidal or intertidal mud environment with an abundant burrowing infauna seems indicated. This environment was evidently sheltered, either by physical barriers such as bars and islands or by water depth, from the active littoral and inner neritic zones of the open sea. Carbonate mud particles were supplied in abundance but, from the limited evidence available, carbonate sand grains seem to be lacking. At the same time, a considerable amount of quartz sand was deposited with the predominant mud, over a prolonged period.

Considering these facts as well as the depositional environment

of Unit 1, the probable disconformity between the two units and the depositional environments of the overlying beds in upper Unit 2, the lower part of Unit 2 can hardly be interpreted otherwise than as "lagoonal" deposits isolated from the open sea by a well-developed system of islands and shoals and probably by a considerable distance. In view of the evidence of prolific production of carbonate sediment, a significant component of carbonate grains would be expected along with quartz sand derived from the high-energy margin of the open sea (shelf edge). This consideration and recognition of the likely paleogeographic pattern at the time (pages 3-18; 3-105) lead to the conclusion that the quartz sand very probably was derived from the land area to the eastward or southeastward, where the poorly consolidated, sandy surface of Unit 1 would have been exposed until covered by the lateral extension of the Unit 2 deposits. The abrupt disappearance of sand in the section about 800 feet below the top of the unit presumably represents the time when transgressing lagoonal deposits covered the entire local area of exposure of sand.

It is not entirely clear why there is a large percentage of fine-crystalline dolostone (like Lithotype I in this respect) in the lower part of Unit 2, while Lithotype II is almost wholly coarser-crystalline. Differences in depositional environment may play some direct role but

differences in mineralogical composition are probably most important (page 3-128).

Although Unit 2 was not studied in the northwesternmost section (Fig. 2-6), several specimens taken from about thirty feet below the top of the unit at this locality contain evidence of an environment of higher physical energy, at least at times, than that of Unit 2 in the rest of the study area (page 3-42 and Plates 3.5-a, b). Thus, a near-surface-to-emergent barrier system may have lain beyond the study area in this direction, with the open sea beyond.

After deposition of the topmost beds of Unit 2, there was probably a period of subaerial exposure somewhat more prolonged than between normal cycles. This is indicated by extensive diagenetic alteration at all localities studied (pages 3-65, 3-119 and Plate 3.12-d). In some places a slightly pinkish or purplish colour was noted in the characteristically rubbly-weathering uppermost layer or so. It is to be expected that small-scale karstic solution pockets would develop on such an emergent surface, although poor outcrop exposure prevented observation of features of this kind. No evidence was seen of significant erosion or of large-scale karst development during this period of subaerial exposure.

Cycles.

The repeated alternation of Lithotypes I and II in the upper part of Unit 2 clearly implies a repeated lowering then rising of mean sea level relative to the depositional surface. In addition, more extended periods of emergence of the sediment surface (into the supratidal zone or above) are inferred from the occurrence of vertically restricted zones of coarse, non-uniform crystallinity and/or pseudobrecciation, generally with associated internal sediments (see "Petrography", "Diagenetic Sequence" and "Diagenetic History"). Mudcracks and very argillaceous, thin, "lumpy" dolostone beds are also present in the most extensive such zone, about 350 to 400 feet below the top of the unit in Section P (Fig. 3-1). These are probably supratidal-to-terrestrial deposits.

As several hundred feet of sediment were deposited under this regime, all fairly near sea level, the cyclical changes in sea level were clearly superimposed on an overall subsidence of the area of deposition. Indeed, the entire thickness of Units 2 and 3, viewed as a whole and on a large scale, appears to have been deposited during a single prolonged period of essentially continuous basin subsidence. It seems likely that the cyclical pattern that occurs

in parts of this basin-filling sequence was controlled by changes in sea level unrelated to local subsidence and possibly worldwide in scope (the alternative explanation, a relatively short-period cyclical variation in basin subsidence rate during parts of Unit 2-Unit 3 time, cannot actually be ruled out).

The commonness of incomplete lithologic cycles; the varying thickness of the members of the cycle, particularly the subtidal member, and the variable extent of diagenetic effects that appear to indicate subaerial exposure, all comprise evidence that a uniform or consistent relationship was not maintained in detail among rates of sedimentation, basin subsidence and sea level change.

There is a close resemblance between the cyclical sequence in upper Unit 2 and that of the Lofer Facies of the Triassic carbonate rocks of the Alps, described by Fischer (1964). The Lofer Cycles also consist essentially of two members, a thick-bedded subtidal one and a thin intertidal one, although Fischer recognizes a third member composed of shale or argillaceous limestone, in many cases represented only by cavity-filling sediment within the underlying

TABLE 3-5

Unit 2 Cycles Compared to the Lofer Cycles

Unit 2	Lofer Facies (Fischer, 1964)
(No definite counterpart)	Member A
<ul style="list-style-type: none"> -Dark-coloured internal sediments with traces of muscovite may be of related origin. 	<ul style="list-style-type: none"> -Thin parting or (commonly) confined to internal cavities in Member C of cycle below. -Consists of argillaceous limestone or shale; commonly pelleted calcilutite in part. -Contains a few ostracods and other microfossils. -Though to have been formed by re-working of residual soil from exposed surface and mixing with new carbonate in advancing sea.
Lithotype I	Member B
<ul style="list-style-type: none"> -Beds less than one metre thick. -Many beds with fenestral fabric. -Fine-crystalline to microcrystalline -Dolostone (not recognized in the few limestone exposures). -Sheet cracks are rare (but somewhat more common in similar beds in Unit 3); prism cracks were not seen in typical Lithotype I in Unit 2. -Internal sediments occur in fenestrae and other early-formed cavities. They are silt-sized carbonate with a granular aspect and are graded in some cases. They are composed of dolomite but may originally have been calcite. -(As to right.) -(As to right.) -Occasional fine laminae occur in many beds. 	<ul style="list-style-type: none"> -Beds less than one metre thick. -Many beds with fenestral fabric ("Loferites"). -Microcrystalline. -Limestone, dolomitic limestone or dolostone. -Sheet cracks and prism cracks (mudcracks) are found. -Internal sediments occur in fenestrae, sheet cracks and other early-formed cavities. They are "mechanically introduced carbonate muds" which, "range from granular and silty to exceedingly fine" and are commonly somewhat graded. They are composed of calcite (but dolomite in landward, facies-equivalent beds). -Spar projects into cavities above internal sediments. -Many fenestrae are spar-filled, only, but almost none are entirely sediment-filled. -Fine lamination is abundant and uniform; commonly mud-cracked into deeply cut prisms.

-Only occasional faint suggestions of algal laminae are visible
 -Pellets are abundant in some beds, although only faint vestiges remain in the dolostone.
 -A few unidentified, microscopic fossil fragments can be seen.

-Intraclastic zones are found, composed of fine to microcrystalline dolostone clasts, generally in a matrix of finer intraclasts, very fine-crystalline dolomite "mud" and dolospar filled former cavities.
 -Interpreted as intertidal to supratidal deposits.

-Algal mat structures (crinkled, etc.) are common.
 -Pellets are the main constituent of some beds.

-Microfossils are abundant in some laminates but low in diversity. Filaments and vesicles (algal?), and rare forams and ostracodes are found in loferites.
 -"Conglomerates" are found, composed of dololite and/or calculite intraclasts in a lutite matrix with numerous spar-filled and internal sediment-filled cavities.

-Interpreted as intertidal deposits, in a wide sense, i.e., considering maximum annual tidal range. Much of supratidal zone of other authors would evidently be included.

Lithotype II

-Beds mostly 0.5 to 3.5 metres thick.
 -Dolostone except in two localities. Generally medium to medium-fine crystalline and lacking vestiges of primary texture. Limestone exposures are peloid micrite with scattered small, lumpy intraclasts. Dolostones were probably once mostly or wholly of this composition.
 -A "hash" of assorted fossil fragments with a large, intact brachiopod and a turreted gastropod, were found in a bed in the northwesternmost locality studied.

-In the limestone outcrops, scattered delicate fragments of trilobites, ostracodes and unidentified fossils occur. There are also layers rich in intact skeletons of Amphipora and several layers also contain intact, large, terebratulid brachiopod shells. In the predominant dolostones, only large gastropods and the large brachiopods are found, except for one probable Amphipora occurrence.

-The brachiopods occur most commonly as bivalved specimens, apparently in life position. They are found in definite horizons in many cases.

-Interpreted as shallow subtidal, quiet-water lagoonal deposits, probably with abnormally low salinities in most or all of the study area.

Member C

-Beds one to twenty metres thick.
 -Limestone ranging from sparry grainstone to packstone and wackestone to "featureless calcilutites". The arenites are composed of fossil fragments, pellets and "compound lumps". Superficial ooids and oncolites are common.

-The biota is richest near the reefs, where calcareous and non-calcareous algae, sponges, corals, bryozoans, brachiopods, gastropods, pelecypods, ostracodes, echinoderms and rare ammonites occur, apparently mostly as transported fragments.

-Well back from the reefs, large gastropods and conspicuous megalodont pelecypods are the principal fossils.

-The megalodonts occur most commonly as, "bivalved specimens in growth position" and are in some cases restricted to "clam horizons" one individual thick.

-Interpreted as sediments deposited, below low-tide line in a vast lagoon, not more than a few metres deep, with normal salinities near the reef and abnormal salinities increasingly restricting the fauna in a back-reef direction.

subtidal member. Table 3-5' compares the cyclical portion of Unit 2 with the Lofer "Cyclothems".

Fischer, too, is inclined to favour eustatic changes in sea level as the cause of the cyclic pattern. He feels that the time spans represented by the Lofer Cycles suggest a relationship of the sea level changes with the periodic changes in the earth's obliquity (Fischer, 1964, p. 146). Such speculations would be entirely unjustified in the case of the cyclical sequence at Robb Lake, due to uncertainty as to the time-spans involved. Fischer's observation that such eustatic sea level changes should also be recognizable in similar very shallow-water sedimentary rocks in other parts of the world does apply as well to the Robb Lake case, however. Cyclical patterns of several kinds are known in Devonian rocks in a number of places (e.g., Read, 1973; Wells, 1956). However the writer is not aware of any examples which are likely to be the same age as those in Unit 2 (probably Lower Devonian or Eifelian - p. 2-9). It may be that a search for such coeval cycles would yield interesting results.

Another significant observation by Fischer (1964, p. 144) applies equally well to the cycles in Unit 2: the evidence indicates

that the period of cyclical sedimentation consisted of submergence and subtidal deposition as the normal state, interrupted periodically by relatively brief intervals of emergence, rather than consisting of subequal emergence and submergence or extended emergence with brief submergences. The principal evidence for this in Unit 2 is the lack of noticeable lateral variation in bed thicknesses and the lack of noticeable karst development (e.g., Quinlan, 1972, p. 161-164) related to the inter-cycle disconformities. Studies of diagenesis of Recent and Pleistocene carbonates (e.g., Harrison, et al., 1972, p. 141-142) suggest that the time required to produce the diagenetic alteration that is associated with these disconformities is insignificant in comparison with the several tens of thousands of years which may be represented by each cycle, by analogy with the Lofer Cycles (Fischer, 1964, p. 144). Relatively brief periods of emergence are also supported by evidence concerning the sequence and mode of origin of certain diagenetic features (page 3-122 to 3-123).

Also applicable to the Unit 2 cycles is Fischer's observation that the Lofer Cyclothems seem to be mainly transgressive deposits (1964, p. 144-146). Part of this impression is illusory because the peak of each transgression is unrecognizable in the subtidal

beds. However, it is also to be expected that the thin intertidal beds formed during regression would commonly be removed by erosion (Fischer, 1964, p. 146). As in the Lofer Cycles, subtidal beds do grade upward into intertidal lithology in some cases in Unit 2, although this is relatively uncommon (page 3-87). The occasional presence of these regressive intertidal layers adds further support to the contention that the period of emergence was relatively short. Indeed, during some Unit 2 cycles the area studied probably never rose above the intertidal-lower supratidal zones (Fig. 3-1).

Diagenetic History.

The repeated changes in sea level, from a few feet below to a few feet above the level of the depositional surface, during deposition of the cyclical portion of Unit 2 brought about repeated, marked changes in the early diagenetic environment of the already deposited sediments. In general, diagenesis of carbonate sediments may be viewed as taking place in one or more of three types of physicochemical environment determined by the chemistry of the pore water contained in, and/or passing through the sediment (or rock).

The influence of, a) meteoric water, b) marine water, and c) sub-surface formation waters isolated from the subaerial and marine realms, determines the three types of environment. The differences in diagenetic effects among these three types of environment and the distinctive diagenetic characteristics of each of them have been the objects of a considerable amount of research but a great deal remains to be learned in this area. Papers by Dunham (1969), Folk (1974), Folk and Land (1975) and Land, et al. (1975) are particularly relevant to the present study. Bathurst (1971, p. 321-543) has summarized much of the work on the subject published prior to 1971 and provides an extensive bibliography.

Employing this partial knowledge of diagenetic processes and their effects, the available evidence concerning the diagenetic history of Unit 2 can be interpreted as described below.

The earliest (penecontemporaneous) diagenetic features observed are evidence of bioturbation in the lower part of the unit (page 3-53), mudcracks in one abnormally thick interval of intertidal-supratidal beds (page 3-53) and fenestrae formed in many intertidal-supratidal beds (page 3-47 and Table 3-4).

FIGURE 3-8

Diagrammatic Cross-Sections Showing Supposed Paleotopography
and Hydrologic Patterns at Different Stages in Cycle -
Upper Unit 2 time.

(Subtidal part of a cyclothem is slant-ruled.)

SEAWARD
BARRIER SYSTEM
↓

STUDY AREA

A. Maximum regression (emergence)

B. Partial transgression (intertidal deposition in study area)

C. Maximum transgression (most common state?)

In the upper part of the unit, a series of other early diagenetic features was observed (Table 3-4). In the cyclical portion of Unit 2, the surface of the subtidally deposited, pelleted mud was exposed to the air as sea level dropped at the end of each depositional cycle. Whatever thin, intertidal-supratidal deposits were formed during the regression must generally have been removed by erosion upon emergence, as most intertidal deposits appear to belong to the beginning of the next cycle (page 3-88).

While the sediment surface was submerged, the abundant interstitial water in the underlying sediment had the composition of sea water. However, with subaerial exposure came exposure to meteoric water at the surface and probably relatively rapid dilution of the ~~existing~~ interstitial water both by fresh water from the surface and by upward movement of the fresh water table which extended from the nearby more permanent land area and in fact very probably underlay the entire lagoonal area even during transgressive maxima (Fig. 3-8).

A subsurface fresh water table extending seaward some miles from the coastline is common in areas of carbonate sediments and rocks

today. Studies of such fresh water "lenses" or "wedges" in the Houston-Galveston area of the Texas Gulf Coast, on the island of Guam, along the east coast and continental shelf of Florida and along the Yucatan Peninsula are cited by Dunham (1969, p. 162) and/or Folk and Land (1975, p. 65). Land, et al. (1975, p. 1617) note two published reports of fresh continental water intruding marine sediments more than 100 km off the east coast of Florida.

Without overlying sea water, the $Mg^{++} : Ca^{++}$ ratio in the interstitial water of the exposed sediment probably soon dropped well below that of seawater (in addition to the greatly lowered salinity), resulting in the chemical environment of "subaerial" or "fresh water" diagenesis (see page 3-262, et seq. and Folk, 1974). Aerated surface water penetrated the sediment surface, forming and enlarging cavities by leaching and particularly removing susceptible aragonitic or partly aragonitic shells such as those of the large brachiopods.

At the surface, itself, and in the top few centimeters of sediment, repeated rainfall and desiccation probably caused repeated solution, precipitation, "re-crystallization" and cracking. This alteration and disruption formed the basis of many of the pseudo-

brecciated and similar textures (page 3-65 to 3-68 at least in some cycles. (The fact that such disrupted tops are not found in all cycles may reflect a combination of variable duration of the period of exposure, variable rainfall and variable amounts of erosion during the next transgression.) Some of these textures bear some resemblance to illustrations of certain modern, subaerial calcareous crust profiles developed on Pleistocene carbonates on Barbados (James, 1972, p. 821, Fig. 4b, d, e). However, dolomitization and the difference in original textures make comparisons difficult.

The occurrence of similar textures, generally along with abundant internal sediment, well beneath bed surfaces may indicate zones into which fresh, surface water was able to penetrate particularly easily at an early stage.

Surface water which had taken on calcium carbonate by leaching, as well as phreatic fresh water rising from below, would begin to precipitate calcite cement, while aragonite inversion and formation of low-Mg calcite from high-Mg calcite would also be expected to begin (page 3-263). Surface water flowing through leached voids and other pores carried calcite crystal silt which filled or partially filled many cavities. Scattered silt-to-clay-sized muscovite

visible in some of this internal sediment suggests an origin at the exposed surface because analysis of insoluble residues showed virtually no clay or silt-sized material in the subtidal beds while clay-sized muscovite is a major constituent of residues of intertidal-supratidal beds (page 3-86 and Table 3-1). Elongate spar crystals (in some cases evidently calcite scalenohedra) were precipitated in some of the larger cavities prior to internal sedimentation (page 3-56).

Some lithification clearly must have occurred at this time, at least where meteoric, surface water penetrated the sediment. A certain amount of rigidity is implied by the presence of otherwise unsupported leached cavities containing internal sediment. Thin, subvertical fractures containing crystal silt have also been found, although they are not common. These may occur near surfaces of exposure but they appear to be brittle fractures rather than shrinkage cracks, sensu stricto (page 3-56).

Early lithification at the surface is also demonstrated by an intraclast found in a crudely laminated sample taken at the bottom of one of the limestone outcrops (page 3-77). The skeletal fragment, calcite spar cavity-lining and dolomitic internal sediment contained

✓
in the intraclast were all lithified as a unit (perhaps along with the attached pelled mud) before transport and deposition in the limestone bed.

However, there is evidence that large volumes of the subtidal sediment escaped lithification at this time. The exposure of the subtidal surface seems to have been relatively rapid and the period of exposure relatively brief in most cycles, as compared to the total length of a cycle (page 3-114). The rapidity of the change in the environment, combined with the natural inhomogeneity of the sediment, must have led initially to an uneven penetration of the sediment by fresh water. Whether this inhomogeneity in the fluid phase could persist throughout the period of exposure, with static marine water trapped in numerous "pockets" in the sediment, is doubtful. Perhaps it is more acceptable simply to say that some combination of hydrodynamics factors, associated chemical concentration variations, and permeability variations resulted in maintenance in many places in the sediment of a pore fluid in which the salt concentrations were high enough to maintain the original mineralogy and prevent any significant amount of lithification.

Whatever the explanation, the zebra structure common in the

subtidal beds was formed in a soft sediment, still capable of shrinkage (page 3-275). Zebra structure is found only in dolostone, and it never contains internal sediment, even in the rare cases where it occurs adjacent to internal sediment, yet the zebra structure must have contained open (water-filled) voids as soon as it formed (page 3-277). Thus, zebra structure clearly formed after the period of subaerial exposure at the end of the cycle in which it is contained.

As the sea moved gradually back onto the mudflats, beginning intertidal-supratidal deposition in the next cycle, marine water would have seeped downward into the partly lithified sediment and begun mixing with the top of the fresh water table. With the passage of the area into the subtidal environment again, the freshwater wedge would have become established in a more-or-less fixed position somewhat below the sediment surface with a permanent but dynamic zone of mixing between it and the overlying sea water (Fig. 3-8). These hydrologic zones would remain in place throughout the prolonged subtidal portion of each cycle, although varying somewhat in size with climatic variations. Moreover, a similar hydrologic pattern would be expected during the shallow-water

depositional phase apparently represented by the non-cyclic lower part of the unit (page 3-106 to 3-107).

In the zone of mixing thus established there is an abundant supply of fresh water, constantly diluting marine water to maintain a relatively low salinity, while there is also a continuous supply of Mg^{++} provided by a constant supply of sea water. These are ideal conditions for the formation of dolomite (Folk and Land, 1975, p. 65).

Moreover, one Recent example (Land, 1973) and a number of ancient examples (Land, et al., 1975; Badiozamani, 1973) of dolomitization by this mixing mechanism have recently been reported.

That the bulk of the dolomite in the cyclical portion of Unit 2 did not form prior to re-submergence is indicated by the evidence for selective leaching of fossils, growth of calcite spar in some cavities, and other textural evidence for normal, subaerial diagenesis prior to dolomitization. That most of the dolomitization and much of the dolomite cementation and cavity filling took place prior to the next cyclical emergence is suggested indirectly by the restriction of internal sediments to certain vertically limited horizons separated by rocks of similar lithology and apparently similar early porosity

but lacking internal sediments. Internal sediments of crystal silt can be deposited as much as 30 or 40 times deeper below sea level than the elevation of the fresh water table above sea level (Dunham, 1969, p. 162). It may be that the vertical restriction of internal sediments in Unit 2 is due to the reduction of permeability in the preceding cycle by dolomitization and dolomite void-filling.

The consistent association of zebra structure with dolostone and the proposed genetic relationship between dolomitization and formation of zebra structure (page 3-278) also imply early, if not strictly cycle-by-cycle, dolomitization.

Collins and Smith (1972, p. 214) note that white dolomite was precipitated in voids in the Ordovician St. George Formation of Newfoundland when the rocks were re-submerged after subaerial exposure and that such white dolomite is common in carbonate rocks which have been exposed to the subaerial environment and then been resubmerged. The mechanism described here for dolomitization on the Robb Lake Property offers a ready explanation for this so-called "white dolomite universal" of Collins and Smith.

Land, et al. (1975), have made effective use of geochemical

evidence in identifying examples of dolomitization by meteoric water-sea water mixing. Distribution patterns of strontium and of oxygen isotopes are particularly significant (ibid.). This work, published well after laboratory work for the Robb Lake study was completed, represents another approach which could be applied to the Robb Lake carbonates, should further evidence of their early diagenetic history be desired.

Any explanation of the dolomitization of Unit 2 must also include the intertidal-to-supratidal beds. These are characteristically fine-crystalline, which leads one to consider that they might have been formed from hypersaline water by one form or another of supratidal dolomitization (Folk, 1974, p. 41; Folk and Land, 1975, p. 62, Fig. 2). However, the lack of any evidence of evaporite minerals or of indicators of their existence such as length show chalcedony (Siedlecka, 1972), as well as the abundant meteoric water supply implied by the mixing model which best explains dolomitization in the subtidal beds, argues against "hypersaline dolomite". The common evidence of leaching and internal sedimentation in both subtidal and intertidal-supratidal beds also indicates plentiful meteoric water. It may also be significant that the dolomite of the intertidal-supratidal beds replaces various common allochems rather than representing a directly precipitated sediment (page 3-43).

Why is there a consistent difference in crystal size between the two environments? A possible explanation is suggested by the common occurrence, in intertidal-supratidal beds, of fenestral fabric, which is commonly associated with, and probably genetically related to, abundant algal growth (page 3-97). A number of organic-rich components of modern carbonate sediments are composed of micritic high-Mg calcite, rather than aragonite (Folk, 1974, p. 49-50). Moreover, the organic portion of blue-green algal mat sediments is known to concentrate magnesium considerably (Gebelein and Hoffman, 1968; Hoffman, 1973, p. 186). This concentration of magnesium in the organic layers appears to be the cause of the selective dolomitization of alternate layers that has occurred in some ancient stromatolites (Gebelein and Hoffman, 1971). Hoffman (1973, p. 186) goes on to suggest that this role of organic matter may explain the distribution of dolomite in many partly dolomitized, laminated and mottled rocks.

Fine crystal size in dolomite evidently cannot be ascribed to "poisoning" by abundant magnesium ions in solution as can restriction of crystal size in calcite micrite, primary magnesian calcite and aragonite (Folk, 1973, p. 138-141). However, micritic dolomite is associated with hypersaline waters with very high Mg/Ca ratios (Folk and Land, 1975, Fig. 2; Land, et al., 1975, p. 1602). The importance

of rate of precipitation (related to concentration of ions in solution) as well as of relative concentration of interfering ions, has been emphasized by Folk and Land (1975, p. 60-61) in regard to the formation of dolomite. The concentration in organic matter of a large percentage (up to at least 50% in algal mats - Gebelein, cited by Hoffman, 1973, p. 186) of the Mg^{++} required for dolomitization would cause a relatively high concentration of Mg^{++} in organic-rich intertidal-supratidal beds as compared to subtidal beds at the time that mixing in of fresh water lowered salinity to the level at which dolomitization could begin. This should result in more rapid formation of dolomite in intertidal-supratidal beds and probably more numerous "nuclei of dolomitization", whether actual free nuclei in pore space or loci of beginning dolomitization on high-Mg calcite crystals. Moreover, the relatively high Mg^{++} concentration would result in dolomitization at a higher salinity than in the subtidal beds. Thus, the interference of other ions in sea water may play a part in restricting the size of dolomite crystals, while more numerous nuclei and more rapid formation as compared to subtidal beds certainly favour relatively small crystal size.

Another prominent difference between subtidal and intertidal-supratidal beds is in contained terrigenous silt and clay (page 3-86).

The considerable percentages of clay-sized material in intertidal-supratidal beds consist largely of muscovite (page 3-3) so they did not function as collectors of magnesium as sometimes occurs (Folk, 1974, p. 49). The possibility of restriction of crystal growth due to interference by clay-sized phyllosilicates cannot be ruled out as a control on crystal size in Unit 2, however.

Lithotype I beds are dark in colour due to very finely divided, probably organic, opaques (page 3-100), supporting the idea that these were organic-rich sediments. The commonly fine crystal size of the light-coloured sandy beds near the bottom of the unit is not clearly associated with original high organic content, although extensive bioturbation indicates plentiful animal life during deposition. Perhaps content of terrigenous material does influence crystal size in these beds.

The preservation of relatively small volumes of limestone in Unit 2 also requires explanation. The limestone remnants were found only at the top of the unit (page 3-23). They have clearly undergone fresh water diagenesis, which caused leaching, calcite silt internal sediments, inversion to, or replacement by, low-Mg

calcite and probably also the virtually complete cementation of the rock with microspar and anhedral calcite spar (Table 3-3). Near the margins of the limestone remnants, white sparry dolomite fills fractures which evidently formed in the limestone after the rock was at least somewhat brittle (page 3-84 and Plates 3.15-f; 3.18-a).

These fracture fillings are continuous with similar dolomite selectively replacing fossils and occurring discontinuously along contacts between fossils and matrix (page 3-84 and Plate 3.13-c; 3.16-f). In some cases, traces of earlier, calcite-filled veins can be seen in dolomitic fossils (page 3-83 and Plate 3.16-e).

The dolomite generally forms an anhedral mosaic. It is not noticeably zoned and is not particularly iron-rich. Inclusions are numerous but not extremely so. Comparison of these data with Table 3-2 indicates that the white dolomite in the margins of the limestones probably corresponds with a relatively late phase of white dolomite in the dolostones.

These characteristics of the limestone outcrops indicate that dolomitizing waters did not come in contact with these rocks until after the rest of the sediment was largely or wholly dolomitized. By this time, much more extensive freshwater diagenesis had taken

place than elsewhere. Complete stabilization of mineralogy as low-Mg calcite probably made dolomitization more difficult and virtually complete filling of the originally large volume of pore space with calcite prevented circulating mixed waters from entering,

There seems to have been a particularly long period of emergence following deposition of the top beds of Unit 2 (page 3-108). Subsequently, the area remained in the intertidal-supratidal depositional environment for an extended period (page 3-197). It may be that the surfaces of the present limestone remnants were slightly higher than the rest of the sediment surface when the first incursions of marine water returned. In any case, whether for this reason or due to depositional permeability variations and/or other controls on circulation patterns of meteoric and marine waters in the sediment, the combination of Mg/Ca ratio and salinity in the future limestone remnants must have remained always within the field of calcite formation (Folk and Land, 1975, Fig. 1). This could have resulted from penetration of so little marine water into this part of the sediment that the low Mg/Ca ratio of relatively pure, meteoric water flowing through the sediment was not raised significantly. Alternatively it could have resulted from continued flow

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through this sediment of predominantly meteoric water sufficiently saline and with an Mg/Ca ratio sufficiently lowered by precipitation of dolomite in the surrounding sediment, so that dolomite could never form (with any additions of new seawater in this sediment being balanced by addition of greater volumes of weakly saline water with a low Mg/Ca ratio). In either case, sparry calcite would form (as observed). However, the second case seems more likely as cementation could take place much more rapidly, with the flow-through of much less water and with less time for changes in the hydrologic regime to alter the necessary conditions.

Sparry dolomite lines or fills many former voids throughout Unit 2 but is most abundant in some subtidal beds where subsequent subaerial exposure resulted in extensive porosity development (page 3-119). This void-filling dolomite is generally zoned with respect to ferrous iron content and concentration of inclusions, in one-sided patterns showing growth away from the walls of cavities (Table 3-2).

Water compositions resulting in dolomitization of a calcium carbonate sediment should also result in precipitation of dolomite in visible voids. Therefore, at least the earliest-formed sparry

dolomite can be assumed to have formed concurrently with dolomitization of the sediment. This assumption is further supported by the observation that the earliest dolospar consistently has the same iron content as the adjacent "host" dolomite (as determined by degree of staining) and is intimately intergrown with it. This first dolospar can also be found occasionally replacing former calcite spar crystals which projected into early-formed voids (page 3-56). The uniform iron content of replacement dolomite and earliest cavity-filling dolomite may reflect the iron content of the original marine sediment.

Direct evidence of the time of precipitation of the succeeding phases of white dolomite overgrowth is meagre. Coarse, elongate dolospar crystals typical of the zoned crystals filling most former cavities in Unit 2 are found as broken fragments in the "trash zone" breccia that occurs near the top of the unit at one locality (Plate 4.3-c). Thus, most of the dolomite overgrowths filling zebra and other early-formed cavities evidently precipitated before formation of the breccia. However, the breccia is also cemented in places with sparry dolomite, indicating that a later stage of dolomite precipitation also occurred, at least where significant amounts of connected porosity provided conduits for fluids. The known

characteristics of the cementing dolomite do not serve to distinguish it definitely from the latest clear phase of the normal void-filling dolomite (see page 4-16 and Table 3-2).

This breccia must have been formed prior to commencement of deposition of the Besa River Shale and it was probably formed during the long period of emergence between deposition of Units 3 and 4, with cementation during Unit 4 deposition and perhaps later (page 4-16).

Large-scale breccias elsewhere (studied mainly in Unit 3) typically contain an abundance of white dolomite cement between fragments (page 4-4). Patches and crude "zones" of differing iron and inclusion content occur in some of these anhedral, sparry dolomite fillings, although distinct zoning bands defining euhedral crystal shapes, as in the earlier cavity fillings, were not seen. Zebra structure nearly or wholly filled with dolospar can be seen in breccia fragments, as in undisturbed beds, again indicating that most or all of the white dolomite found in unbrecciated dolostone precipitated prior to brecciation. These other large-scale breccias probably also formed and were cemented prior to Besa River Shale time (page 4-16).

It has already been noted (page 3-125) that severe restriction of permeability by dolomite precipitation prior to the end of the cycle following that in which a given bed was precipitated might explain the vertically restricted distribution of internal sediments in the cyclical portion of Unit 2.

Meyers (1974) has related iron and manganese zoning in calcite cements of the Lake Valley Formation, to phreatic fresh-water diagenesis during several prolonged subaerial exposures geologic periods apart. However, the dolomite zones visible in Unit 2 do not appear to be either as numerous or as correlatable as those of Meyers (Table 3-2). Additional data might show that better correlation of dolomite zoning is possible within single cycles, indicating an early origin of the zones related to the cyclic hydrologic changes. Present information allows only the observation that a first zone with the same slight-to-high iron content as the "host" dolomite and a later, thick zone of non-ferroan dolomite are characteristic. Intervening and subsequent iron zones vary and inclusion zoning is also variable (Table 3-2). If the early ferroan zone is due to iron in the original sediment (page 3-133), the thick, non-ferroan zone may have been contributed by the same or similar dolomitizing mixed waters after the primary iron had been used up. The cathodoluminescence

technique used by Meyers (1974, p. 837, 841) might be effective in providing a better understanding of the zoned dolospar in the Robb Lake Devonian dolostones.

Migration of fluid hydrocarbons through the dolostones after precipitation of all cavity-filling dolomite is revealed by coatings or bubbles of pyrobitumen in many zebra cavities and other voids (page 3-30). In some cases, bituminous particles are incorporated in the last thin dolomite zone (Table 3-2). The Besa River Shales were probably good hydrocarbon source-rocks and fluids squeezed out of them during compaction would be expected to move into the more permeable underlying carbonates.

Transparent, well-formed quartz crystals projecting from the dolomite linings of a few vugs appear to have grown slowly, from a solution free of impurities, relatively late in the diagenetic history of these rocks (Table 3-4). Probably, suitable conditions existed when Unit 2 was deeply buried after Middle Devonian time. Although there was certainly sufficient primary quartz in the Robb Lake carbonates to account for all diagenetic quartz present, detrital quartz is (and evidently was) scarce in the upper part of

Unit 2. Thus, slow movement of chemically suitable waters either upward or downward across a considerable thickness of rock seems required. This might best be accomplished during prolonged burial.

- a. Thick-bedded dolostone: upper Unit 2, Section P. Staff in upper-middle of photo is 5 feet long, marked in tenths of a foot.
- b. Topmost beds of Unit 2, Section P. Lowest bioturbate layer (Unit 3) is marked with an X. Staff shows scale as in (a).
- c. Dolomite crystals lining vug, with several late, transparent quartz crystals projecting into void in lower middle part of photo: Section G, Unit 2.
- d. Microcline (?), rounded quartz grains with overgrowths and embayments, broken quartz "round". (Apparent "cross" in feldspar is actually two twin directions.) First thick bed above base of Unit 2, Section P. Scale bar shows 1 mm. (Crossed nicols.)
- e. Typical quartz sand distribution in dolostone; embayed grains; minor overgrowths; vestiges of mollusc or similar shell (centre). Same specimen as (d). Scale bar shows 1 mm.; arrow shows stratigraphic top. (Thin-section, plane light.)
- f. Remnant of rounded feldspar grain (untwinned), largely replaced by dolomite: same specimen as (d). Scale bar shows 1 mm.; arrow shows stratigraphic top. (Thin-section, plane light.)
- g. Twinned plagioclase grain and fine quartz grains in dolostone: same specimen as (d). Scale and arrow as previously. (Crossed nicols.)
- h. Muscovite grain adjacent to quartz silt grain: same specimen as (d). Scale bar shows 0.5 mm. between cross bars. (Thin-section, crossed nicols.)

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PLATE 3 · 3.

a. Dolomite mosaic (left) and pocket of silt-sized dolomite (probable internal sediment) at right: lower part of Unit 2, location F. Scale shows 1 mm.; circular specks are bubbles in slide. (Thin-section, plane light.)

b. Pyritomorphic hematite in mosaic dolomite: upper-middle Unit 2, Section P. Scale shows one mm. (Thin-section, plane light.)

c. Eroded surface of finely fenestral dolomite overlain by intra-clastic dolomite: upper Unit 2. Arrow indicates stratigraphic top. (Polished hand specimen.)

d. Brachiopod casts in outcrop: upper Unit 2 adjacent to Section H.

e. Part of brachiopod shell with internal sediment filling, in vuggy fractured dolostone: Section G, upper middle Unit 2. Arrow indicates probable stratigraphic "up".

f. Elongate dolomite crystals oriented approximately perpendicular to shell surface (probably replacing original shell structure): same specimen as (e). Thin-section, crossed nicols. Scale bar shows 1 mm.

g. Steep-sided (scalenohedral) crystal shapes projecting downward into cavity filled with dolomite internal sediment. Crystal shapes are now a polycrystalline dolomite mosaic. (Same specimen as (e); thin-section, plane polarized light; scale bar shows 1 mm.)

h. As previous but note at least 2 phases of internal sediment; fractures cutting both sediment and crystals projecting from shell but with fillings probably replaced or re-crystallized with shell and cut by stylolite in sediment. Also thinner fractures which do not appear to cut crystals projecting from shell.

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- a. High-spired gastropod in bioclastic dolomite: Section Y, about 30 feet below top of Unit 2.
- b. Brachiopod shell with valves opposed as in life: same location as (a). Shape is somewhat foreshortened in this view due to exposure at a corner of the specimen.
- c. Amphiporid (?) traces (white) in light-grey dolostone partly removed and replaced by cavity-filling dolomite silt internal sediment (dark grey). Arrow shows stratigraphic top. (Upper-middle Unit 2, Section P.)
- d. Unidentified fossil fragments in fine-crystalline, fenestral dolostone: upper Unit 2. Scale bar shows 1 mm.; arrow as previously. (Thin-section, plane light.)
- e. Unidentified fossil fragments in quartz-sandy, fine-crystalline dolostone: Section P, near bottom of Unit 2. Scale and arrow as previously. (Thin-section, plane light.)
- f. Fenestra filled with relatively coarse dolomite, partly zoned with respect to iron and inclusions in idiomorphic shapes: upper Unit 2. Scale and arrow as previously. (Thin-section, plane light, stained with potassium ferricyanide.)
- g. As in (e). One probable ostracod shell (or small mollusc or brachiopod?). Scale identical to (e); up is toward top of page. (Thin-section, plane light.)
- h. Thinly laminated, very fine-crystalline dolostone forming lowermost layer of Unit 2 at Section P.

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PLATE 3.5

3.6

- a. Laminated, mainly silt-sized dolomite of specimen in 3.5-h. Note that variations in crystal size and content of intercrystalline opaques cause laminated appearance. (Thin-section, plane light.) Scale bar shows 1 mm.
- b. "Broken" dark laminae and fining-upwards layers in fine-crystalline dolostone: upper Unit 2. Arrow indicates stratigraphic "up".
- c. Flame structures (middle, left side) in unusual graded laminae: upper Unit 2, Section G. Scale in cm.; arrow shows stratigraphic top; scratches are due to contaminated grinding compound. Several thin, cross-cutting fractures also present.
- d. Same specimen as (c): to show cross-cutting tube filled with dolomite of about the same crystal size as the coarser (lighter) layers (probable fluid injection structure).
- e. Discontinuous dark laminae in fenestral dolostone: upper Unit 2 (same specimen as 3.7-f). Scale bar shows 1 mm. and arrow as previously. (Thin-section; plane light.)
- f. High magnification of fine lamina in a fenestral layer (left to right across middle of photo), showing that the vague darker laminae are distinguishable due to greater content of opaques and finer average crystal size than their surroundings. Scale shows 0.5 mm. between cross-bars. (Thin-section, plane light.)
- g. Coarse and fine fenestral fabric, with several dislocations in the lowest set of laminae: a few feet below the top of Unit 2, Section P. Arrow shows stratigraphic top. Also note intraclasts; thin, parallel fractures; fine lamination in part.
- h. Relatively coarse-crystalline, somewhat sucrosic dolostone with numerous pockets of silt-sized dolomite (internal sediment). Note sub-vertical tubes filled with silt (burrows or possibly gypsum casts? - unusual). Arrow as previously.

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PLATE 3·6

- a. Fine-crystalline dolostone with rounded quartz grains: top bed of sandy lower portion of Unit 2, Section P. Scale in cm.; arrow as previously. Note scattered (bioturbate) sand distribution.
- b. Coarse and fine intraclasts in fine to medium-fine crystalline dolostone: upper Unit 2; Section P. Arrow as previously.
- c. Intraclastic dolostone (top) and probable fenestrae filled with internal sediment (bottom): upper Unit 2, Section P. Scale in cm.; true stratigraphic "up" unknown.
- d. Intraclastic dolostone: upper Unit 2. Note many ovoid, dark intraclasts resembling fecal pellets. Arrow shows stratigraphic top.
- e. Intraclastic dolostone: upper Unit 2, Section P. Also note small vugs and ill-defined patches and streaks of white dolomite in vaguely laminoid orientation. Scale in cm.
- f. Fine-crystalline, laminoid-fenestral dolostone: upper Unit 2, Section P. Also note dark, finely laminated band in upper middle of photo. Arrow shows stratigraphic top.
- g. Laminoid-fenestral dolostone: upper middle Unit 2, Section G. Direction of stratigraphic top unknown.
- h. Intraclastic, laminoid-fenestral dolostone with a layer disrupted to form larger intraclasts: upper Unit 2, Section P.

PLATE 3.7

- a. Fine-crystalline dolostone with silt-sized internal sediment fillings and white dolomite fillings: upper Unit 2, Section P. Scale in cm.; stratigraphic top direction approximate.
- b. Partly fenestral dolostone cut by crack filled with internal sediment and white dolomite (formerly calcite?). Note crystal forms projecting into sediment locally; later cross-cutting fractures. Scale in cm.; arrow shows stratigraphic top. (Upper Unit 2, Section P.)
- c. Medium-fine crystalline dolostone with vaguely delimited white blebs (fenestral?). Note dark internal sediment topped by white dolomite in one particularly well-defined pocket (left side). Upper Unit 2, Section P. Scale in cm.; arrow as previously.
- d. Zebra dolostone: white layer crosses middle of photo, left to right, with inclusion-rich and iron-rich zones faintly visible in some of the coarse crystals which grew from the "host" walls at top and bottom. Note vague inclusion patterns suggestive of pellets or intraclasts in host dolomite at bottom. Scale shows 1 mm. (Thin-section; plane light; stained with potassium ferricyanide.)
- e. Internal sediment (dark coloured-2 phases?) and white dolomite: upper middle Unit 2, Section P. Note former crystal facets (now polycrystalline) projecting into sediment on top side of large former cavity, only.
- f. Internal sediment in rock with texture approaching pseudobreccia: upper Unit 2, Section P. Arrow shows stratigraphic top.
- g. Enlargement of part of previous photo, showing collapsed pyrobitumen lining in a vug. Scale in cm.
- h. Fine-crystalline dolostone with patchy limonite stain and bioturbate sand distribution: lowest thick bed at bottom of Unit 2, Section P. Scale in cm.; arrow as previously.

PLATE 3-8

- a. Fine-crystalline, laminoid-fenestral dolostone with crystal silt on shoulder of fracture, covered by fracture-filling mosaic, dolomite (formerly calcite?): upper Unit 2, Section P. Scale bar shows 1 mm.; "up" arrow as previously.
- b. Dolostone showing intensive diagenetic alteration: upper middle Unit 2, Section P. Dark colour is silt-sized internal sediment; light colour is presumably largely re-crystallized or replaced host rock. Note crudely laminoid orientation of internal sediment pockets. Scale in cm.; arrow as previously.
- c. Diagenetic breccia? Dolostone fragments in a matrix of granular dolomite crystals: upper middle Unit 2, Section P. Scale in cm.; arrow as previously.
- d. Bituminous fragments scattered in fine to medium-fine crystalline dolostone (probably disrupted, desiccated algal mats): upper middle Unit 2, Section G.
- e. Mudcracked surface of dolostone bed: upper middle Unit 2, Section P.
- f. Stylolite following border between internal sediment (top) and re-crystallized (?) host rock (below): upper Unit 2, Section P. Specimen shown in Plate 3.8-f. Scale bar shows 1 mm.; arrow as previously. (Thin-section, plane light.)
- g. Muscovite flakes in (largely re-crystallized?) internal sediment: upper middle Unit 2, Section P. Scale shows 0.5 mm. between cross bars; arrow as previously. (Thin-section; plane light.)
- h. Internal sediment composed of granular silt-sized dolomite, filling a fenestra in a fine-crystalline, laminoid-fenestral layer: upper Unit 2, Section P. Note slight size grading (fining upward); intercrystalline opaques (bitumen?). Scale shows 0.5 mm. between cross bars. (Thin-section, plane light.)

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a. Complex filling of a fenestra in L.-F. layer: crystal silt internal sediment covers idiomorphic, zoned crystals which grew upward from bottom of cavity. A fracture cuts silt and crystals as well as host rock but is filled with dolospar which may be continuous with that overlying the silt. An earlier, thin layer of silt may line the bottom of the former cavity but this is difficult to distinguish from host. Note that the upward-projecting crystals are steep-sided and some now consist of polycrystalline dolomite (probably replacing calcite spar). Iron zoning pattern follows "stubbier" dolomite crystal shapes, suggesting compositional zoning originated during replacement. Scale bar shows 1 mm. (Thin-section, plane light, stained with potassium ferricyanide.)

b. Size-graded crystal silt in fenestra: upper Unit 2, Section P. Note crystal outlines projecting into silt but now polycrystalline dolomite. Scale bar shows 1 mm.; arrow as previously. (Thin-section, plane light. Line across lower left corner is an artifact of thin-section preparation.)

c. Laminoid fenestral dolomite (same specimen as (a) and (b)). Several dolospar-filled fenestrae and one fenestra well lined with spar and then filled with crystal silt internal sediment. Some projecting crystal outlines visible, now composed of polycrystalline dolomite (probable replaced calcite spar lining). Scale bar shows 1 mm. (Thin-section, plane light.)

d. Fine zebra structure: upper Unit 2, Section P. Note early fractures which "smear together" dark layers on one side and have white fillings continuous with white layers. At left and top, white layers give way to incomplete white dolomite linings coated with bitumen facing open vugs. See also (e). Scale shows 1 cm.; arrow shows stratigraphic top. Photo is not out of focus: apparent blurring is a feature of the rock surface.

e. Enlargement of part of (d). Note: probably two phases of early fractures; dark layers sometimes do not correlate well across fractures. Scale shows 2 cm.

f. Enlargement from Plate 3.11-h, showing irregular, somewhat ill-defined layer boundaries, and locally dislocated dark layers. Scale shows 1 cm. between cross bars; arrow as previously.

g. Contact between replaced brachiopod shell (below) and host dolomite (above). A spar-filled fracture extending downward from the upper right across middle of photo has been offset by the stylolitic contact between shell and host rock and was apparently replaced along with shell and host. Later fracture (silt-filled?) follows early one in upper right part of photo. Upper middle Unit 2, Section G (same specimen as Plate 3.4-e). Scale bar shows 1 mm. (Thin-section, plane light.)

h. Stylolites in medium-fine crystalline dolostone with traces of lamination in lower part: upper Unit 2, Section P. Arrow as previously.

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PLATE 3-10

- a. Intensely diagenetically altered dolostone: upper middle Unit 2, Section P. Dark grey-to-black colour is internal sediment (crystal silt), laminated in part; light grey is presumably re-crystallized original rock. Note several bedding-parallel stylolites and partially sucrosic texture in "host" rock. Arrow shows direction perpendicular to bedding.
- b. Vuggy dolomite with white dolomite linings and fillings in crudely bedding-parallel "layers": upper Unit 2, Section P. Scale in cm.
- c. Zebra structure grading to weakly laminated dolostone: upper Unit 2, Section P. Scale in cm.; arrow shows stratigraphic top. Note: probably at least two phases of fractures, and zebra layers do not correlate across these in some places.
- d. Zebra structure grading to uniform, light grey dolostone. Note zebra structure ends abruptly at thin, dark-coloured, sub-vertical fractures. Black colour is crystal silt internal sediment. Black at bottom of specimen is sediment-filled brachiopod mold. Fractures cut this mold (and probably the sediment in it) but without appreciable displacement. Upper Unit 2, Section P. Arrow as previously.
- e. Dolomite pseudobreccia: upper middle Unit 2, Section P. Arrow as previously.
- f. Fine to medium-fine crystalline dolostone with texture approaching zebra structure: upper Unit 2, Section P.
- g. Brecciated zebra "pocket" with small remnant vug. Taken adjacent to hammer head in Plate 3.18-c (upper Unit 2, adjacent to limestone). Arrow as previously.
- h. Typical zebra structure with a few pin-head-sized vugs remaining in white layers: upper Unit 2, Section P. Arrow as previously.

d

e

c

b

a

f

a

e

PLATE 3-11

- a. Intense diagenetic alteration: upper Unit 2, Section P. Two phases of internal sediment can be seen (numbered), separated in time by precipitation of void-filling carbonate, cracking of this along with sediment and host, and precipitation of coarse grey carbonate in cracks. First sediment is crystal silt; second appears to be coarser, sucrosic dolomite crystals in part. Scale in cm.; arrow as previously.
- b. Diagenetically altered dolostone: near top of Unit 2, Section P. Pseudobreccia in part. Crack from upper left to centre, filled with internal sediment, then white dolomite. Host rock is light grey.
- c. Intact dolostone grading upward to pseudobreccia: upper Unit 2, Section P. Scale in cm.
- d. Leached and disrupted dolostone: less than one foot below top of Unit 2, Section P. Note: two phases of internal sedimentation separated and also overlain (followed) by periods of spar precipitation (now white dolomite). Also associated small-scale fracturing and dislocation of fillings and, to some degree, host (probably local collapse - shrinkage? - structure).
- e. Unusual "boxwork" dolostone with granular-looking dolomite "matrix": upper middle Unit 2, Section P.
- f. Unusual, dark-matrix dolostone with apparently fractured remnants of white dolomite. May represent replaced anhydrite(?). Upper middle Unit 2, Section P, close to (e). These textures found nowhere else in Robb Lake area.
- g. Pseudobrecciated dolostone with a few vague, possible fossil forms (amphiporids?): upper Unit 2, Section P. Scale in cm.
- h. Diagenetically altered dolostone: upper Unit 2, Section P. Largely rhombic-sucrosic host dolostone with sediment-filled former cavities. Irregular downward extensions of some former voids suggest leaching.

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a. Cavity in pelleted limestone, floored with calcite crystal silt. Uneven row of prismatic calcite crystals projects upward from silt surface and, less uniformly, from roof of cavity. Cavity filled with anhedral calcite spar. Scale bar shows 1 mm.; arrow shows stratigraphic top. (Thin-section; plane light; left edge stained with alizarin red; hand specimen shown in (d).) Upper Unit 2, location AC.

b. Anhedral, coarse dolomite in fossil shown in (c): upper Unit 2, location AC. Scattered quartz grains across middle of photo. Scale bar shows 1 mm. (Thin section; plane light.)

c. Brachiopod cast in amphiopod-rich, microcrystalline limestone: upper Unit 2, location AC. Note scattered dolomite crystals in limestone and dolomite-filled fracture continuous with dolomite in brachiopod cast. Fine grooves in limestone are due to rapid digestion in strong acid. (Etched fracture surface: scale in cm.)

d. Microcrystalline limestone with spar-filled cavities and local dislocations of layering: same location as previous. Arrow as previously.

e. Micritic intraclast in peloid limestone of specimen in (d). Scale bar shows 1 mm. (Thin section; plane light.)

f. Silt- and spar-filled cavity produced by dislocation of layering in specimen in (d). Scale bar shows 1 mm.; arrow as previously. Note vague size-layering and varying percentage of spar across layering. (Thin section; plane light.)

g. Complex intraclast in limestone of (d). Clast contains pelmicrite (upper left), an unidentified fossil fragment (upper right) and a former cavity containing spar and internal sediment (lower right and middle). Scale bar shows 1 mm. (Thin section; plane light.)

h. Enlargement of former cavity within intraclast in (g). Radial calcite projects into crystal silt at centre of photo. Radial and anhedral spar occupy all space not filled with silt. Crystal silt is now dolomite and all fillings were lithified prior to truncation at the edge of the intraclast. Scale bar shows 1 mm. (Thin section; plane light.)

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PLATE 3-13

- a. Pelletoid limestone: upper Unit 2, location AC. Note microspar, calcisphere, small micritic intraclast. Scale bar shows 1 mm. (Thin-section, plane light.)
- b. Irregularly shaped micritic peloids and small intraclasts: same location and scale as previous. (Thin-section, plane light.)
- c. As previous, but showing trilobite fragment and indistinct layering due to varying grain size and spar-microspar content. Scale shows 1 mm.; arrow shows stratigraphic top. (Thin-section, plane light.)
- d. Scattered, delicate fossil fragments in intraclastic pelmicrite-pelmicrosparite: location as previously. Scale bar shows 1 mm., arrow as previously.
- e. Ostracode shell fragment in peloid limestone: location, scale, arrow as previously. (Thin-section, plane light.)
- f. Probable foraminifer test: location, scale as previously. Note micritic outline (former micrite coating?) lined with irregular palisade of fine, prismatic calcite crystals and then filled with anhedral spar.
- g. Possible foraminifer test visible as spar-filled micritic outline: location, scale as previously. (Thin-section, plane light.)
- h. Unidentified fossil: same thin-section as (g). Scale as previously.

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PLATE 3-14

a. Unidentified fossils and sparry patches in pelmicrite-pelmicrosparite: upper Unit 2, location AC. Scale shows 1 mm., arrow shows stratigraphic top. (Thin-section, plane light.)

b. Cross-sectional view of amphiporid skeleton: same location as previous. Note axial canal, traces of "network" skeletal structure. Scale shows 1 mm. (Thin-section, plane light.)

c. Amphiporid skeleton, showing axial canal but little trace of other internal structure: location, scale as previously. Note "corroded", spar-bordered edges.

d. Amphiporid skeleton, showing internal "network" and pronounced micritic border: location, scale as previously. Note sparry calcite partly surrounding fossil (probably filling a leached cavity). (Thin-section, plane light.)

e. Partial skeletons of two amphiporids: location, scale as previously. Micritic borders and part of internal calcite have been removed adjacent to the spar-filled area, while pellet sediment protected by shell fragment at right remains. An incomplete layer of fine calcite crystals coats the shell surface facing the spar. (Spar evidently fills a cavity formed by leaching.)

f. Edge of a brachiopod cast (bottom) and amphiporid skeleton (above, left): location, scale as previously. Note dolomite-filled fracture (slightly darker than fossil-filling spar) cutting from top to bottom across both fossils and matrix. (Thin-section, plane light, hand specimen shown in Plate 1.13-c.)

g. Side view of terebratulid specimen from upper Unit 2, location AC. For scale, see Plate 3.16-c. Dark colour behind specimen is mounting material.

h. As previous but silhouette. Note elongate shape and lack of a noticeable beak.

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PLATE 3-15

a. Posterior silhouette of specimen in Plate 3.15-g. Scale: see (c).

b. Dorsal (ventral?) view of same specimen as previous. Note that weak rugae (or growth lines?) can be faintly seen on parts of the specimen. Also note elongate shape.

c. Posterior view of same specimen as above.

d. Former cavities in peloid limestone: location as previously; scale bar showing 1 mm., up arrow as previously. Note partially shell-supported cavity, below, and other, irregularly shaped cavities above shell. Crystal silt fillings grade downward into peloid sediment and are overlain by calcite spar. (Thin-section, plane light.)

e. Dolomite mosaic in brachiopod mold: locality as previously. Note healed fracture shown by trail of included opaques and calcite in dolomite crystals. Scale bar shows 1 mm. (Thin-section, plane light, stained with alizarin red.)

f. Same thin-section as (e). Note pellet sediment at bottom, dolomite in shell mold, scattered calcite crystals (apparently geopetal) across middle and dolomite-filled fracture cutting sediment at lower left. White crack across photo is an artifact of thin-sectioning. (Plane light, stained with alizarin red; scale bar shows 1 mm.)

g. Brachiopod fossils in outcrop: same location as previously. Note different shell orientations, light grey material replacing shell (still calcareous?) and white dolomite within shell, probably replacing internal structures and possibly also an inner shell layer. An elongate, gently convex overall shape is discernible. (Photo shows a surface approximately parallel to bedding.)

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PLATE 3-16

- a. Field aspect of limestone exposure at location AC. Lighter-coloured material at upper right is largely dolomitized. Red-handled hammer shows scale.
- b. Limestone-dolostone transition at base of limestone cliff. Upper part of photo is a closeup view of lower right corner of (a). Limestone at top grades downward to partially dolomitized rock in the lower half of the photo. Hammer handle is one foot long.
- c. Brachiopod casts exposed on surface approximately perpendicular to bedding. Note elongate, non-spherical sections and lack of beak (fossil at right shows slight dislocation of valves in non-longitudinal section but no beak). Fossils are restricted to one layer. Orientations vary. (Location AC.)

a

b

c

PLATE 3·17

a. Limestone exhibiting a network of thin fractures filled with white dolomite. Taken close to dolostone contact, below and to right of Plate 3.17-a. (See "b" below.)

b. Hammer is in same location as in (a). Fractured limestone on left and dolostone on right. Compositional change coincides approximately, but not exactly, with subvertical fissure near middle of photo, behind rucksack.

c. Weathered dolostone surface with pockets of zebra structure, approximately two feet to right of right edge of (b). Sample in Plate 3.11-g taken above hammer.

PLATE 3-18

UNIT 3

Field Characteristics

As in Unit 2, most of the volume of the third Devonian unit consists of thick and medium beds of light-coloured, buff and light grey-weathering dolostone (Plates 3.20-a; 3.22-a, b, c). However, Unit 3 begins with a section less than 50 feet to 200 feet or more thick, composed mostly of thin, fine and microcrystalline, recessively weathering beds (Plates 3.19; 3.22-d, f). These beds lie with evident conformity on the top beds of Unit 2 (page 3-23, 3-108). A number of these lowermost beds are dark or medium grey on fresh surfaces but many are light grey or tan-grey. Quartz sand is visible in many beds and burrowed horizons are common (Plates 3.22-d; 3.35-c). Mudcracks occur at several levels and a few ripple-marked layers were seen (Plates 3.22-e, g). At or very near the bottom of the unit in all four localities where this level was studied, are several microcrystalline, medium grey beds with the laminoid-fenestral fabric already described in Unit 2 (Plates 3.19-a; 3.34-c and page 3-167).

Above this basal zone of microcrystalline, mainly thin beds, an alternating pattern of thick and thin, medium-crystalline and fine-crystalline beds much like that in the upper part of Unit 2 gradually becomes established, at least in the southeastern half of the area. Here, as in Unit 2, the thicker, coarser beds make up the bulk of the section, particularly in the easternmost locality (Plate 3.20-a, b; 3.22-b, c). (See also Fig.'s 3-1, 2, 3, 4, 5, 9 and bed thickness distributions in Appendix IV.) But in Unit 3, a number of thin-bedded, fine-crystalline intervals are more extensive and more varied than in Unit 2, in some cases including nearly the full range of lithologies and colours found in the bottom part of Unit 3 (Plates 3.22-h; 3.23-a, b; 3.35-f). Depression- or channel-filling structures, some of them clearly erosional channels, can be found in some of these zones as well as some extremely smooth planar bed surfaces (Plates 3.23-a, b, c; 3.28-a; page 3-171).

The thick, massive beds are also somewhat different from those in Unit 2. No large brachiopods or other large fossils are present but zebra structure is very common and more varied than in Unit 2. There is not as high a correlation between thick bedding and medium crystallinity as in Unit 2, since relatively thick beds with fine crystal size are found, particularly in the northwestern outcrops (Appendix II and Table 3-10).

In general, although there is a grossly bipartite, cyclical pattern in most of Unit 3 (Fig. 2-5), several different, intergrading lithologies can be recognized within each "part" of the cycle, even in the field. Moreover, particularly in the northwestern part of the area, above the lowest 600 feet, the occurrence of intermediate types of beds, notably quartz-sandy, medium-crystalline, medium and moderately thick beds, makes it impossible to recognize a cyclic pattern in the field (Fig. 3-1).

Much more information was obtained concerning lateral variability for Unit 3 than for Unit 2. However, if the extent of vertical variability can be taken as an index of the extent of local lateral variability, then Unit 2 is considerably less variable than Unit 3, considered on the same scale and over the same lateral distance within the study area. For example, very thick, massive beds and a strongly cyclic pattern are best developed in the southeastern part of the area (Plates 3.20-a, b; 3.22-c; Fig. 2-5), whereas there are more even bedding and more evenly distributed sand in the upper part of the unit farther west (Plate 3.22-a; Fig. 2-5). More detailed differences are discussed in the following pages.

A small remnant of limestone was found at a different stratigraphic

level in each of three of the sections logged (Fig's. 3-1, 3-4, 3-9). The largest limestone outcrop, about ten feet thick and essentially consisting of one thick bed, occurs near the middle of the unit in Section G (Fig. 3-4). In this exposure, the massive, microcrystalline limestone grades upward into thin, "lumpy" beds at the top, with mudcracked, shaly partings (Fig. 3-4 and Plate 3.34-h). Dolomitized "pods" near the top interfinger laterally with limestone in an irregular pattern. There are also dolomitized patches near the bottom of the bed.

The other two limestone exposures consist of similar, microcrystalline limestone but they occur as parts of thinner, mainly dolomitized beds and are bounded by cross-cutting contacts.

The top contact of Unit 3 is covered nearly everywhere. Beds just below the contact at Section J are quartz-sandy, massive, light-grey dolostone, intensely fractured and subsequently healed. Evidence from Unit 4 (q.v.) indicates an unconformity of major significance between Units 3 and 4.

TABLE 3-6

Insoluble Residues - Unit 3: Percentages Contained and Descriptions for Representative Specimens

Specimen No.	Weight % Insol. Res.	Description	
		Light Fraction	Heavy Fraction
MIDDLE OF UNIT - SECTION P			
P-241	44	Coarse to med. quartz sand and clay.	Minor hematite and unidentified min.
P-229	30	1/2 coarse to fine quartz sand; 1/2 clay and silt. Since smaller than 5 phi are quartz, muscovite and minor feldspar (x-ray diffract.)	Few grains of tourmaline, goethite, zircon, "rutile", identified by x-ray diffraction.
P-225	26	Clay, silt, sand (coarse to fine). Composite of fines as prev.	Minor pyritomorphous hematite and unidentified grain.
P-221	3	Rounded quartz grains (some with overgrowths); Indary quartz.	Pyritomorphous hematite (or goethite?).
P-220	1	Rounded quartz sand.	Pyritomorphous hematite.
P-253	1	Silt, clay?	-- 1 --
P-205	1	Med. to coarse quartz sand, well rounded.	Pyritomorphous and irregular hematite.
P-217	1	Fine sand, bitumen.	-- 1 --
P-200	0.5	Secondary quartz and fine quartz sand.	Pyritomorphous hematite. (approx. equal wt. to lights)
P-233	0.5	Bitumen and possibly tr. clay.	
LOWER PART OF UNIT - SECTIONS G AND V			
G-44	47	Silt and clay. (X-ray analysis shows quartz, muscovite and microcline.) Sample not well disaggregated.	
V-14	37	Silt, minor fine sand and minor clay.	
G-44	19	Silt to very fine sand, subequal to clay, trace of bitumen.	
V-21	9.75	Silt, lesser clay, trace of bitumen and of pyritomorphous hematite.	
G-82	3.3	Silt, minor clay (including visible muscovite), trace of pyritomorphous hematite.	
G-71	3.0	Silt, minor sand and clay. Trace of pyritomorphous hematite, mica flakes, and secondary quartz (fracture fillings?).	
V-28	3.0	About 65% fine sand. Rest is silt and clay in subequal amounts. Trace of pyritomorphous hematite.	
V-25	2.0	Mostly clay; About 20% silt; trace of bitumen.	
MID- TO UPPER PART OF UNIT - SECTION K			
K-87	44	About 90% very fine sand. Minor large quartz grains; silt; trace to minor clay; trace bitumen.	
K-83	5.0	Nearly all clay. Trace pyritomorphous hematite. (Some residue lost during wash prior to weighing.)	
K-56	2.9	Subequal amounts of quartz sand and clay, minor bitumen and trace pyritomorphous hematite.	
K-79	1.0	About 95% quartz sand: partly rounded grains, partly idiomorphic (authigenic) faceted and irregular overgrowths. Minor clay, trace bitumen and hematite.	
K-57 (dark) (L.F.)	0.5	Clay.	
K-67	0.4	99% or more clay. Minor sand, hematite and bitumen. Trace unidentified, soft, white material (Leucosphaera?).	
K-114	0.35	Mainly bitumen and other organic material; trace hematite (hematite?).	
K-42	0.04	More than 90% sand: some rounded quartz grains but mostly authigenic surfaces. Minor bitumen-as clay aggregates and trace pyritohedra.	

Petrography

Minerals.

Dolomite

Many thick beds are nearly pure dolostone but Unit 3, as a whole, contains much more detrital quartz and micas than all but the bottom 200 feet of Unit 2. Sample compositions range from 100% dolomite to 55% or less, with rare quartz sandstone layers (Table 3-6).

The overall range of dolomite crystal sizes is the same as for Unit 2 (pages 3-25 to 3-26). Semi-quantitative graphs of crystal size are shown on the detailed sections (Fig's. 3-1, 2, 3, 4, 5, 9). Thin beds are usually fine-crystalline and thick ones medium-crystalline but there is considerable overlap in medium beds. The correlation of crystal size and thickness is not as good as in Unit 2 (Appendix II, Table 2). Within some fine-crystalline beds where primary clastic textures are well preserved, crystal size of the replacing dolomite varies somewhat.

in correspondence with the crystal size that must have existed in the various (calcareous?) primary components (Plate 3.29-b, d). However, in such beds dolomitization seems to have resulted in a reduction of overall crystal size range.

As in Unit 2, a mosaic of equant dolomite crystals is characteristic except in void fillings. Dolomite cavity fillings (Plates 3.23-d, e, f; 3.26-c) are generally similar to those in Unit 2.

Quartz

Quartz sand and silt are much more abundant throughout Unit 3 than in all but the lowest 200 feet of Unit 2 (Fig. 2-5). Quartz forms from zero to more than 40% of individual beds in Unit 3 and in some cases forms layers of differing sand concentration within beds (Plates 3.23-g; 3.33-a, d).

There is a wide range of grain sizes and size sorting, with a tendency toward poorer sorting and finer mean size in thin, fine and microcrystalline beds than in thick, medium-crystalline ones (Plates 3.23-h; 3.24-a, b, c; 3.25-a, c; 3.26-a, b, g, h; etc.).

In the thin-bedded, lower part of Unit 3, quartz sand and silt is found homogeneously scattered in some beds, forming isolated layers in others, and patchily distributed in still other beds (compare Plates 3.33-a, d and 3.39-c). Where a strongly cyclic bedding pattern is present, higher in Unit 3, detrital quartz is concentrated in thin-bedded intervals but lesser amounts are scattered in many thick, medium-crystalline beds (Fig. 3-9; Appendix II, Table 2). In parts of the section where medium beds predominate, particularly in the western and southwestern exposures (Sections P and H), quartz sand is homogeneously scattered in many beds, regardless of thickness, and quite commonly makes up 5 to 15 percent of the rock, occasionally forming as much as 40% (Fig's. 3-1, 5 and Plates 3.23-g, h; 3.24-a, b, c; 3.27-a).

Quartz sand grains are mostly rounded-to-well rounded, as in Unit 2, although some more angular grains occur (Plates 3.23-h; 3.24-c; 3.25-a, c; etc.). Embayments and partial replacement are extensive in some layers and overgrowths are slight (Plates 3.24-a, b, c; 3.26-a, b; etc.).

Idiomorphic, prismatic quartz crystals project into some of the open vugs throughout the unit. The crystals and their occurrence are as described for Unit 2 (page 3-30) but they are much more common in Unit 3.

Quartz-filled or partly quartz-filled fractures are also quite common (Plate 3.24-d).

Discontinuously silicified horizons a foot or more thick occur in the middle part of the unit at several localities (Fig's. 3-1, 4). Parts of these horizons are brecciated (Plates 3.24-e, 3.39-e, f) but elsewhere quartz-sandy dolomite bands are preferentially silicified without disruption (Plate 3.24-f).

In the small limestone remnants in Unit 3 are numerous, microscopic, doubly terminated quartz crystals showing concentric zoning expressed by calcite inclusions (Plates 3.24-g, h).

Calcite

Calcite is very rare except in the few small exposures of partially dolomitized limestone (e.g., Section P at +200 feet; Section G at +470 feet, and Section K at +600 feet). A few very thin fractures are partly calcite-filled (page 3-180 and Plate 3.25-a). Coarse calcite crystals were seen in vugs in drill core from near the upper part of Section G and in outcrop about 3 feet below a

small limestone remnant (Section P, -195 feet, Fig. 3-1).

Calcareous dolomite or calcite also occurs in a few vug linings in Section Y (Fig. 3-3) and in fractures in Section G. The calcite occurs as a last precipitate covering white dolomite cavity linings.

The forms and distribution of calcite within the small limestone remnants are as described for Unit 2 (page 3-72) except that fossils are scarce and internal sediments are dolomite rather than calcite. In the remnant in Section K (Fig. 3-9), a uniform micrite without pellets seems to have been the predominant primary component (Plate 3.24-h).

Muscovite

Muscovite is not visible in hand specimens but forms a large percentage of the insoluble residue of many fine-crystalline samples. X-ray diffraction showed the clay-sized fraction of several of these samples to consist of muscovite and a little quartz.

Silt and clay-sized muscovite can be seen in some thin-sections from thin, fine-crystalline beds. Here, it is scattered in the very finely crystalline (micritic) parts of the rock.

Bitumen

As opposed to Unit 2, Unit 3 contains almost no bitumen. Only four of the five hundred or more hand specimens collected from Unit 3 contain recognizable bitumen and none was seen elsewhere during extensive, detailed field studies. The little bitumen that is present, in Sections Y and P, is softer than in Unit 2 and occurs as a filling or coating, in small amounts, at the centres of former cavities lined with dolomite and some calcite (Plate 3.25-b). A few insoluble residues from Unit 3 contain finely divided, black, non-crystalline material which is probably bitumen. The only sign of this in hand specimen is a black trace along occasional bedding-parallel stylolites. (Also see page 3-153.)

Clays

In several very sandy specimens there are occasional grain outlines now filled mainly by cryptocrystalline, probable clay minerals. These were evidently feldspar grains (Plate 3.26-b).

Pyrite

Pyrite is found in association with sphalerite and galena in the mineralized breccia in Section Y (Fig. 3-3; Plate 3.25-f). Identification by X-ray diffraction confirmed that this is indeed pyrite and not marcasite.

Aside from this, pyrite is represented only by very common cubic and pyritohedral pseudomorphs found mainly in thick, medium-crystalline beds (see "Hematite", below).

Hematite

Small amounts of hematite are very common throughout Unit 3 in the form of occasional specks and patches, invariably including at least a few distinctly pyritomorphic shapes (Plate 3.25-c). Most insoluble residues contain cubes and pyritohedrons, and framboids are also very common (Plate 3.25-d). X-ray identifications show that these are now composed entirely of hematite. Distribution of hematite is as described for Unit 2 with the addition that pyritomorphs are sometimes found included within large dolomite crystals (Plate 3.25-e).

Goethite - "Limonite"

Rusty-looking, yellowish-brown and brown opaque material occurs in some samples, associated with hematite, along stylolites, and in diffuse "trails" outlining burrows in bioturbate layers (Plates 3.35-d, h; 3.36-a).

Sphalerite and Galena

One small, ore-grade occurrence and two minor "showings" of sphalerite and galena were encountered in the sections logged across Unit 3. The ore-grade occurrence, in Section Y near the "Ed Showing" (Fig. 3-3), is from a rubbly, almost entirely covered zone of chaotic but relatively fine breccia. The sphalerite and galena occur as patches and coarse-crystalline masses in the matrix of the breccia (Plate 3.25-f) and, to a lesser extent, in some of the fragments (apparently replacing dolomite). In some places, the sphalerite in the breccia matrix exhibits a clastic texture (possibly cataclastic?).

The locations of the minor occurrences of sphalerite and galena are shown in Figure 2-5. They consist of scattered crystals of sphalerite and galena in pseudobrecciated-to-locally brecciated dolostone in the first few inches of rock adjacent to well developed bedding surfaces. Sphalerite and galena mineralization occurs discontinuously along the outcrop of these bedding surfaces for at least 100 feet (probably more) laterally from the line of section. The crystals of sphalerite and galena generally occur in white dolomite adjacent to dark dolomite fragments (Plate 3.25-g). The sphalerite is often leached away in weathered samples, leaving angular voids coated with a light brownish powder (Smithsonite?) - (Plate 3.25-h). The crystals of sphalerite are very dark brown-to-reddish brown.

Feldspar

Although feldspar was definitely identified in only two thin-sections from Unit 3, the fine insoluble fractions smaller than 5 ϕ of all fine-crystalline, sandy samples X-rayed contain minor amounts of feldspar (probably mainly microcline). Plate 3.23-g shows one of these samples. Diffractograms of sizes smaller than

80 did not show definite feldspar peaks, suggesting that the feldspar is mainly silt-sized, as might be expected.

A few fine sand-sized, rounded grains of plagioclase and microcline are present in one thin section, along with considerable amounts of quartz sand and silt (Plate 3.26-a). A solitary, small, rounded grain of untwinned feldspar was also found in a nearly pure dolostone sample. In several samples there are clay-filled, detrital grain outlines which probably represent former feldspars (Plate 3.26-b).

Trace Minerals

A few grains of zircon and tourmaline and a trace of rutile were identified by X-ray diffraction after manual separation from the heavy residues of representative fine-crystalline, quartz-sandy samples. Zircon and tourmaline grains were also seen, rarely, in thin sections from both fine and medium-crystalline beds. The heavy minerals occur as well-rounded, fine sand grains (Plates 3.26-g; 3.27-b, d).

Unidentified Minerals

Small amounts of a whitish-yellowish-grey, opaque mineral (mineraloid?) are common in many dolostone specimens as a lining in open, intercrystalline voids and along stylolites. The substance has a granular texture under moderate-to-high magnification. In a few thin-sections, a patchy aggregate that may be the same material occurs in dolomite adjacent to hematite (but with no brownish "limonite") and as isolated patches within dolomite crystals or crossing several of them.

Some limestone samples contain traces of a partly rusty-looking, whitish opaque in fractures and following traces of former fractures. This material lacks the gritty appearance just mentioned but may be of the same composition.

A vaguely delimited, black, opaque stain occurs as spots in dolomicrite in one thin-section.

An unusual, colloform coating was also seen on a dolomite crystal projecting into an open vug in a "zebra" dolostone sample (Plate 3.26-c). The coating consists of an alternation of transparent, microprismatic

layers (apparently dolomite, at least in part) and dark brown, opaque layers (goethite?).

The whitish minerals were not recognized in insoluble residues and could not be isolated from thin sections for X-ray identification. However, rutile was identified by X-ray diffraction in a few small, relatively soft, greyish, heavy mineral grains. Leucoxene is generally composed of very finely crystalline rutile (Deer, Howie and Zussman, 1966, p. 413). It may be that most or all of the whitish-greyish material just described, as well as the (altered?) grains analyzed, is leucoxene. This mineral (mineraloid?) is a common accessory in some carbonate rocks.

Allochems.

Intraclasts

Small, rounded, oval-to-tabular intraclasts like those described for light coloured beds in Unit 2 (page 3-37 to 3-38) make up the bulk of a number of horizons or entire beds in Unit 3 in the north-

western part of the study area (Section Y - Fig. 3-3; to a lesser extent Section P - Fig. 3-1). Farther east, intraclastic textures similar to these were not encountered except in small parts of two widely separated thin-bedded intervals between massive beds in Section K (Fig. 3-9, at plus 750 feet and at plus 905 feet; Plate 3.26-f). The size range and general description of this type of intraclasts is as in Unit 2. However, in the northwestern part of the Unit 3 outcrop area they form a framework in a number of thick layers (Plate 3.26-g). These intraclasts generally show only a weak preferred orientation parallel to bedding. This along with their oval shape and micritic composition, suggests that many of them may in fact be large fecal pellets.

At two horizons in the upper half of Unit 3 at Location P (Fig's. 2-5, 6; 3-1), larger and less rounded intraclasts occur in very quartz-sandy layers also containing abundant fossil debris (Plates 3.27-f, g). These intraclasts range from about 0.4 mm to more than 8 mm in longest dimension. Many have a micrite matrix or a combination of spar and micrite but a few are entirely sparry. Most contain clasts, including quartz grains, fossil fragments, other intraclasts and the oolitically coated equivalents of all of these. Rather thorough lithification before break-up and re-sedimentation

is indicated not only by the subangular shapes of most of the intraclasts but by boundaries which cut across contained fossils, intraclasts, spar patches and in some cases quartz grains (Plates 3.26-g, h; 3.27-a, b, c, d). A very thin, dark, micrite coating surrounds these intraclasts and the other particles present. Similar but smaller intraclasts occur in better-sorted quartz-sandy calcarenites higher in the same section (Fig. 3-1). Idiomorphic (authigenic) quartz crystals in some of these are cut off at intraclast borders (Plate 3.27-e).

A third type of intraclasts is formed by the tearing up and deposition, without significant transportation, of parts of dense, micritic layers in some of the sandy, fine-crystalline beds of the middle part of the unit (Plates 3.27-h; 3.28-a, b, c, d). These intraclasts occur in Section G, at plus 505 feet, in Section P, at plus 360 and plus 535 feet, and in Section K, at plus 800 feet (Fig's. 3-1, 4, 9). Some of them have been bent into curving shapes (Plate 3.28-a, b). In Section G, intraclasts of this kind occur in and adjacent to a channel (page 3-171). Three other examples consist of intraclasts in very sandy, relatively planar layers overlying finer sediment from which the intraclasts are clearly derived. In one case, well-developed ripple marks top the sandy layer and are covered with faint mudcracks (Plate 3.28-c, d).

In the small limestone remnants in Unit 3, numerous irregularly shaped, rounded, "lumpy", micritic intraclasts less than 2.5 mm in longest dimension can be seen in thin-section, scattered among the predominant pellets with occasional larger intraclasts aggregated from the same material (Plate 3.28-e).

Intraclasts can be seen in polished surfaces as well as thin-section many of the medium-grey (and darker), laminoid-fenestral layers in Unit 3 (Plates 3.28-f, g, h). This occurrence is as described for similar lithologies in Unit 2 (pages 3-35 to 3-36) with the exceptions that intraclasts are more numerous in some such beds in Unit 3 and that quartz sand and/or silt is often present with the intraclasts in Unit 3. Similar intraclasts occur less commonly in lighter-coloured, laminoid-fenestral beds. Plate 3.29-a (Section P, plus 393 feet) shows intraclasts grading upward to light-coloured laminoid-fenestral lithology. In certain L-F layers where primary texture is particularly well preserved, a few microscopic, micrite intraclasts are visible as well as locally broken-up micrite layers (Plate 3.29-b, c).

In thin-sections, intraclasts can be seen in a few other fine-crystalline dolomite layers with particularly well preserved primary texture.

Pellets

Pellets are generally not visible except in thin-section. They form the bulk of the rock in the limestone remnants, although in some limestone thin sections they are very vaguely outlined and almost invisible (Plates 3.28-e; 3.39-a). These pellets resemble those described for Unit 2 limestones (page 3-75). In some cases, less regular shapes are common, better called small "peloids" (after Bathurst, 1971, p. 84-87).

In certain fenestral layers (both light and dark-coloured) pellets are numerous, generally being unevenly distributed and concentrated at certain levels in vertically oriented thin-sections (Plate 3.29-g). (Particle percentage composition of this sample is given in Appendix I, Table 21.) In this type of occurrence pellets are associated with micritic intraclasts and quartz sand and silt.

Pellets are also present in intraclasts in some of the very quartz-sandy and fossil-fragment-rich calcarenites in the middle part of the unit in the western part of the study area (Plates 3.26-h; 3.27-a, b). There may also be pellets in the traces of micritic matrix in these beds.

Dolomitized, laminated intrapelmicrite occurs at one place (Section P, plus 660 feet; Plate 3.29-e) but it is not common, at least in a recognizable state. Even in this one example, primary texture has been very severely obscured by diagenesis (Plate 3.29-f).

Ooids

Oolitic rocks are not common in Unit 3 but they do occur in several arenitic beds in the western part of the area (Section P, plus 560 feet and plus 665 feet). Here, many quartz sand grains and sand-sized fossil fragments have oolitic coatings averaging about 0.06 mm thick. In the best-preserved examples, concentric layering can be seen within the coatings, even though they have been replaced by a mosaic of equant dolomite crystals (Plate 3.29-h). Intraclasts in some of these beds contain similar ooids and in some cases ooids occur only within intraclasts (Plate 3.27-c, d). Broken ooliths and fragments of oolitic coatings separated from their nuclei occur in one bed studied (Plates 3.27-d; 3.30-a).

Numerous ooids are also present in a rather unusual, four foot bed a few feet above the limestone remnant in Section G (Fig. 3-4,

plus 479 feet; Plate 3.30-b). Here, the ooids were all coated with a layer of micrite. The oolitic calcium carbonate (presumably aragonite) was leached away during diagenesis and the quartz cores of many ooids dropped to the bottoms of the micrite "shells". Subsequently, compaction deformed the micrite envelopes (Plate 3.30-c, d and page 3-204). The rock is a dolomitized, leached, intra-clastic, packed oomicrite.

A few other thin beds may contain ooids which are more difficult to recognize due to diagenesis.

Fossils

Recognizable fossils and fossil fragments are uncommon in Unit 3, although small fragments were probably minor original constituents of many beds.

Fossils are most abundant and most varied in the dolomitized, quartz-sandy calcarenites of the upper middle part of the unit in Section P (Fig. 3-1). Most of the non-intraclastic carbonate grains forming large percentages of these beds were probably of

fossil-fragment origin, although the effects of diagenesis make positive identification difficult in many cases. (Appendix I, Table 22 shows representative percentage composition.) Plates 3.27-a; 3.30-e, f, g, h; 3.31-a, b, c, d (thin sections) show particularly well preserved and coarse-grained examples with a variety of fossil fragments. The types of fossils represented include horn corals (solitary rugosa: Plate 3.30-e), a few colonial rugosa, cylindrical bryozoans, trochospiral gastropods, crinoids (columnals and other echinoderm fragments: Plate 3.30-f), and brachiopods and/or pelecypods (Plates 3.27-g; 3.30-g, h; 3.31-a, c). Most fossil material is in the form of sand- and small gravel-sized fragments. Fragmentation and rounding is variable, with many unidentifiable sand-sized, worn fossil fragments (Plates 3.30-h; 3.31-a, b, e). Brachiopod and/or mollusc fragments and echinoderm debris are thoroughly fragmented and generally well rounded except for a few nearly intact gastropod shells. Corals and bryozoans are invariable broken pieces but fragmentation and wear vary greatly among grains. Many are well rounded, small fragments (Plate 3.31-d). Some fossil fragments are contained in intraclasts in these rocks, as well, and a calcisphere was seen in one quartz-sandy, micritic intraclast (Plate 3.27-b). Clasts composed of probable calcified

algal tubules and cells were also noted (Plate 3.31-h; 3.30-a, b). A number of carbonate clasts are corroded at the edges by fine, tubular holes perpendicular to clast surfaces (Plate 3.31-g). These are probably caused by boring non-calcareous algae.

At about the same stratigraphic level in Section P (Fig. 3-1), another arenitic layer contains at least one orthocone cephalopod fragment as well as several types of solitary and semi-colonial corals and the other types of fossils just mentioned.

There are a few other, isolated occurrences of fossils in the sections logged across Unit 3. One is in certain dark, fine-crystalline, relatively thin beds in the lower part of the unit in Section P. An example is the partly fenestral sample shown in Plate 3.28-f, which contains scattered, well worn, small fragments of moderately thick shells (probably brachiopod or mollusc fragments; Plate 3.28-g). Some of these fragments could possibly also have been algal plates.

Farther east, imprints of delicate, small brachiopods are preserved on bedding partings in an isolated, thin, shaly interbed (plus 73 feet, Section G: Fig. 3-4; Plate 3.32-c, d). The best preserved brachiopods appear to belong to the Dalmanellacea but

more accurate identification could not be made.

Somewhat higher in the unit, in the northwest part of the study area, a few scattered, poorly preserved horn corals and other possible fossil fragments occur at plus 86 feet in Section Y (Fig. 3-3), in dense, uniform, medium-grey, medium-fine crystalline dolostone. Higher in the same section, occasional small gastropods occur in a similar but darker dolostone bed. A poorly preserved, involute, trochospiral specimen was recognized.

Considerably higher in the unit, in the easternmost section (studied, vague, dolospar-filled molds resembling amphiporids in shape and distribution pattern occur at plus 750 feet (Fig. 3-9 and Plate 3.32-e). A similarly ill-preserved horn coral and a few thin, brachiopod or pelecypod shells occur at plus 891 feet (Fig. 3-9 and Plates 3.32-f, g). The exterior of the coral resembles the Cretaceous coral, Pleurocora texana more closely than any common Silurian or Devonian forms. Internal structure is not preserved. Casts of a few small, delicate brachiopods or pelecypods can also be faintly discerned at a lower stratigraphic level in Section G (Fig. 3-4, plus 560 feet).

Finally, the limestone remnants in Sections P and G (Fig's. 2-5, 3-1, 3-4) contain a few (less than 1.5%) small fossil fragments scattered sparsely among the predominant pellets and visible only in thin sections or peels. These include delicate brachiopod or mollusc fragments and other bivalve shell fragments in Section P and gastropod (Plate 3.32-h) and amphiporid (?) fragments and other unidentifiable fragments in Section G. These limestone remnants are probably representative, in this respect, of the majority of the relatively thick and relatively coarse-crystalline beds in the unit, implying a similar content of fine fossil fragments for much of the unit.

Aside from the occurrences described above, the several sections logged in great detail across Unit 3 are devoid of recognizable traces of fossils.

Textural and Structural Features.

Lamination

Lamination (definition: page 1-21) is common throughout Unit 3. Thin lamination (laminae less than 3 mm thick) is highly correlated with fine or microcrystalline dolomite crystal size. (Lesser character matching coefficients are 0.60 to 0.84 for four sections logged in Unit 3. See page 1-17 and Appendix II.)

A lamination commonly somewhat thicker than in fine-crystalline beds occurs in a number of coarser layers in Unit 3. Figures 3-1, 2, 3, 4, 5, 11 show the distribution of lamination in the sections measured.

Lamination occurring in laminoid-fenestral layers is as described for Unit 2 (page 3-46). As well as this type, thin lamination is common in many otherwise uniform, fine and microcrystalline dolostone beds in the lower part of the unit, particularly in the central part of the study area (Fig's. 3-2, 3-4). The lamination is due to differences in predominant dolomite crystal size (silt v.s. clay-sized), differences in colour (due to concentrations of included and intercrystalline, submicroscopic opaques), differences in composition

(percentage of quartz sand or silt), or more often to a combination of two or more of these factors (Plate 3.33). In some places, cut-off lamination and locally gently cross-dipping sets of laminae can be seen (e.g., Plate 3.3-f: Fig. 3-4, plus 71 feet). Dark partings or films of high (organic?) opaque content commonly form wavy and discontinuous lamination (Plate 3.33-e).

Some thin layers of quartz grains are quite continuous laterally. The layer of quartz grain concentration shown in Plate 3.33-d, only a little thicker than what would normally be called a lamina and contained in the middle part of a thin bed, was followed for 150 feet along the outcrop with the only change laterally being a variation in the distinctness of separation of the total sandy layer into two bands.

Higher in Unit 3, the types of lamination just described are mainly confined to the thin-bedded intervals between thicker-bedded segments of the section (Fig's. 3-1, 3, 5). In a few places, laminae have been disrupted, forming minor intraformational conglomerates (page 3-156 and 3-171). Elsewhere, slightly-to-largely disrupted lamination can be seen in many bioturbate layers (page 3-173 and Plates 3.33-c; 3.35-g, h; 3.36-a).

Laminae in a few sandy, light grey, fine-crystalline layers and in one or two coarser-crystalline beds form occasional convolutions or series of peaks which are difficult to explain except as a result of the influence of thin algal mats (Plates 3.33-h; 3.34-e).

Planar lamination is also faintly visible in a few relatively coarse-crystalline layers in the middle and upper parts of Unit 3. In the coarser beds (medium to medium-fine crystalline), there is a complete gradation between purely primary lamination and an inter-layering of primary laminae and secondary white dolomite layers (Plates 3.34-a, b, and see page 3-177).

Fenestral Fabric

Laminoid-fenestral fabric (page 3-47) is found in some parts of Unit 3. Fenestrae are filled as described for Unit 2 except that bitumen was not observed in fillings in Unit 3. Dark-coloured L-F layers like the typical variety in Unit 2 occur in the bottom 20 to 30 feet of the unit (Plates 3.19-a; 3.34-c), in a few thin interbeds between thick beds in the middle part of the unit in the easternmost

section (Plate 3.29-c) and at a number of levels in the northwesternmost section (see Fig's. 3-1, 2, 3, 4, 9).

In Unit 3, L-F fabric also occurs in some fine-crystalline, light grey layers in the middle and upper parts of the unit in the central and eastern sections (Plate 3.29-a). Moreover, quartz sand is prominent in many L-F layers in Unit 3, in contrast to Unit 2 (Plate 3.34-d).

There are also some beds in Unit 3 containing non-laminoid, white, sparry "blebs" of about the same size as fenestrae. Such blebs can be seen in some thin sections to be filled cavities formed by leaching and most of them probably had this diagenetic origin. However, in some cases cavities with shapes produced by leaching occur in the same sample with laminoid fenestrae and intermediate cavity types can be observed whose origin is uncertain (Plates 3.34-d, f). Probably, true fenestrae (primary or penecontemporaneous) are commonly modified by subsequent leaching, sometimes to the point beyond which they cannot be distinguished from cavities of entirely secondary origin that may have developed in the same layers.

Mudcracks

Mudcracks occur in a number of very thin-bedded, argillaceous intervals in the bottom 100 feet of Unit 3 (Fig. 3-2, 3, 4 and Plate 3.22-e). There is a considerable range of sizes of polygons and depth of development but most mudcracks are relatively superficial, having been formed in a very fine-grained, argillaceous film covering a dolomite surface or in the "muddy" topmost few millimetres of a bed.

Higher in the unit, mudcracks are found very occasionally in thin-bedded intervals. At plus 220 feet in the northwesternmost section, a superficially mudcracked surface contains isolated dolomite rhomb outlines (Fig. 3-3; Plate 3.34-g). Near the centre of the area, the limestone remnant in Section G has a decreasingly massive aspect, upward, in the upper few feet and the top of the layer actually consists of thin, very uneven beds separated by mud-cracked, fine-crystalline partings (Fig. 3-4, plus 474 feet; Plate 3.34-h).

Yet higher, in the same section, mudcracking evidently produced the cracks and separations of layers visible in cross-section in the lower part of a channel filling (page 3-171).

In the easternmost section (Fig. 3-9), mudcracks occur on ripple marks at +797 feet (Plate 3.28-d). A different type of desiccation cracking occurred in the darkened, coarse-crystalline tops of several cyclical lithologic sequences at about +665 to +710 feet in Section K (Plate 3.35-a and page 3-196).

Ripple Marks

Like mudcracks, ripple marks occur at a number of places in the bottom part of Unit 3, although they appear to be less common than mudcracks in this part of the unit. As well as occurrences in the measured sections (Fig. 3-3, plus 40 feet; Fig. 3-4, plus 170 feet), ripple-marked talus blocks were encountered in several other parts of the study area, in the same stratigraphic interval (Plate 3.22-g).

Ripple marks are also present in three of the thickest zones of thin, fine-crystalline and sandy beds in the upper middle part of Unit 3 in the easternmost section (Fig. 3-9 : plus 624 feet, plus 723 feet, plus 797 feet; Plates 3.35-b; 3.28-c and see page 3-139). In most cases ripples were seen on displaced blocks whose

correct orientation could not be determined. The ripples at plus 723 feet have crests trending at 76 degrees when rotated to horizontal about a horizontal hinge. (The correction is small in this case, as the plunge direction of the crests is not far from the direction of bedding dip.)

Ripples are symmetrical in every case in which shapes were well enough preserved to determine this. Wavelengths lie in the range of 2 to 5 cm and amplitudes are less than 3 cm.

Intraformational Conglomerates

The only features in Unit 3 which can be described under this heading are small-scale, local "rip-ups" of thin layers in a few fine-crystalline sections (page 3-166). The largest and most prominent example encountered consists of a channel with a crescentic cross-section about 4 feet wide and one foot deep cut in very fine, dense, light-grey dolostone and filled with very sandy dolostone and chips and bent pieces of thin, micritic layers some of which are cracked and pulled apart. This coarse fill is overlain by finely laminated, fine dolostone exhibiting convolutions probably

of algal origin (Plates 3.28-a, b; 3.33-h). The whole layer (channel and surrounding dolostone) is overlain without noticeable interruption by fine-crystalline, light grey dolostone like that surrounding the channel. This feature is located at plus 505 feet in Section G (Fig. 3-4).

Cross-bedding

Two widely separated, thin, very quartz-sandy beds in the middle part of the unit in Section K, and one in Section P at about the same level, are partly or thoroughly cross-bedded (Fig's. 3-1, 3-9). The cross-"bedding" in Section K consists of fine cross-lamination of quartz grains in the upper 5 to 10 cm of beds which are, themselves, 1.5 to 0.8 feet thick. In Section P, a dolomitic quartz sandstone layer about 1.4 feet thick, between sandy dolostone beds, is thoroughly cross-bedded. Individual cross-sets are less than 20 cm high.

Aside from these isolated occurrences, only the faint cross-dipping and cut-off lamination occasionally visible in fine-crystalline, sometimes silty, dolostones is noteworthy (page 3-166 and Plate 3.33-f).

Bioturbation and Burrows

A distinctive type of bioturbation pattern occurs in Unit 3, in fine-crystalline, light-grey, usually quartz-sandy beds lacking any traces of fossils. When well developed, this type of bioturbation results in a "wormy" appearance on deeply weathered surfaces (Plate 3.35-c). On fresh or cut surfaces, most of the rock can be seen to consist of a mass of curving tubes outlined by concentrations of hematite and goethite, in an otherwise uniform, light-coloured dolostone (Plate 3.35-d). In most cases, the tubes (feeding burrows?) tend to extend more parallel to the bedding than across it, although no internal layering is preserved in thoroughly burrowed rocks. In some fissile, incompletely bioturbate layers, burrows trace concentric and looping patterns on partings (Plate 3.35-e). There is a complete gradation from thoroughly bioturbate layers to partially burrowed beds retaining a considerable amount of lamination, to laminated or non-laminated layers containing only a few streaks of iron minerals to indicate sporadic burrowing (Plates 3.35-c, d, f, g, h; 3.36-a). The intensity of burrowing is indicated diagrammatically on the detailed stratigraphic sections (Fig's. 3-1, 2, 3, 4, 9).

This distinctive bioturbation occurs at or near the bottom of

Unit 3 in most places but is common in thin, fine-crystalline, light-coloured beds throughout the unit, particularly in the central and eastern sections. A core-logging experiment (Appendix V) shows that the bioturbation is even more noticeable in drill core than in outcrop. In surface exposures burrowed beds often weather recessively and their weathered appearance varies in distinctiveness (Plates 3.33-b, c; 3.35-f, g). In one well exposed location, a very thoroughly burrowed bed can be followed laterally through a gradual transition to the intraclastic, ripple-marked lithology of Plate 3.28-c, d, over a distance of 40 feet.

Soft-Sediment Deformation Structures

Deformed, thin layering in the edge of a channel has already been described (page 3-171). Sand injection structures occur at plus 991 feet in Section K, where several thin, dolomitic sandstone layers occur (Plate 3.36-b). Also, a very quartz-sandy, laminated dolostone bed underlying a cross-bedded sandstone layer in Section P (page 3-172) is locally brecciated and filled with sandy dolostone. A few small sandstone dykes following planar, subvertical fractures were seen near the top of the same section. No other soft-sediment deformational structures were encountered in Unit 3.

Internal Sediments

Internal sediments are common in Unit 3, although they seldom form as large a percentage of a bed as in certain layers in Unit 2 (page 3-56). Zones of very extensive internal sedimentation were not encountered. The nature and distribution of the internal sediments in Unit 3 is as described for Unit 2, except that light-grey to tan coloured, microcrystalline internal sediments are also common in Unit 3, although not as common as darker, silty sediments like those in Unit 2. Where both types of internal sediment occur in the same sample, the light-colored micritic sediment clearly predates the darker, coarser one (Plate 3.36-c, d).

A partially dolomitized limestone sample from Unit 3 contains a laminated internal sediment composed of dolomite silt (Section P, plus 200 feet; Plate 3.36-e, f, g). A few calcite crystals remain at the edge of an extension of the sediment-filled cavity, but the coarse, radiaxial spar, projecting into the main cavity has been replaced by a randomly oriented, equant dolomite mosaic (Plate 3.36-f, g).

A large "sheet crack" (Fischer, 1964, p. 114), filled almost

entirely with internal sediment, can be seen in Plate 3.36-h. Note that this internal silt-filled crack cuts across white dolomite layers as well as across the original finely laminated sediment. A smaller "sheet crack" is shown in Plate 3.28-g, this one filled entirely by various internal sediments.

Internal sediments were not found in, or in contact with, typical zebra structure in this unit. Although internal sediment occurs in the brecciated top portion of a bed (Plates 3.21-a; 3.39-g; and page 3-196), none is present in the more zebra-like layering at the top of a similar bed (Plates 3.21-b; 3.37-g).

Some of the somewhat zebra-like beds described here as "semi-laminated" or "semi-zebra" (page 3-178) do contain recognizable (usually micritic) internal sediments. In most cases, these are in early-formed voids (fossil-sheltered and fenestral) and not in the numerous streaks of white dolomite parallel to bedding. However, one sample was found which appears to contain internal sediment within the white layering (Plate 3.39-h).

Internal sediments can also be seen in Plates 3.24-d; 3.25-a; 3.28-f, g; 3.29-c, g; 3.30-b; 3.32-e, f?; 3.34-d, f; 3.36-c, d, e, f, g, h; 3.38-e; 3.39-a, e, f, g, h?.

Zebra Structure

Zebra structure as described for Unit 2 (page 3-57) is very common in Unit 3, as well (Fig's. 3-1, 3, 4, 5, 9; Plate 3.37-a, b). Moreover, it occurs in definitely intraclastic, arenitic layers in the upper part of Section P (Plate 3.37-c). There are also several variants which may be related in origin. One distinctive variant that is unique to Unit 3 is here called "layered zebra". It consist of dark-light layering like zebra but dipping consistently at about 45 to 55 degrees and confined within planar layers one to two cm thick which are themselves repeatedly interlayered with uniform, dark, fine-crystalline dolostone (Plate 3.37-d). In all cases studied, all the zebra laminae in all the layers of a single sample or bed dip approximately parallel to a single plane. The dark laminae of the zebra layers are invariably attached to the underlying dark dolostone at their lower edges but most are detached at their top edges.

Discontinuous, thin white dolomite layers and lenses following primary layering are common in many places in the relatively thick beds of Unit 3 (Plates 3.34-a, b; 3.36-h; 3.39-h). In some places,

there is a gradation from these patterns to a pattern more closely resembling zebra structure (Plates 3.37-e, f). Intermediate-looking patterns seen in isolation in outcrop are labelled "semi-zebra" or "semi-laminated" on the detailed stratigraphic columns (q.v.), depending upon which end of this gradational "spectrum" they most closely resemble.

There is another occurrence of interlayered white and darker dolostone that may have a related origin to typical zebra structure. This is found in the upper parts of relatively coarse-crystalline, usually thick beds and is best displayed in the upper-middle part of the unit in the easternmost section, where it is associated with a regular vertical sequence of lithologies grading one-to-the-next in a single bed or across several beds (page 3-196). There is an upward gradation from purely primary lamination to a pattern commonly very like typical zebra structure. However, there is increasing disruption of the dark layers, upward, and the tops of many such beds consist of a breccia of fragments of dark layers surrounded by white dolomite (Plates 3.20-c; 3-21; 3.37-g, h; 3.38-a, b, c, d). In no case are the fragments bent or "curled", although apparent desiccation cracks cut a blackened upper surface of a similar bed lacking the disrupted, uppermost level (Plate 3.35-a).

Fractures

Fractures in Unit 3 are as described for Unit 2 (page 3-83), with additions as follows:

Iron-zoned, white dolomite fracture fillings are not common, although they do occur, in the rocks selected for thin sectioning from Unit 3. Thin, filled fractures at a high angle to bedding are common but many of them are filled by anhedral dolomite and quartz crystals which are in part overgrowths of adjacent dolomite crystals and quartz grains, rather than by zoned dolospar (Plates 3.24-d; 3.25-a; 3.28-h; 3.34-d; 3.36-c; 3.38-e).

Most thin-sections and some hand specimens indicate a history of several stages of fracturing (Plates 3.33-c; 3.36-d; 3.38-f, g). In some, one set of fractures has been cemented and then reopened before another set was formed in a different orientation.

An unusual effect was produced by tension fractures filled with overgrowths in one specimen. Parts of micrite envelopes were pulled away from grains by fractures breaking around the grains.

The result is a "double image" effect produced by isolated pieces of micrite envelope mimicking the shapes of adjacent grains (Plate 3.38-h; Section P, plus 560 feet).

In some specimens, internal sediment fills parts of fractures with various orientations. A partially dolomitized limestone sample from the edge of a limestone remnant (Section P, plus 200 feet) contains fractures which cut the replacing dolomite crystals and are filled partly by internal sediment (Plate 3.39-a). Earlier, calcite-filled fractures in the same specimen are replaced by dolomite along with their host-rock, in dolomitized parts of the sample.

Sandstone dykes were observed in joint-like planar fractures perpendicular to bedding of upper Section P (page 3-174).

En echelon fractures occur in several samples, usually filled by overgrowths (e.g., Plate 3.33-h).

As well as ordinary fractures, sheet cracks (Fischer, 1964, p. 114) of penecontemporaneous origin can be recognized in a few thin sections and hand specimens (page 3-175).

Many of the plates accompanying this text illustrate various types of fractures occurring in Unit 3.

Stylolites

Small, bedding-parallel stylolites and partly stylolitic partings occur occasionally throughout Unit 3 (e.g., Plates 3.38-b; 3.39-b, c). However, larger and more numerous stylolites occur only in a few places, mainly in the easternmost section. Typical of these occurrences is the segment of Section K between about plus 980 feet and plus 1020 feet (Fig. 3-9 ; Plate 3.22-c). Here, relatively large stylolites occur in medium-crystalline, thick beds and a number of discontinuous, stylolitic bedding surfaces are present.

Local Breccia and Pseudobreccia

Local breccia and pseudobreccia are as described for Unit 2 (page 3-65). They are most common within very thick beds in the easternmost section (Plate 3.20-b) where they are associated with

① "pockets" of coarse zebra structure and large vugs containing protruding, coarse dolomite and quartz crystals. Numerous relatively small, irregularly shaped or lenticular volumes of disrupted rock which grade in all directions into undisturbed, medium-crystalline dolostone are typical.

These breccia "pockets" exhibit textures ranging from normal breccia to pseudobreccia (page 3-67) but the "clotted" and "nebulous" end of the spectrum (page 3-66) and the gradation to coarsely recrystallized, uniform dolostone are found only in a few, much thinner beds (e.g., Plate 3.39-d; Fig. 3-9, plus 1060 feet). Here, these textures are commonly associated with internal sediments.

Sections Y, P and to a lesser extent V, are affected by large-scale, cross-cutting breccias. (See page 4-1.) Most of the brecciation in these sections belongs to, or is related to, these large breccias and is cross-cutting. However, there is some local brecciation of the first type described above in the upper part of Section P (Fig. 3-1) and probably in Section Y (Fig. 3-3).

There is also a zone of coarse breccia about 6 feet thick in

Section P (Fig. 3-1: plus 700 feet) that appears to be unique in the entire area. It contains jumbled blocks up to one foot long in a matrix composed of white dolomite and a large amount of quartz. A sample from the lower part of this strata-bound breccia contains idiomorphic quartz crystals which project into a former cavity now filled with lithified debris consisting mainly of quartz crystal fragments and dolomite crystals (Plate 3.39-e, f). The intact quartz crystals and the host dolomite (edge of a breccia block?) are very severely fractured but very few fractures cut the cavity-filling detritus (Plate 3.39-f).

Another type of local breccia is prominent in the easternmost section logged in Unit 3, as already described (page 3-178). In these brecciated tops of beds, tabular fragments of thin, dark layers are upended and vertically displaced to varying degrees but the fragments appear to have been moved very little from their places of origin (Plate 3.39-g). The degree of disruption commonly can be seen to vary laterally as well as decreasing downward in a bed (Plate 3.21-a, b). For further discussion of the textural sequence of which this is a part, see page 3-196.

Porosity

Comments concerning the nature and distribution of porosity in Unit 2 (page 3-69) apply to Unit 3, as well, with the following modifications:

Clear (and some white) quartz crystals are very common in vugs in Unit 3, along with white dolomite crystals, and bitumen is rare.

Visible porosity is very low in the lower part of Unit 3, particularly in the central and eastern sections, due to the strong predominance of dense, fine and microcrystalline beds (Fig's. 3-2, 3-4). Porosity is very variable both laterally and vertically, higher in the unit. It is probably greatest in the eastern part of the study area, where vugs and relatively coarse crystallinity seem to be most abundant (see also page 3-195).

TABLE 3-7

Diagenetic Sequence - Unit 3

<u>Diagenetic Feature</u>	<u>Evidence for Position in Sequence</u>	<u>Illustration (Plate No.)</u>
1. <u>Bioturbation & Mudcracks</u>	Penecontemporaneous in nature. Position relative to (2) uncertain.	3.22-e; 3.28-d; 3.34-g, h; 3.35.
2. <u>Fenestrae & possibly penecontemporaneous sheet crack-like voids.</u>	Never cross-cut any feature below. Lobate and irregular outlines elongate parallel to bedding.	3.25-a; 3.28-f; 3.29-a, c; 3.34-c; 3.36-d; 3.38-e.
3. <u>Cavities due to early leaching (slight to extensive) & partial lithification of muddy matrix.</u>	(4) found in leach-shaped cavities, some lithification required for existence of leached cavities.	3.24-d; 3.28-g; 3.36-d.
4. <u>Micritic internal sediment.</u>	Found in leached cavities but not typical sheet cracks.	As for (3).
5. <u>Sheet cracks.</u>	Cut muddy intraclasts but not harder grains; cut early-formed cavities when they were open.	3.28-g; 3.29-g.
6. <u>Cavities formed or enlarged by further leaching (variable: extensive to nil).</u>	Ooids leached while matrix still fairly plastic and before (7) & (8). Some cavities contain only (8) while others in same specimen contain (4). (4) partly removed prior to emplacement of (8).	3.30-c, d; 3.36-d; 3.28-g; 3.29-g.
7. <u>Radial to blocky spar void linings (coarse & fine).</u>	Found on walls of many cavities filled with (8), and in (6).	3.36-c, d, e, f, g; 3.30-c, d.
8. <u>Crystal silt internal sediment.</u>	Covers (7); fills (6) and is covered by (9). Also found in some fractures.	3.36-e, f, g; 3.25-a; 3.30-b; 3.34-d.
9. <u>Anhedral, void-filling spar.</u>	Covers (8), fills some (relatively early) fractures but cut by other fractures.	

***Note*:** Dolomitization probably took place after (8) and (9) in the bulk of the unit (interpretative reasoning cited for Unit 2 applies, and see Plate 3.36-e, g). However, there is evidence of minor, earlier-formed dolomite in several places (Plates 3.29-b; 3.34-g). The sequence of later diagenetic features is as shown in Table 3-4, on the same evidence.

Diagenetic Sequence

The diagenetic effects seen in Unit 3 that can be most accurately placed relative to each other on a time scale are shown in order in Table 3-7. This table is based mainly on several fine-crystalline dolostone samples which retain primary textures well, plus samples from two limestone remnants. Not all samples contain every feature listed but only features which can be placed without contradiction were used. Evidence for the relative positions of the various diagenetic effects is noted in the table.

Preservation of primary and earliest diagenetic textures is poor in the relatively thick and coarsely crystalline beds. As a result, diagenetic features such as zebra structure, local breccia and pseudobreccia cannot be placed relative to most of the features in Table 3-7 on the basis of direct evidence (see page 3-205).

Of the relatively early diagenetic effects in Table 3-7, only silt-sized internal sediments have been recognized with certainty in medium-crystalline and coarser rocks. These are often surrounded by a moderately thick lining or partial filling of coarse white dolomite which may represent former radial spar linings and/or

TABLE 3-8

Dolospar Zoning Patterns - Unit 3

Specimen:

<u>K-106.4</u>	<u>K-106.5</u>	<u>K-84.95</u>	<u>P-200</u>
<u>Ferroan with numerous inclusions (host mosaic).</u>	<u>Ferroan with numerous inclusions (host, finer mosaic than K-106.4).</u>	<u>Sl. ferroan dolomicrite and internal silt.</u>	<u>Moderately ferroan host dolomite.</u>
<u>Coarse, ferroan dolospar on host.</u>	(As for K-106.4) <u>Fewer inclusions than host.</u>	<u>Equally ferroan to crystal silt but numerous submicroscopic inclusions.</u>	<u>Minor ferroan dolospar on host.</u>
<u>Non-ferroan overgrowth (moderately thin): inclusions in all or part.</u>	<u>Non-ferroan overgrowth (thick): inclusions decreasing in outer part.</u>	<u>Highly ferroan band (moderately thick) in dolospar with inclusions.</u> <u>Sl. ferroan overgrowth with inclusions decreasing in outer part.</u>	
<u>Highly ferroan band (thin) in clear outer edge of previous phase. (Only in large openings.)</u>	(As for K-106.4, to left.)	<u>Moderately to strongly ferroan zone in clearer outer edge of previous phase.</u> <u>Inclusion-rich band just outside previous zone (sometimes a thin, clear layer between).</u>	
<u>Clear, non-ferroan dolospar (minor).</u>	(As for K-106.4, to left.) <u>Sl. ferroan dolospar with moderate number of inclusions. Inclusions fewer in last part precipitated.</u>	<u>Clear, non-ferroan overgrowth filling all remaining space.</u>	<u>Clear, non-ferroan overgrowths bordering open pores.</u>

anhedral spar filling. The internal sediments in these beds generally fill all remaining space (Plate 3.36-e, f) but rarely they are topped by anhedral, coarse, white dolomite fillings.

Coarse dolomite crystals zoned with respect to ferrous iron content and with respect to inclusions occur in many samples representing a variety of lithologies in Unit 3, as throughout the entire Devonian carbonate rock section in the Robb Lake area. Zoning is limited to one side, or end, of the crystals, and most commonly outlines idiomorphic crystal shapes which evidently projected into a former cavity (now partly or entirely filled by overgrowths on the same crystals). Zoning patterns observed in thin-sections from Unit 3 are shown in Table 3-8.

TABLE 3-9

Selected Most Significant Matching Coefficients
- Unit 3.

("N" is number of data points in section.)

Character Pair	Section Y N=184	Section G-top N=179	Section P N=314	Section P Hand Spec. N= 56	Section K N=250
"Positive" -----					
Mic. or / ≤ 1 foot Fine / thick.	0.01	-0.10	{ -0.38 } { Fn. only }	0.25	0.28
Med. or / > 2 feet Med. Fine / thick	0.41	-0.31	{ -0.27 } { M.F. only }	{ 0.00 } { Weak data }	0.32
Med. or / Med. Fine / Vugs	-0.82	-0.07	{ -0.66 } { Med. only }	-0.21	0.47
Fine or / Mic. / Laminated	-0.84	-0.17	{ -0.62 } { Fn. only }	-0.33	0.05
≤ 1 foot / thick / Laminated	-0.84	-0.64	0.00	-0.37	-0.37
"Negative" -----					
Mic. / > 5 feet thick.	-1.00	-0.83	-1.00	-1.00	-1.00
Fenestral / Cse or med. cse.	-1.00	-1.00	-1.00	-1.00	-1.00
≤ 1 foot / thick / Vugs	-1.00	-1.00	-0.97	-0.75	-0.96
Fenestral / Vugs	-1.00	-0.95	-0.96	-1.00	-1.00
Fenestral / Zebra	-1.00	-1.00	-1.00	-1.00	-1.00
Mic. / Vugs	-1.00	-1.00	-1.00	-1.00	-1.00
Zebra / Mic.	-1.00	-1.00	-1.00	-1.00	-1.00
Zebra / Lamination	-1.00	-0.93	-0.96	-1.00	-0.96
Zebra / ≤ 1 foot thick	-1.00	-0.95	-----	-1.00	-0.92

Lithotypes and Patterns of Variability

Although a gross subdivision of the lithologies found in Unit 3 into a fine-crystalline, thin-bedded type and a coarser-crystalline, thick-bedded type is possible in most places, a clearcut distinction of two basic lithotypes with little overlap cannot be made.

Discrete-state matching coefficients were computed from regular-interval sampling of data from the section logs (Fig's. 3-1, 2, 3, 4, 9) and from some of the hand specimens (page 1-16). Normal, "two way" matching coefficients show few high correlations. However, they do permit identification of the few significant, relatively highly correlated characteristics of these rocks (Table 3-9). It is clear that the most positive correlation for Unit 3 is between fine or microcrystalline dolostone and bed thickness of one foot or less. From "directional" matching coefficients based on the presence of the least common characteristic of a pair (page 1-17), it can be said that fine or microcrystalline dolomite forms from 80% to 98% of all the beds one foot or less thick, depending on the measured section in question (Table 3-10). (The average for all sections together, weighted on the basis of the numbers of sample points with bedding less than or equal to one foot, is 87%.)

Correspondingly, medium-fine or coarser crystal size is relatively highly correlated with bed thickness greater than two feet (Table 3-9). In general, from 67% to 85% of beds more than two feet thick are medium or medium-fine crystalline. An exception occurs in Section G (Fig. 3-4), where the presence of several thick, fine or microcrystalline, dark-coloured beds in a predominantly thin-bedded section results in a much lower correlation (Tables 3-9 and 3-10). Even including Section G, the weighted average (computed as before) is 76%. However, as there are few medium-coarser or coarse beds, most of the remaining percentage of thick beds is fine or microcrystalline, forming a considerable overlap with thin beds.

Other relatively high correlations (Tables 3-9 and 3-10) show that certain other characteristics can be related to bed-thickness and crystal size:

- 1) Fine lamination is found mainly in beds one foot or less thick and in fine or microcrystalline beds. The exception is in Section Y, where lamination is visible in certain thicker and somewhat coarser-crystalline beds. Lamination is very rarely found with zebra structure.

2) Fenestral fabric occurs in fine or microcrystalline dolostone with almost no exceptions. It never occurs with zebra structure and almost never with vugs.

3) Most zebra structure (68% to greater than 92%) occurs in medium-fine or coarser dolostone and none is in microcrystalline dolostone. Zebra structure is rarely found in beds one foot or less thick or with fine lamination or with intraclasts.

4) Vugs occur mainly in beds greater than one foot thick, nearly always in medium-fine or coarser-crystalline beds and never in microcrystalline beds.

These and other relationships can be found directly in, or derived from, the matrices in Appendix II. However, the coefficient matrices must be used with care, as a knowledge of the limits of the sampling procedure and of variations in the quality of the original data sets is required to properly evaluate the meaningfulness of many of the coefficients.

Specimens from thick (greater than 2 feet), medium-crystalline or coarser beds also generally have much smaller insoluble residues than thinner, finer-crystalline beds (Table 3-6). However, some thick, relatively coarse-crystalline beds contain enough quartz sand to produce residues larger than the 0.3% maximum typical of Lithotype II in Unit 2.

Three other field-observable characteristics, mudcracks, ripple marks and a distinctive bioturbation pattern (page 3-173), are associated mainly with thin, relatively fine-crystalline beds. However, in Unit 3, relatively dark colour is neither predominant in, nor restricted to, thin or fine-crystalline beds, although it is most commonly found in such beds. (See particularly Figures 3-3 and 3-4.)

Layers typical of Lithotype I (page 3-85) occur at or near the bottom of Unit 3 (Fig's. 3-1, 2, 3, 4) and also as isolated, thin interbeds between thick beds in the upper-middle part of the unit in the easternmost section (Fig. 3-9). (See also Plates 3.19-a; 3.20-b; 3.22-c; 3.29-c; 3.34-c.) However, light-grey and buff-coloured beds with some or all of the other characteristics of Lithotype I are more common and there is a continuous spectrum of

intermediate shades of grey among fine-crystalline, thin beds. Quartz sand is scarce or absent (less than 1%) in dark-coloured laminoid-fenestral beds but it is commonly abundant in light-coloured L-F beds.

*Thus, the rocks of Unit 3 can be viewed as consisting of two basic, somewhat overlapping groups corresponding approximately to Lithotypes I and II of Unit 2. The generally thin-bedded and fine-crystalline type can then be divided into dark coloured and light-coloured subgroups, the light-coloured subgroup being volumetrically predominant over the dark.

The variation in matching coefficient values from one section to another (Tables 3-9, 3-10 and Appendix II) indicates considerable lateral variation in the lithology of Unit 3 as a whole. A significant lateral change in bedding character can be seen in the field (page 3-140). It is also noteworthy that a number of coarsely clastic, quartz-sandy calcarenite layers, several of them rich in fossil fragments and ooids (page 3-159), are present in the middle to upper-middle part of the unit on the northwest side of the study area, while these give way to somewhat less sandy, more thick-bedded rocks with only rare traces of fossils or calcarenitic texture at the same stratigraphic level in the east (Fig's. 2-5, 3-1, 3-9).

Moreover, the bottom part of the unit contains markedly less thin-bedded and sandy, fine-crystalline dolostone in the northwest than in the central-to-eastern sections (ibid.; also compare Plates 3.19-b and 3.22-d, f). In the upper part of the unit a distinctly cyclic alternation of thick, relatively coarse-crystalline, vuggy, zebra-bearing beds and thin, fine-crystalline interbeds occurs in the east but such a cyclic pattern is not apparent farther west (Fig's. 2-5, 3-9, 3-5, 3-1).

All the measured sections show a pattern of change up-section, as well. Everywhere the bottom of the unit was studied, the section begins with a thin-bedded zone containing beds with "wormy" bioturbation (page 3-173) and laminoid-fenestral beds (page 3-167 and Fig's. 3-1, 2, 3, 4). The occurrence of mudcracks and ripple marks in this zone has already been noted (page 3-138). Delicate brachiopod imprints were found on a shaly parting in this zone in a central section (page 3-162 and Fig. 3-4).

Above this basal zone there is a transition to predominantly thick beds, with numerous intervals of thin, generally finer-crystalline and sandier beds interspersed (page 3-139). The transition takes place lower in the section, and apparently more abruptly, on the

northwest than in central and eastern sections (Fig's. 3-2, 3, 4). This assemblage of thick, massive beds and thin beds becomes ordered into an alternating, cyclical pattern in the upper half or less of the unit on the east side of the property (Fig. 3-9).

Much of the cyclical sequence is similar to that in Unit 2 (page 3-84) but a series of beds in the lower part of it requires special comment (Fig. 3-9, plus approximately 660 feet to 720 feet). In these beds, each cycle begins with medium-to-light grey, fine crystalline dolomite, commonly weakly laminated and dense, without vugs or white dolomite. Either within the same bed or across a weakly developed bedding surface, this lithology grades upward to an increasingly coarser-crystalline dolostone in which bedding-parallel streaks of white dolomite appear. Higher in the layer, somewhat zebra-like banding of white and dark layers has developed. In some cases, this is topped by a well-developed, uneven bedding surface, commonly blackened and exhibiting former cracks (Plates 3.21-b; 3.35-a). In other cases, the top part of the layer, or all but the fine-crystalline bottom, is a breccia of small, dark-coloured fragments in an abundant matrix of white dolomite and in some cases micritic internal sediment (Plate 3.20-c; 3.21-a; page 3-183). The entire cyclical pattern is generally completed within two to four feet of stratigraphic thickness.

Interpretations

Environments.

The basal beds of Unit 3 are evidently the initial, intertidal-supratidal layers deposited during a transgression over the previously emergent surface of Unit 2 (page 3-108). The lowermost beds normally include several laminoid-fenestral layers (page 3-97) and several "wormy" bioturbate layers (page 3-173). The latter have been burrowed enough to destroy lamination in most places but not enough to homogenize the burrow tracks, themselves. This and the consistently similar bioturbation patterns from place to place suggest a very restricted environment, such as intertidal-supratidal flats, where a limited amount of organic activity, probably by only one species, was possible.

The rest of the thin-bedded lower part of Unit 3 consists mainly of a variety of dark and light-coloured, quartz-sandy and/or silty, thin, fine-crystalline dolostone beds. Laminoid-fenestral fabric is uncommon above the bottom part of the zone but varying degrees of "wormy" bioturbation are common throughout (though generally less well developed than at the bottom of the unit).

The common mudcracks are direct evidence of subaerial exposure and occasional small-amplitude oscillation-ripple marks (page 3-170) suggest local pools of water on a subaerially exposed mudflat. Taken together, and in the context of the environmental and paleogeographic interpretation of Unit 2 (page 3-96, et seq.), these features indicate a supratidal-to-upper- intertidal environment of deposition, with lime-mud sediment settling from sea water which intermittently flooded the surface and with a more or less continuous supply of terrigenous sand, silt and clay which had been absent or much less prominent during upper Unit 2 deposition. The action of weak tidal currents (ebb-flow of marine floodwaters?) during sedimentation is shown by cross-lamination occasionally visible in silt-sized carbonate in this zone (page 3-166 and Plate 3.33-f).

Thick, zebra-bearing beds occur lowest in the section in the northwest (Fig's. 2-5, 3-3). Many of the lowest of these beds are medium-fine to fine crystalline and some contain finer and darker-coloured, laminoid-fenestral dolostone at the bottom. Fenestral lithology occurs in a number of places above the lowermost few beds in this section, while it is rare in all but the bottom of the thin-bedded zone elsewhere. Thus, the northwestern part of the area seems to have been slightly lower than elsewhere, topographically, during

early Unit 3 deposition, so that it remained in the (lower?) intertidal zone much of the time and temporarily entered the uppermost subtidal zone sooner than the central and eastern parts of the area.

Eventually, gradual transgression brought the entire area into the subtidal realm, where massive, thick beds like those of Lithotype II (Unit 2) were deposited (Fig. 2-5, etc.). A particularly thick subtidal sequence, with only brief interspersed returns to the intertidal-supratidal realm, seems to have been deposited from about 230 to 320 feet above the base of the unit. This part of the unit, which was subsequently severely brecciated where studied, is not exposed in Sections G, H or K (Fig. 2-5). While it was not logged at Section V, where it is imperfectly exposed, an increasingly thick-bedded or massive, coarser-crystalline section was noted there in this interval.

This subtidal period was followed by a prolonged period of intertidal-supratidal (probably mainly supratidal) deposition represented by a thick section of very thin, microcrystalline and fine-crystalline, very sandy, silty and argillaceous beds. Most of these beds are finely laminated. Cross-lamination or small-scale cross-bedding can be seen locally (Fig's. 3-1, 3-9).

The transition from the thick, subtidal section below is through several alternations of typical thick beds and zones of laminoid fenestral lithology (lower intertidal?) which grades to other thin beds, mostly sandy, some finely laminated, some fine crystalline and others coarse-crystalline and lumpy-bedded. Intraclasts are common in these thin beds (Plate 3.29) and in one case a granule conglomerate was found (Fig. 3-1, plus 330 feet).

Extensive diagenetic alteration has taken place in the thin, lumpy, coarse-crystalline, mottled beds and in locally brecciated parts of some thick beds with abundant white dolomite and coarsely recrystallized textures. Internal sediments can be seen in a few places. These features appear to indicate periods of subaerial exposure during the transitional phase (see Unit 2 - Interpretations).

Intertidal-supratidal deposition eventually gave way again to a pattern of periodic subtidal submergence followed by exposure. Associated with the lowermost subtidal beds of this sequence, about 450 feet above the base of the unit, are remnants of microcrystalline limestone and evidence of prolonged subaerial exposure at several levels (Fig's. 2-5, 3-1, 3-4, 3-9). A cyclical pattern like that in upper Unit 2, with fine-crystalline, laminated and/or laminoid-

fenestral, intertidal lithology grading upward to a coarser, thicker, subtidal layer, can be seen in some beds in Section P (Fig. 3-1) as well as more commonly and clearly in Section K (Fig. 3-9). However, even where best developed, the cyclical pattern is interrupted, apparently non-rhythmically, by thin-bedded zones exhibiting evidence of subaerial exposure and intertidal-supratidal deposition. Some of the thickest of these zones seem to be correlative across the study area, although data is increasingly limited upward in the section (Fig. 2-5). The overall lithologic pattern suggests a regular, regional or more far-reaching rise and fall of sea level as for Unit 2 (page 3-109) but with a superimposed irregular, local variation in subsidence rate and/or perhaps in sediment supply.

A seaward source of sediment seems indicated for all of Unit 3. With the (local?) transgression that started deposition of Unit 3 came an influx of terrigenous sand into an area where there had been almost no sand supply for some time (presumably since Unit 2 deposits buried the surface of Unit 1 - page 3-107). A local, landward source of sand is thus hard to imagine but supply of sand by long-shore currents to dunes along a seaward barrier zone is compatible with the likely paleogeographic pattern as described for Unit 2 (page 3-108). Such dunes might have accumulated during the

relatively low stand of sea level between Unit 2 and Unit 3 deposition and might have moved landward with the succeeding transgression, providing both storm-deposited and wind-deposited sand and silt to the broad mudflat area under study here.

Higher in Unit 3, more direct evidence of a seaward source of quartz sand is presented by the association of abundant quartz sand with abundant fossil fragments, oolite and other transported calcarenite grains in a number of beds in Section P (page 3-104). These arenites, some of them pebbly grainstones, are evidently storm deposits from an active barrier zone not far away. Their restriction to the northwestern part of the area indicates the general direction of the nearest part of the seaward barrier system, agreeing with similar evidence from Unit 2 (page 3-108).

The presence of light-grey, mainly medium and thick bedded, medium-fine-crystalline dolostone with up to 30% or more quartz sand at the top of Unit 3 at Sections J and H (Fig. 2-6) suggests that the general pattern of deposition of the upper part of the unit probably prevailed until relatively abrupt withdrawal of the sea (regional tectonic or epeirogenic uplift?) resulted in emergence

and erosion. It is possible, of course, that subsequent erosion removed a capping zone of intertidal-supratidal beds similar to those at the base of the unit. However, contrary to the common pattern for clastic sediments, little intertidal sediment seems to have accumulated during regressive phases in these and similar rocks (page 3-114).

Evidence from Unit 4 (page 3-254) indicates a prolonged period of emergence and considerable erosion after the deposition of Unit 3, creating an unconformity of major significance in the area.

Diagenetic History.

Comments concerning the earliest-formed diagenetic features in Unit 2 (page 3-116) apply equally to Unit 3 (Table 3-7). (In general, the reader is referred to the diagenetic history description for Unit 2 for explanation of terminology and evidence used here without explanation. Only significant differences and new information will be described here.)

Internal sediments and other fresh-water diagenetic features associated with subaerial exposure are found in Unit 3 as well as Unit 2. Some of the fine-crystalline, intertidal-supratidal beds contain micritic internal sediment emplaced prior to the more usual crystal silt (page 3-175). This is also the type of internal sediment found in the brecciated top of one of the cyclic sequences (page 3-196). The micritic internal sediment is probably simply marine lime-mud, essentially the same as the host rock, which filtered into very near-surface cavities produced during exposure of a mud layer prior to the next flooding.

An unusual example of the effects of fresh-water leaching beneath a subaerially exposed surface occurs in a rare oolitic layer where leaching of aragonite ooids resulted in the dropping of quartz cores to the bottoms of the by then somewhat deformed micrite envelopes. Subsequently, fine-crystalline linings and then anhedral sparry fillings were precipitated in the hollow, former ooids (page 3-160). This bed is composed entirely of dolomite, although it overlies a limestone remnant. However, the sparry ooid-fillings closely mimic typical sparry calcite fillings and do not resemble known void-filling dolomite such as that in zebra structure. Calcite

spar linings, in some cases quite coarse, are known elsewhere in this unit (page 3-175). Thus, it seems likely that the anhedral sparry fillings in this layer were precipitated as calcite and subsequently dolomitized.

Although a cyclical pattern of sea level change is not apparent in much of Unit 3, there is abundant evidence for repeated alternations of periods of submergence and periods of subaerial exposure (page 3-198, et seq.). Under these circumstances the mode and timing of dolomitization (and formation of zebra structure) indicated for Unit 2 (page 3-118) apply as well to Unit 3. The unusual "layered zebra" structure observed in a few places in Unit 3 (page 3-177) is apparently the response of the zebra-forming mechanism to invisible, prograding cross-lamination sets in the lime sediment, probably produced by settling from the ebb-tidal flow.

Internal sediments of dolomite crystal silt, even in limestone (page 3-175), and probable dolomite rhomb casts on a mudcracked bedding surface at one locality (page 3-169) indicate a limited amount of dolomite formation at subaerially exposed surfaces, prior to re-submergence. Probably the best explanation for this is the superficial, "rainwater-mixing" dolomitization mechanism suggested by

Folk and Land (1975, p. 65) for formation of dolomite crusts in the Bahamas.

The reason for the consistently fine crystal size and commonly relatively well-preserved primary textures of the intertidal-supratidal beds remains imperfectly explained (page 3-127). Again in Unit 3, abundant evidence of the effects of fresh water argues against hypersaline dolomitization. Moreover, evaporite minerals, necessarily associated with hypersaline supratidal dolomite, evidently were never present in these beds. This is particularly apparent in the numerous beds with relatively well-preserved primary and penecontemporaneous textural features. Again, the apparently correlative variation in abundance of muscovite (illite?) may offer an explanation not yet understood (page 3-129). Concentration of magnesium by organic matter, an appealing mechanism for Unit 2 (page 3-128) seems less promising for the many non-fenestral, light-coloured beds in Unit 3. On the other hand, laminoid-fenestral fabric is also common in light-coloured beds in this unit (page 3-168) and many non-fenestral, fine-crystalline beds are finely laminated. Possibly, originally abundant organic matter was removed from these beds, leaving them abnormally high in magnesium.

There is particularly clear evidence of the early formation of "local breccia" at the tops of the distinctive, thin "cyclothems" in Section K (page 3-196). Micritic internal sediment in the brecciated top of one of these beds shows that brecciation took place during subaerial exposure, prior to re-flooding and deposition of the next layer. Internal sediment does not fill all inter-fragment spaces, however. Where present, it is largely surrounded by white dolomite. Some of this white dolomite may replace host-rock fragments but much of it clearly does not. The smooth boundaries of the internal sediment suggest that it has not, itself, been replaced in part. Thus, the white dolomite or whatever cementing mineral it replaces, evidently also predates the micritic sediment and the re-flooding of the sediment surface. Perhaps the coarse, white dolomite replaces calcite spar, which is known to have formed elsewhere during subaerial exposure and fresh-water diagenesis. However, the effects of fresh water diagenesis have not been seen in these particular "cyclothems", while extreme desiccation of their tops seems characteristic (page 3-170). In this setting (probably unique in the entire Robb Lake section) the growth of an evaporite mineral (e.g., gypsum) in the desiccated surface sediment can be proposed as a reasonable alternative, and one which would help to explain the apparently expansive disruption of the top parts of these beds.

Dolomite zoning in Unit 3 is interpreted as for Unit 2.

Clear quartz crystals are very common as a last filling in vugs in Unit 3 (page 3-145). Their presence is easily understood as a result of remobilization of silica from the abundant quartz sand throughout the unit. Sandy beds commonly show plentiful evidence of grain boundary modification (page 3-145). As in Unit 2 (page 3-136), remobilization may have occurred quite late, under conditions of deep burial.

The origin and history of the minor lead-zinc mineralization encountered in sections measured in Unit 3 is included in the general discussion on page 4-19.

TABLE 3-10

Selected Most Significant Directional
Matching Coefficients - Unit 3.

<u>Character Pair</u> (If first character is present, coefficient shows commonness of 2nd character.)	Section Y N=184	Section G-Top N=179	Section P N=314	Section P Hand Spec. N=56	Section K N=250
1 foot / Mic. or thick / Fine	.70	.96	-.13* (Weak data)	.67	.61
2 feet / Med. or thick / Med.-Fine	.68	-.14*	.70	.33	.70
Zebra / Med. or / Coarser	.78	.67	.36	.42*	.92
Lamination / Mic. or / Fine	.67	.84	.43	.80	.66
Lamination / 1 foot / thick	-.11	-.07*	.54	1.00	.31
Fenestral / Mic. or / Fine	.70	1.00	-.17	1.00	1.00

* indicates 2nd character less common than first.

N is total number of data points in section.

3.19

a. Thin-bedded dolostone near bottom of Unit 3, Section V.
• Hammer shows scale.

b. Weathered aspect of medium to dark grey, fine-crystalline,
mainly laminoid fenestral dolostone beds at the bottom of Unit 3,
Section V (a few feet below (a)).

a

b

PLATE 3-19

3.20

- a. Panoramic view of Unit 3 strata at Section K. Stratigraphic top is to right. Cyclic pattern of thick, massive beds with thin, recessive "breaks" between, in part. The thickest beds in view are approximately 15 feet thick.
- b. Typical vuggy, breccia-pocketed thick bed, Section K. Underlying and overlying thin beds are discernible locally. Red-handled hammer in lower part of photo is one foot long.
- c. "Coarsening upwards" cyclothem, as in 3.21-a, but here consisting of a uniformly fine-crystalline, faintly laminated lower member and a nearly uniform, coarse-crystalline upper member with abundant white dolomite. Part of another cycle can be seen in background at top.

a

b c

PLATE 3·20

3.21

a. One of a cyclical series of "coarsening upward" layers in Section K, this one at +693 feet on Figure 3-9. Note fine to medium-fine-crystalline base, grading upward to coarser crystallinity and zebra-like inter-layers of white dolomite, and culminating in a disrupted (brecciated) upper part with abundant white dolomite. Plate 3.38-g was taken from this layer.

b. Another cyclical unit, as in (a), but with a less disrupted upper part and topped by a blackened (probably desiccated) layer and massive, coarse white dolomite. (Figure 3-9, +676 feet.)

a

b

PLATE 3·21

3.22

a. Field aspect of middle Unit 3, Section P. Stratigraphic top is toward background of photo. Thickest bed in foreground is about 7 feet thick.

b. Bedding aspect, upper-middle Unit 3, Section K. Field notebook in foreground is $7\frac{1}{2}$ inches tall. Thickest bed in middle distance is approximately 4 feet thick.

c. Thick, vuggy beds with thin, fine-crystalline interbeds, upper-middle Unit 3, Section K. Uppermost (thickest) bed is 7 feet thick.

d. Basal beds of Unit 3, Section P: lowermost, bioturbate beds in foreground; laminoid-fenestral beds farther back, overlain by thin-bedded zone. Staff is 5 feet long, marked in tenths of a foot.

e. Mudcracks in talus from basal thin-bedded zone, Unit 3, Tennessee Mountain. Staff is marked in feet.

f. Predominantly thin-bedded dolostone immediately above that shown in (d), Section P. Staff as in (d).

g. Ripple marks in talus from basal thin-bedded zone, Unit 3: east peak of Texas Ridge. Hammer handle parallels ripple crests.

h. Major zone of thin beds: middle Unit 3, Section K. Hammer handle at centre of photo is one foot long.

a

b

c

d

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PLATE 3-22

3.23

a. Thin-bedded zone, middle Unit 3, Section K. Bed on which hammer rests has very planar top surface but fills channels or depressions in surface of underlying bed.

b. Extremely smooth top surface of one of the beds in (a).

c. Shallow channel filled with dolostone continuous with the overlying bed: lower part of thin-bedded zone in Plate 3.21-h.

d. White, sparry dolomite nearly filling a formerly large ~~vug~~: middle Unit 3, Section G. Note zoning pointing into former ~~vug~~. Small circles are bubbles in thin-section. Three black bars at lower left show two millimetres. (Plane light.)

e. Concentric layers of grey and white dolomite in a complex cavity-filling: middle Unit 3, Section G. Scale in cm.; arrow shows stratigraphic top.

f. Enlargement of part of (d), showing a zone very rich in ferrous iron and inclusions as well as several weaker zones. (Thin section, plane light, stained with potassium ferricyanide. Scale bar shows 1 mm., arrow as previously.)

g. Very sandy dolostone: upper-middle Unit 3, Section P. Note single thin lamina near top composed entirely of quartz grains. Arrow as previously.

h. Enlargement of part of (g) to show roundness and sorting of quartz grains. Also note scattered, ill-defined dark patches most or all of which represent former carbonate grains (intraclasts?). Scale shows 1 cm.; arrow as previously.

PLATE 3-23

a. Poorly sorted quartz grains in a dolomite matrix evidently replacing micrite (dark, fine-crystalline) and some spar (coarse, relatively clear). Note varying angularity and degree of corrosion of quartz grains. Dolospar apparently replaces edges of corroded grain at centre. (Upper-middle Unit 3, Section P. Thin section, plane light; scale bar shows 1 mm.; up arrow as previously.)

b. Quartz grain at centre shows embayment formed prior to deposition in this sediment (embayment filled by small grains). Also note slight partial quartz overgrowths. Same specimen as (a). (Thin section, crossed nicols.)

c. Quartz-sandy dolostone, upper-middle Unit 3, Section P. Note irregular overgrowths on many rounded grains, partial replacement of quartz by dolomite (upper right), and irregularly shaped dolospar patch probably representing a leached cavity. (Thin section; plane light; black bars show scale in mm.)

d. Fracture filled with quartz (white) and dolomite: weakly laminoid-fenestral bed a few feet above bottom of Unit 3, Section P. Note that fracture cuts clasts, matrix and two generations of internal sediment. Internal sediment (black and dark grey) and overlying dolospar fill former cavities whose irregular shapes suggest formation or enlargement by leaching. Scale bars at top show mm.; arrow as previously. (Thin section, non-polarized light.)

e. Silicified pocket, middle Unit 3, Section G. White to light grey is dolostone; dark grey to black is largely quartzose, with fine dolostone fragments. Scale in cm.; arrow as previously.

f. Silicified, quartz-rich bands weathering in relief in dolostone: middle Unit 3, Section G. Arrow as previously.

g. Authigenic quartz crystal with calcite inclusions: limestone remnant, middle Unit 3, Section P. Note essentially pure, probably detrital, silt-sized nucleus. Scale bar shows 1 mm.; arrow as previously. (Thin section, plane light, stained with alizarin red.) Circular "halo" is due to reflection in microscope tube.

h. Authigenic quartz crystals in micrite: middle Unit 3, Section K. (Plexiglass peel of highly etched surface, plane light.) Seemingly anomalous angles are due to varying inclinations of crystal axes and deep etching of limestone surface. Scale shows 1 mm.

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PLATE 3-24

- a. Fenestral filling and cross-cutting fracture in quartz-sandy L-F dolostone: upper middle Unit 3, Section K. Quartz (white) dolomite (grey) and calcite (dark grey) fill fracture. Probable roof-collapse material fills most of left side of fenestra. Rest of fenestra is filled by minor primary debris grading upward to crystal silt and overlain by dolospar. Scale bar shows 1 mm.; arrow shows stratigraphic top. (Thin section, plane light, stained with alizarin red.)
- b. Small vugs lined with dolomite and a thin coating of bitumen: lower middle Unit 3, Section Y. Arrow as previously.
- c. Pyritomorphic hematite (black) along the surface of a clast: upper middle Unit 3, Section P. Also note contained intraclasts and quartz grains, many with oolitic coatings, in a largely sparry dolomite matrix. Scale bar shows 1 mm. (Thin section, plane light.)
- d. Pyritomorphs (now hematite) from insoluble residue of dolomitized grainstone or packstone: upper middle Unit 3, Section P. Scale shows 1 mm.
- e. Pyritomorphic hematite included in coarse-crystalline dolomite replacing limestone: edge of small limestone remnant, middle Unit 3, Section K. Scale bar shows 1 mm. (Thin section, plane light.)
- f. Thoroughly fractured, honey-coloured sphalerite (a) and lesser galena (b) in polymict dolostone breccia: Unit 3, Section Y. (Figure 3-3, +220 feet.)
- g. Locally brecciated to pseudobrecciated dolostone with traces of reddish sphalerite (a) and galena (arrow) in white dolomite. Galena crystals occur along surface of a dark grey fragment.
- h. Weathered surface of mineralized dolostone from which sphalerite and galena have been leached. Adjacent to a bed surface, middle Unit 3, Section K. (Scale in cm.)

a

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- a. Quartz, carbonate and feldspar clasts in probable former grainstone: middle Unit 3, Section P. Note plagioclase(?) feldspar grain (F) and both slight overgrowths and slight embayments of quartz grains. Scale bar shows 1 mm. (Thin section; crossed nicols; light blur near centre is due to reflection in microscope.)
- b. Grain outline filled largely by clay minerals but partly by dolospar (probable former feldspar grain): same specimen as (a). Also note slight overgrowths and embayments of quartz grains. (Thin section; crossed nicols; "halo" due to reflection as previously.) Scale bar shows 1 mm.
- c. Unusual colloform coating on dolomite crystal projecting into an open void in the coarse-crystalline top of a cyclothem bed: upper-middle Unit 3, Section K. (Same layer as in Plates 3.19-d and 3.36-g, h.) Scale shows 1 mm.; arrow shows stratigraphic top (not vertical). (Thin section, plane light.)
- d. Dolostone composed mainly of ovoid, dolomicrite intraclasts (probably fecal pellets): middle Unit 3, Section Y.
- e. Enlarged photo of a layer similar to (d), showing packing of clasts. Note very weak preferred orientation of clasts parallel to bedding; some irregularly shaped clasts. Lower-middle Unit 3, Section Y. Scale in cm., arrow as previously.
- f. Dolostone clasts similar to (d) and (e) in quartz-sandy, light coloured dolostone: upper-middle Unit 3, Section K.
- g. Part of a large intraclast in a dolomitized quartzose calcarenite layer: middle Unit 3, Section P. Intraclast is left of thin, sub-vertical line (micrite coating?) across right side of photo. Note zircon grain (arrow) and micrite coated polycrystalline quartz grain (re-sedimented dolomitic orthoquartzite?). Blurred circle is due to reflection in microscope. (Thin section; crossed nicols; scale shows 1 mm.)
- h. Fine-grained intraclast in quartzose calcarenite: same layer as (g). Note greater rounding and mean size outside intraclast; pellets or remnants of micrite matrix in intraclast. Scale bar shows 1 mm.

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PLATE 3-26

- a. Quartz grains, intraclasts and carbonate grains (now dolomite mosaic): middle Unit 3, Section P. Note micrite envelopes on carbonate grains and some quartz grains; remnants of micrite matrix with quartz silt (or disrupted intraclasts?). Scale bar shows 1 mm.; thin section, plane light.
- b. Another complex intraclast in same specimen as (a). Note tourmaline grain cut off at edge of intraclast (arrow); calcisphere in intraclast (near bottom of photo); possible scattered pellets in intraclast; thin micrite coatings on intraclast and many grains inside and outside it. (Thin section, plane light; scale bar shows 1 mm.)
- c. Intraclast containing a variety of rounded, micrite-coated or oolitically coated grains: same specimen as (a) and (b). Coatings suggest algal influence. Scale bar shows 1 mm. (Thin section, plane light.)
- d. Oolitic coating but not quartz core cut off at edge of micrite-coated intraclast: upper-middle Unit 3, Section P. Also note superficial ooids outside clast and zircon grain (dark) just above clast. Scale bar shows 1 mm. (Thin section, plane light.)
- e. Authigenic quartz crystals in micrite (now dolomite), cut off at edges of intraclast: upper-middle Unit 3, Section P. (Scale crossbars mark $\frac{1}{2}$ mm.; up arrow as previously; thin section; plane light.)
- f. Rounded intraclasts, and quartz sand and granules: middle Unit 3, Section P (same specimen as (a), (b) and (c), above). Scale in cm. Note coral fragment at bottom edge of specimen.
- g. Intraclastic, fossiliferous, quartz sandy dolomite: upper middle Unit 3, Section P (same bed as (d) above). Note fragments of coral and a brachiopod or pelecypod.
- h. Local intraformational conglomerate produced by disruption of micritic layers: middle Unit 3, Section P. Lithology is quartz-sandy dolostone. Arrow as previously.

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PLATE 3-27

- a. Cracked and contorted, fine-crystalline dolomite layers grading upward to coarsely intraclastic, quartz-sandy dolostone: part of a channel filling in middle Unit 3, Section G. Scale is in centimetres; arrow shows stratigraphic top.
- b. Closeup of part of (a). Note bent fragments; alteration along early cracks; later, through-going fractures. Scale shows one centimetre; arrow as previously.
- c. Quartz-sandy, fine-crystalline dolostone: upper-middle Unit 3, Section K. Note intraclasts; ripple-marked top. Scale shows centimetres; arrow as previously.
- d. Top surface of specimen in (c), showing mudcracks on the ripple marked surface. Scale as previously.
- e. Peloid limestone with numerous fine, micritic intraclasts and one large, irregularly shaped intraclast: middle Unit 3, Section G. Scale bars show millimetres.
- f. Weakly developed laminoid-fenestral fabric and numerous intraclasts in dark-coloured, fine-crystalline dolostone: bottom twenty feet of Unit 3, Section P. Also note internal sediments (darkest colour) and late-formed fractures.
- g. Part of specimen in (f), showing intraclasts, probable fossil fragments and a sheet crack filled partly (first) by internal sediment (darkest colour). Scale bars show millimetres; arrow as previously. Thin-section, plane light.
- h. Another part of specimen in (f), showing intraclast with probable calcisphere, and fracture filled by quartz (white) and dolomite. Scale bars show millimetres; thin-section, plane light.

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PLATE 3 · 28

- a. A highly intraclastic zone grading upward to well-developed laminoid-fenestral fabric in quartz-sandy, light-grey dolostone: lower-middle Unit 3, Section P. Scale shows centimetres; arrow shows stratigraphic top.
- b. Microscopic dolomicrite intraclasts grading to vaguely defined probable peloids: upper-middle Unit 3, Section K. Scale bar shows one millimetre; arrow as previously. Also note fine quartz grains (white, slightly rounded) and scattered relatively coarse dolomite crystals. Thin section, plane light.
- c. Same specimen as (b), showing weak laminoid-fenestral fabric, scattered quartz grains, small amounts of internal sediment (black), and at least two phases of fractures, one early, connecting fenestrae and one late and wholly cross-cutting. Scale in centimetres; arrow as previously.
- d. Large and small dolomicrite intraclasts in a largely oolitic, quartzose dolostone: middle Unit 3, Section G. Scale bars show millimetres; arrow as previously. Thin section; plane light.
- e. Pellets or peloids and larger, micro-intraclasts revealed by "paper filter" technique in medium-fine to fine-crystalline dolostone. Scale shows 1 mm.; arrow as previously. (Upper-middle Unit 3, Section P.)
- f. Approximately the same view as (e) but without "paper filter." Thin section; plane light; scale and arrow as previously.
- g. Part of Plate 3.28-g but using "paper filter" to reveal pellets across middle of photo. Also note colour grading in internal sediment in sheet crack. Thin section; plane light; paper filter. Scale bars show millimetres.
- h. Dolomitized superficial ooids on rounded quartz grains: upper-middle Unit 3, Section P. Note concentric layering visible in one ooid; penetration of ooid shell by adjacent grain (pressure solution); dark, micrite coatings on ooids and other grains. Scale bar shows one millimetre; thin section; plane light.

PLATE 3·29

a. Same bed as Plate 3.29-h. Note fragment of oolitic coating; micrite coatings on all clasts. Scale bar shows one millimetre. Thin section; plane light.

b. Diagenetically altered quartz-sandy ~~omicrite~~ (now quartz-sandy dolostone): middle Unit 3, Section G. Note sheet cracks and other former cavities floored partly with internal sediment and then filled with spar (now white dolospar). Scattered micritic intraclasts are also visible. Scale shows centimetres; arrow as previously.

c. Part of specimen in (b). Note deformed micrite envelopes; partly radiaxial lining of small spar crystals on insides of micrite envelopes; traces of carbonate silt and pyrite inside the bottoms of envelopes (geopetal); quartz cores which have settled geopetally within their envelopes; breaks or holes in many envelopes, connecting the interiors of adjacent ooids; anhedral, sparry cement filling former aragonitic part of ooids and all other diagenetic voids. Scale shows one millimetre; arrow as previously; thin section, plane light.

d. Another part of specimen in (b). Scale, etc., as in (c).

e. Weathered surface of extremely quartz-sandy dolostone bed containing a "hash" of fossil fragments including horn corals: middle Unit 3, Section P. Scale shows centimetres.

f. Poorly preserved, replaced fossil fragments in quartz-sandy former calcarenite: upper-middle Unit 3, Section P. Note echinoderm fragment with traces of sieve-like texture. Black patches are pyrite. Scale bar shows one millimetre: thin section, plane light.

g. Specimen from same bed as (f), showing large fragments of brachiopod (pelecypod?) shells.

h. Another part of same specimen as (f), showing part of a brachiopod or mollusc shell and unidentified, worn fossil fragments. Also note oolitic coatings on some quartz and carbonate grains; micrite envelopes on most clasts. Scale bar shows one millimetre: thin section; plane light.

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PLATE 3 · 30

a. Assorted replaced fossil fragments, including a probable brachiopod shell: same bed as last of previous plate. Scale shows one millimetre. Thin section, plane light.

b. Worn fossil fragments; same specimen as (a). Also note micrite envelopes; ooids. Scale shows one millimetre; thin section, plane light.

c. Worn brachiopod(?) fragment showing traces of original plicated shell structure: quartz-sandy dolostone, middle Unit 3, Section P. Scale shows one millimetre; thin section, crossed nichols.

d. Worn fossil fragment (bryozoan or coral?): same bed as (c). Scale shows one millimetre; thin section, plane light.

e. Former calcarenite originally composed mainly of sand-sized fossil fragments and a lesser percentage of quartz grains. Original texture revealed in dolostone by the "paper filter" method. Thin section; scale shows one millimetre. Upper-middle Unit 3, Section P.

f. An adjacent part of same thin section as (e), showing that, without "paper filter", only traces of primary structure in one gravel-sized fragment can be seen. Scale as previously; thin section; plane light.

g. Carbonate fragment with probable algal borings, now filled with dark micrite: same bed as (a) and (b). Also note prominent micrite envelopes; quartz grains; diagonally cross-cutting fracture now represented only by a trail of inclusions. Scale shows one millimetre; thin section, plane light.

h. Quartz-silty, micritic clast with tubular structure probably formed by algae: middle Unit 3, Section P. Scale shows one millimetre; thin section, plane light. (Dark blur near centre of photo is due to reflection in microscope tube.)

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h

PLATE 3-31

a. Rounded micritic-looking clast composed largely of minute spheroids (probably algal cells): same thin section as Plate 3.31-h. Light "halo" is due to reflections in microscope tube. Scale shows one millimetre.

b. Enlargement of part of (a), showing probable algal cells. Scale shows one millimetre; thin section, plane light. (Reflection "halo" as in (a).)

c. Flattened imprints of brachiopods in a shaly parting: lower Unit 3, Section G. Scale shows centimetres.

d. Imprints of brachiopods and possibly other fossils: same shaly layer as (c). White carbonate represents former shell material.

e. Possible amphiporid cross-sections in diagenetically altered dolostone: upper-middle Unit 3, Section K. Also note traces of internal sediment (dark) in bottoms of fossil outlines; residual vuggy porosity in some fossil outlines. Scale shows centimetres; arrow shows stratigraphic top.

f. Unidentified horn coral (no internal structure preserved): upper-middle Unit 3, Section K.

g. Faint, curving traces of brachiopod (or pelecypod) shells in medium- to medium-fine-crystalline dolostone: upper-middle Unit 3, Section K. Scale shows one centimetre. (Diagonal N.W.-S.E. scoring is saw marks.)

h. Gastropod(?) fragments in pitted limestone: middle Unit 3, Section G. Scale bar shows one millimetre.

PLATE 3.32

a. Discontinuously laminated, partly bituminous, silty dolostone with a layer where rounded quartz sand predominates: lower Unit 3, Section V.

b. Wavy, locally cross-dipping lamination on weathered surface of very fine-crystalline, argillaceous dolostone: lower Unit 3, Section V. Scale divisions are centimetres; arrow as previously.

c. Polished surface of specimen in (b), showing that lamination is partly disrupted by bioturbation (black specks with bleaching around them, etc.). Two or more phases of fracturing seem to have affected the specimen. Scale shows centimetres.

d. Very fine-crystalline dolostone with discontinuous, wavy lamination and layers where rounded quartz sand is concentrated: lower Unit 3, Section G.

e. Discontinuous, wavy, dark laminae in fine-crystalline dolostone: lower Unit 3, Section G.

f. Cross-lamination in fine-crystalline (silt-sized) dolostone: lower Unit 3, Section G. Scale shows centimetres; arrow as previously.

g. Laterally continuous colour-lamination in very fine-crystalline dolostone: lower Unit 3, Section G. Note fracture with about 0.5 cm. offset in plane of section.

h. Undulating, "tufted" lamination probably produced by blue-green algal activity, covering intraclastic debris which fills a small channel in fine-crystalline dolostone: middle Unit 3, Section G. Note that lowest laminae are interrupted and curled at edges (by desiccation cracking). Also note set of late-formed fractures.

a

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PLATE 3.33

a. Stratiform white dolomite largely following primary lamination in medium-fine crystalline dolostone: middle Unit 3, Section G. Note several white dolomite casts of naturally opposing brachiopod valves. Scale shows centimetres; arrow as previously.

b. White dolomite between primary laminae adjacent to a local breccia "pocket": middle Unit 3, Section G. Scale shows two centimetres.

c. Laminoid-fenestral fabric in dark-coloured, fine-crystalline dolostone: bottom twenty feet of Unit 3, Section P. Scale shows centimetres; arrow as previously.

d. Quartz sand and silt in very fine-crystalline dolostone in a weakly laminoid-fenestral layer (Plate 3.29-c): upper-middle Unit 3, Section K. Note very late horizontal fracture and earlier vertical ones filled with dolomite and quartz. Crystal silt internal sediment levels the bottoms of two former cavities and a probable earlier, "muddy" internal sediment occurs near the centre of photo. The shapes of the borders of several former cavities suggest modification (formation?) by leaching. Scale bar shows one millimetre; arrow as previously. Thin-section, plane light.

e. "Peaked" lamination suggesting algal influence in medium- to medium-coarse-crystalline dolostone: weathered outcrop, upper Unit 3, Section K. Length of hammer point in view is approximately 9 centimetres.

f. Leached bomicrite: middle Unit 3, Section G. Note irregularly shaped former cavities evidently formed largely by leaching and subsequently filled with internal sediment and some spar. (See also Plate 3.30-b, c, d.) Scale bar shows one millimetre, arrow as previously.

g. Superficial mudcracks and rhombic dolomite crystal casts in an argillaceous dolomite film on the top surface of a medium-crystalline dolostone bed: lower to lower-middle Unit 3, Section Y. Scale shows centimetres.

h. Mudcracks in an argillaceous parting in microcrystalline limestone: middle Unit 3, Section G.

PLATE 3.34

3.35

- a. Blackened and desiccation-cracked top surface of a coarsening-upwards dolostone layer: upper-middle Unit 3, Section K. (See Plate 3.21.)
- b. Ripple-marked bed surface: middle Unit 3, Section K.
- c. Weathered surface of "wormy" bioturbated dolostone, base of Unit 3, Section P.
- d. Polished section through a bioturbated specimen like that in (c). Limonite outlines burrowing patterns.
- e. Probable feeding burrow patterns spreading within thin layers: upper-middle Unit 3, Section K.
- f. Uneven, crudely bedded aspect of bioturbated thin beds: upper-middle Unit 3, Section K.
- g. Virtually complete destruction of lamination by bioturbation (left), grading to partially disrupted lamination at right: upper-middle Unit 3, Section K.
- h. Cut surface of bioturbated specimen in which a few traces of primary layering remain: upper Unit 3, Section K.

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PLATE 3·35

- a. Bioturbated dolostone which retains a considerable amount of lamination: lower Unit 3, Section G. Dark flecks are limonite stain.
- b. Downward sand-injection structure in a dolomitic sandstone layer found between laminated, sandy dolostone layers intervening in a thick-bedded dolostone section: upper Unit 3, Section K.
- c. Diagenetic features in part of a weakly laminoid-fenestral layer: upper-middle Unit 3, Section K. Note former cavity containing formerly micritic internal sediment (1) covered by crystal silt internal sediment. Both sediments and host are cut by a fracture with spar filling apparently continuous with spar filling the top of the cavity. Scale bar shows one millimetre; arrow as previously. Thin section, plane light.
- d. Two phases of internal sediment in weakly laminoid-fenestral very fine-crystalline dolostone: lower Unit 3, Section V. Sequence of sediments and cement is visible at right centre in leached cavity or burrow: light-coloured, micritic internal sediment, then dark-coloured crystal silt, covered by sparry cement (now dolospar). Also note stylolite; set of late, hairline fractures in almost the same orientation as internal sediment-filled early fracture. Scale shows 2 centimetres; arrow as previously (approx.).
- e. Partially dolomitized, microcrystalline limestone with former cavities with radiaxial linings, filled with crystal silt: lower to lower-middle Unit 3, Section P. Dolomite: white to light grey; limestone: medium grey; internal sediment: black. Polished surface etched in HCl. Scale shows centimetres; arrow shows stratigraphic top.
- f. Part of a silt-filled cavity in specimen shown in (e). Note laminated internal sediment; dolomite pseudomorphs of projecting calcite spar crystals bordering silt (lower right); slightly darker coloured, dolomitized host rock; remnants of calcite spar (lower left). Thin section; plane light; left half stained with alizarin red. Scale bar shows one millimetre; arrow as previously.
- g. Detail mostly in lower left corner of (f). Calcite spar (black), partly as scalenohedra projecting into the granular crystal silt (now dolomite); coarse dolomite mosaic of replaced host rock. Scale bar shows one millimetre. Same thin section as (f), plane light.
- h. Flat-topped internal sediment filling most of a sheet crack in laminated dolostone: middle to lower Unit 3, Section P. Scale shows centimetres.

a

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PLATE 3-36

- a. Typical zebra structure with residual porosity in white "layers": upper Unit 3, Section K. Scale shows centimetres; arrow as previously.
- b. Coarsening-upwards zebra structure cut by early and late fractures: middle to upper Unit 3, Section K. Scale shows centimetres; arrow as previously.
- c. Zebra structure in intraclastic, calcarenitic dolostone: upper Unit 3, Section P. Scale shows centimetres; arrow as previously.
- d. "Layered zebra" structure in fine- to medium-fine-crystalline dolostone: upper-middle Unit 3, Section G.
- e. Interlaminated host dolomite and secondary, white dolomite, grading to a texture resembling zebra structure: upper Unit 3, Section K. Also note vugs in probable fossil molds and in white dolomite bands. Arrow shows stratigraphic top.
- f. Another interlaminated specimen: lower Unit 3, Section G. Shape of white dolomite lens at upper right suggests replacement of nodular anhydrite.
- g. Coarse, zebra-like upper part of a cyclical, coarsening-upwards dolostone layer: middle Unit 3, Section K. Host rock is black to dark grey. Scale shows centimetres, arrow as previously.
- h. Host dolomite crystallinity in specimen in (g). Also note early fracture visible only as trail of clear dolomite across the coarse crystals. Scale shows one millimetre; arrow as previously.

PLATE 3.37

- a. White dolomite interlaminated with host rock; traces of primary lamination at bottom: 10 inches below location of Plate 3.37-g, h-same layer. (See Plate 3.21-b) Scale at bottom shows centimetres; arrow as previously.
- b. Host-rock crystallinity in (a): same scale as Plate 3.37-h. Note stylolite and finer crystal size than Plate 3.37-h.
- c. Fine crystalline, laminated dolostone: 9 inches below location of (a) - same layer. Scale shows one centimetre; arrow as previously.
- d. Crystallinity in (c): same scale as (b) and Plate 3.37-h.
- e. Early diagenetic effects in a weakly laminoid-fenestral, quartz-silty and sandy bed: upper-middle Unit 3, Section K. Note crystal silt in bottoms of fenestrae probably modified by leaching; narrow passage joining upper fenestra to adjacent fracture; fracture split into smaller, irregular cracks at bottom of large fenestra; spar fillings (now dolospar) of fenestrae and fracture appear continuous and single-phase. Scale bar shows one millimetre; arrow as previously.
- f. Partly quartz-filled fracture which cut through, then around (or vice versa?) a quartz grain (centre) and resulted in idiomorphic dolomite facets against quartz (at left). Scale shows one millimetre. (Upper Unit 3, Section P.)
- g. Early and late fractures in pellet-intraclast limestone: middle Unit 3, Section G. Scale marks at lower left show two millimetres.
- h. Filled fractures causing double-image effect due to break-away of micrite envelopes from clasts: upper-middle Unit 3, Section P. Scale bar shows one millimetre. Arrow indicates fragment broken away with envelope, from clast at right.

a

b

c

d

e

f

g

h

PLATE 3-38

a. Re-opened fracture cutting large dolomite crystal (near centre) and host micritic limestone: lower to lower-middle Unit 3, Section P. Note granular, probable internal sediment (dark) in fracture; authigenic quartz crystals (white) and dolomite (lighter grey than limestone) scattered in limestone. Scale bars show millimetres; arrow as previously.

b. Well-developed stylolite in very fine-crystalline dolostone: lower Unit 3, Section G. Arrow as previously.

c. Light coloured, fine-crystalline dolostone with an abundance of rounded quartz sand: lower Unit 3, Section G. Note stylolite. Arrow as previously. (Faint N.W.-S.E. scoring is traces of saw marks on partly polished surface.)

d. Pseudobreccia texture: upper Unit 3, Section K.

e. Quartz crystals (white) projecting into former cavity filled with quartz and dolomite debris: upper to upper-middle Unit 3, Section P. Polished surface, slightly etched and heavily stained with potassium ferricyanide-alizarin red mixture. Scale shows centimetres; arrow as previously.

f. Stained acetate peel from lower left part of (e), showing fine, crushed-looking quartz and dolomite debris and severely fractured state of large quartz crystals projecting from host dolomite. White areas are faults in peel. Scale bar shows one millimetre; arrow as previously.

g. White dolospar and light grey, microcrystalline, internal sediment in disrupted top of the coarsening-upward layer shown in Plate 3.21-a. Host dolostone fragments are black to very dark grey.

h. White dolomite interlaminated with fine-crystalline host dolostone, including cross-lamination: upper-middle Unit 3, Section K. Note probable internal sediment (dark coloured) flooring white dolomite lenses at bottom right. Scale shows centimetres.

a

b

c

d

e

f

g

h

UNIT 4

Field Characteristics

The thin, uppermost carbonate rock unit in the Devonian section is poorly exposed in the study area. It is mostly medium- and thin-bedded and contains both limestone and dolostone (Figs. 2-5, 3-9, 10, 11 and Plates 3.40; 3.41-a, b). The arithmetic mean bed thickness is approximately one foot and the range of thicknesses is considerably less than in Units 2 and 3 (Appendix IV).

Although it is not immediately obvious (Plates 3.40-a, d), there is clear evidence for an unconformity of considerable significance between Units 3 and 4 (page 3-254). In the eastern part of the property, dark grey dolostone and calcareous dolostone make up the bottom five-to-fifteen feet of Unit 4 (Plate 3.40-b). This dolostone is succeeded upward by a laterally varying thickness of limestone, which is predominantly medium and dark grey and micro-crystalline (Plate 3.40-c; 3.41-a). The greatest thickness of continuous limestone found is about 60 feet (Section E, Fig. 2-5

and Fig. 3-11). Above this, the rest of the unit is dark grey, mostly medium-crystalline dolostone, with small remnants of limestone in the middle part of the unit at some locations (Sections E, J: Figs. 3-10, 3-11). In the east-central part of the property (Sections J and K, Figs. 3-9, 3-10), the upper half of the unit contains many beds with zebra structure and/or local brecciation and much white secondary dolomite (Plates 3.46, 3.52). There are also a number of biostromal horizons in the upper and middle parts of the unit (Plates 3.45-f; 3.46-a, b, c). Farther south (Section E, Fig. 3-11) these parts of Unit 4 contain less white dolomite and fewer fossils and they have a more massive aspect. The uppermost three or four feet of Unit 4 are thin-bedded, argillaceous and very dark-to-black coloured dolostone interbedded with shaly dolostone or dolomitic shale (Sections J and K: Figs. 3-9 and 3-10).

Aside from the eastern outcrops just described, only two small exposures probably belonging to Unit 4 were encountered. One of these can be assigned with considerable confidence to Unit 4 on the basis of lithologies as well as stratigraphic position. It outcrops for 4 to 5 stratigraphic feet, only six stratigraphic feet above the topmost exposure of Unit 3 at that locality (Section H, top: Figs.

2-5, 2-6, 3-5). The beds exposed closely resemble the middle and upper-middle parts of Section J (Fig. 3-10) although preservation of fossils and other primary features is poorer.

The other exposure is a very poorly exposed band of stromatopod-rich, dark-coloured rocks grading from biolithites (Folk, 1962) to poorly sorted, partly rudaceous calcarenites. This string of outcrops occurs along the top of the well-exposed upper part of Unit 3 at and near Location S (Fig. 2-6).

Both of these exposures of somewhat uncertain affinities are discussed further on page 3-251 .

At the top, Unit 4 grades rapidly upward to conformably overlying shale of the Besa River Formation (Plate 3.41-c).

Petrography

Minerals.

Calcite

Calcite forms nearly 100% of the rock in pure, non-sandy limestones and is entirely absent in most dolostone beds. A few dolomitic limestone layers do occur (e.g., Plate 3.42-a, b). Appendix I, Tables 23-27 show percentage compositions of representative samples from Unit 4.

A wide range of calcite crystal sizes is present in all samples, partly because of diagenetic effects. Most limestone beds are microcrystalline. In these, micrite is far more abundant than coarser calcite (Appendix I, Table 23), but a continuous range of crystal sizes up to 0.15 mm or more exists in representative samples. A secondary size mode may exist at about 0.05 mm in some samples (Appendix I; Table 28). In rare calcarenitic layers (Plate 3.42-a; 3-43-f), micrite is minor and an even wider crystal size range exists than in microcrystalline limestones (Appendix I, Table 29).

TABLE 3-11

Insoluble Residues - Unit 4: Percentages Contained and
Descriptions for Representative Specimens

Specimen No. and Lithology	Weight % Insol. Res.	Descriptions
K-13 (Upper dolostone)	1.9	Mainly fine to very fine quartz sand, minor silt, very bituminous.
E-30 (Limestone)	1.9	Silt, lesser sand, minor clay, much finely divided bitumin.
E-34 (Dolomitic limestone)	1.4	About 55% silt and 45% quartz sand with overgrowths, little bitumin.
E-23 (Upper dolostone)	0.9	About 95% silt; minor coarser quartz, mainly sand-sized; most quartz looks secondary. Bituminous coatings on residue.
K-16 (Upper dolostone)	0.5	Mainly quartz sand, minor silt and clay, trace pyritomorphic hematite and unidentified heavy mineral.
K-3 (Upper dolostone)	0.5	About 60% sand and 40% silt. Trace pyritomorphic hematite. Sand-sized quartz may be partly secondary.
E-27 (Upper dolostone)	0.07	Subequal amounts of quartz sand grains and silt. Trace pyritomorphic hematite.

TABLE 3-12

Dolospar Zoning Patterns - Unit 4

Specimen:

E-23

E-27

Slightly ferroan
"host" with inclusions

Slightly ferroan
"host" with fine inclusions

Slightly ferroan
coarse, clear dolomite
interlocking with host.

Thick overgrowth with
numerous fine inclusions.

Sharply defined band of
very numerous submicro-
scopic inclusions.

Clear dolomite zone with
an Fe-rich band in it.

First dolospar, slightly
more ferroan and slightly
coarser than host. Contains
numerous submicroscopic
inclusions, many with vague
borders (bitumin?).

Coarse, less ferroan dolospar
as overgrowths and interlocking
new crystals. Abundant
bituminous and minor pyrite
inclusions as well as submicro-
scopic opaques.

Thin zone of clear overgrowths
with a very thin Fe-rich band
in it.

Microspar is most commonly found within fossil outlines and other (unidentified) sharp-bordered, sparry shapes rather than replacing the micrite matrix, although one bed studied does contain typical inter-pellet microspar (Plate 3.43-h).

The occurrences of sparry calcite and calcite silt are as described for the limestones of Unit 2 (page 3-72).

Dolomite

More than half of Unit 4 is composed of dolostone. Insoluble residues of randomly selected samples show that most dolostone beds are more than 98% pure (Table 3-11).

The dolostones of Unit 4 are characteristically medium-to-medium-fine crystalline. A sample from near the top of the Unit representative in this respect, has a mean crystal size of about 3ϕ (0.12 mm) and sizes ranging from 0.01 mm to 0.5 mm (Appendix I, Table 30). Many beds also contain lenses, pockets and fracture-fillings of medium-coarse and coarse white dolomite similar to that described for Units 1 through 3.

As in the other units, a mosaic of more-or-less equant crystals (granoblastic-polygonal to idiotopic: Spry, 1969, p. 6, 160-161) predominates in the dark dolomite of most beds in Unit 4, Plate 3.42-d. However, some layers, particularly bituminous and pyritic beds near the top of the unit, have a more sucrosic texture, with many rhombic or partially rhombic crystals (Plate 3.42-e).

The dark colour of Unit 4 dolostones may be partly due to the numerous submicroscopic opaque inclusions within the crystals but it probably results mainly from abundant intercrystalline opaques. (See "Bitumen" and "Pyrite", page 3-222 and 3-225).

White dolomite in Unit 4 is zoned as described for the units below (page 3-27). Table 3-12 shows zoning patterns observed in thin sections from Unit 4.

Dolomite crystals of microspar and spar sizes occur in partially dolomitized limestones, where they evidently replace pre-existing calcite and occur mainly in areas of sparry calcite rather than in micrite in most samples (Plate 3.42-a, b, g). However, an unusual, crudely laminated sample from 90 feet below the top of Section E contains dolomicrite grading to micrite, as well as silt-sized

dolomite which is apparently partly a product of replacement and partly an internal sediment (Plate 3.42-h).

Dolomite in pyritic, shaly siltstones (page 3-246; 3-256 is ferroan.

Quartz

Quartz sand and silt are abundant in a few beds in Unit 4 but are absent in many. Traces of detrital quartz can be seen in thin-sections from all parts of the unit, including the topmost bed, but amounts greater than 1% are restricted to parts of the lower half of the unit (Figs. 3-10, 11) and quartz grains in thin-sections from above the middle of the unit are invariably silt-sized.

Maximum size and size sorting of quartz grains varies widely. Quartz is well-sorted in (rare) calcarenites (Plate 3.42-a; Appendix I, Table 31); moderately well-sorted in some microcrystalline limestone beds (Plates 3.42-g; 3.47-d, g; Appendix I, Table 32), and poorly sorted in a few fine-grained, clastic-looking, pyritic dolostone layers (Plate 3.43-c and Appendix I, Table 33) and in

certain pyritic beds whose proper classification ranges from greywacke to silty shale (Plates 3.44-b, c, e). A bimodal quartz-grain size distribution is evident in an unusual, light-coloured, porous, dolomitized calcarenite sample from the middle of the unit in Section E (Plate 3.44-d).

Point-count roundness values for quartz grains in sandy layers cover a fairly wide range, although angular sand grains are not found. The most nearly angular sand grains occur in the greywacke (sandy shale) layers (Plate 3.43-c). In other sandy beds mean roundnesses lie in the subrounded or rounded ranges (Appendix I, Tables 34-35), but roundness is difficult to estimate in many samples particularly in the case of the smaller grains, due to authigenic overgrowths. It is probable that true mean roundness is somewhat higher than the counts indicate and that the true range of roundness in many samples is considerably less than the counts indicate.

Visual estimates indicate that quartz sand in Unit 4 is not characterized by a particularly high sphericity. A fairly wide range of sphericities, with a moderate mean sphericity, seems characteristic (Plates 3.43-d, f; 3.47-g).

Silt-sized, detrital quartz has a roundness ranging from angular to rounded and is commonly subangular-to-subrounded. However, overgrowths are even more difficult to recognize in the silt-sizes and many grains cannot even be definitely identified as detrital (Plates 3.42-g, h; 3.43-e, h). A wide range of sphericities exists in the silt sizes.

Overgrowths are very common (Plates 3.42-a; 3.43-d, f, g, h; 3.44-a), although in some specimens slight embayments and stylolitic borders against dolomite occur as well. Overgrowths range from thin "rims" nearly or entirely indistinguishable from the detrital grain except for their irregular outline (Plate 3.43-f, g) to large, asymmetric extensions conforming to adjacent dolomite crystal facets (Plate 3.43-d) or projecting idiomorphically into cavities. All of these forms of overgrowth can be found in a single thin-section. In one thin section an apparent rounded overgrowth occurs (Plate 3.43-f). None were recognized elsewhere.

Dolomite or calcite inclusions are present in overgrowths in a few samples (Plates 3.42-a; 3.43-e, h; 3.44-a). Submicroscopic inclusions are common but not abundant in most detrital quartz grains (Plate 3.43-f, g). A small tourmaline inclusion was identified in one grain.

Quartz crystals are found in some vugs in Unit 4. This occurrence is the same as described for Unit 3 (page 3-149).

Muscovite and Clays

No phyllosilicate minerals are visible in thin-sections from Unit 4 except in certain argillaceous and quartzose layers in the middle and bottom parts of the unit (Fig. 3-10: -60 feet, -100 feet, -125 feet; Fig. 3-11: -102 feet). It is possible that small amounts of fine sericite or clays escaped notice in the dolostones and limestones, although a careful search was made. Insoluble residues from a random selection of limestones and dolostones are composed mostly of quartz sand and silt, and bitumen, although a small amount of clay-sized material appears to be present in a few cases. Insoluble residues are small, in any case (Table 3-11).

In a few shaly sandstone and sandy shale layers present, extremely fine-crystalline sericite is common-to-abundant (Plates 3.43-c; 3.44-b, c). Where abundant, the sericite has a preferred orientation parallel to bedding and often an undulating pattern evidently due to compaction around sand grains. Occasional small, randomly oriented crystals of authigenic muscovite occur in some of these beds.

In the one bed where extensive overgrowths on quartz grains form a relatively pure quartzite, sericite is mostly distributed along crystal contacts but some is included in the outer parts of crystals (Plate 3.44-a).

Pyrite and Marcasite

Pyrite is a very common accessory mineral throughout Unit 4 and in certain parts of the unit the mineral is abundant (Figs. 3-10, 11). Marcasite crystal forms were found in a poorly exposed, pyritic gossan adjacent to Section J (Plate 3.44-d), but X-ray diffraction patterns show that the material is now entirely pyrite.

In most of the dolostones and limestones of the unit, pyrite occurs as occasional specks and small aggregates both in cavity fillings and in the host rock (Plates 3.42-c, e; 3.43-f; 3.44-b, c, e). Some pyrite crystals are commonly idiomorphic. The outer parts of pyrite crystals in some samples have been altered to hematite and a yellowish-brown limonite stain is often present in surrounding dolomite or limestone.

Many beds in the top five feet of Unit 4 are very pyritic (up to 10% pyrite or more, ~~by~~ volume). However, the pyrite is so finely disseminated and so intimately associated with large amounts of bitumen that it cannot be seen in hand specimens from these beds (Plate 3.42-e, f). Both pyrite and bitumen are intercrystalline in most beds but pyrite is also concentrated in the tests of probable tentaculitids in one bed (Plate 3.49-c, d).

Lower in Unit 4, several thin-bedded-to-shaly layers rich in pyrite are present in Section J and the lowermost beds exposed are pyritic (Fig. 3-10). Lenses and small aggregates of fine-crystalline pyrite are visible in hand specimens from some of these beds but in other beds there is only an iron-stained surface or no visible evidence of pyrite. Thin-sections from hand specimens with little or no visible pyrite contain from one to twenty per cent pyrite by volume (see Plates 3.43-b, c; 3.44-b, c, e). Bitumen is minor or absent in most of these beds. The pyrite occurs as scattered-to-clustered idiomorphic crystals and (where most abundant) as massive aggregates with a granular texture (Plates 3.44-c, e). In very pyritic samples, lenticular-to-elliptical or spherical concentrations of pyrite can be discerned (Plate 3.44-e). These may represent burrows and/or replacements of organisms. The pyrite replaces

sericitic matrix, dolomite and quartz but where all these minerals are present, dolomite seems to be preferred.

Sphalerite and Galena

Traces of both sphalerite and galena were found in the cores of white dolomite fillings of a few fractures and possible dissolved patches in the upper and middle parts of Section J (Plate 3.54-d and page 3-242). The only other occurrence of these minerals encountered in Unit 4 is in a small, brecciated, poorly exposed, streambed outcrop of dark dolostone approximately at the base of the limestone part of Section E (Fig. 3-11). Here, sphalerite and galena are very abundant locally, both in white dolomite and apparently replacing dark dolostone. A somewhat similar, though less concentrated, occurrence was found by others in fractured dark dolostone higher in the unit, close to Section E ("Showing Number 9" of the writer's field report to the Robb Joint Venture).

Bitumen (and other organic residues?)

Bitumen is very abundant as an intercrystalline "matrix" in the top 5 feet of Unit 4 (Plate 3.42-e). Lower down, much smaller amounts are prevalent as coatings along crystal boundaries in the dolostones and as scattered specks and along stylolites in micritic limestone. Vugs in dolostones often contain hard pyrobitumen like that described for Units 2 and 3 (Plates 3.44-f, g). In many dolostone specimens, crystals have numerous submicroscopic inclusions which may be bituminous.

Occasional late remnant voids in fractures in limestone also contain bitumen fillings (Plate 3.44-h). Most of the insoluble residues obtained from Unit 4 samples contain considerable amounts of very finely divided bitumen (Table 3-11).

Although large amounts of bituminous matrix often have associated pyrite, bitumen is much more widely distributed throughout the unit than pyrite and is more highly correlated with dark colour than pyrite (Appendix II, Table 3). For these reasons, it seems certain that the dark colour of most of Unit 4 is due to abundance of bitumen, rather than to pyrite.

Hematite

As well as the altered outer parts of pyrite crystals in one sample (page 3-222), pyritomorphs entirely, or almost entirely, composed of hematite occur in one relatively porous dolostone sample from the upper part of Section E (Fig. 3-11: -50 feet). Except for these occurrences, no hematite was identified in Unit 4.

Unidentified Minerals

Aside from stains probably of organic and pyritic origin (bituminous(?) and limonitic), the only unidentified mineral noted in Unit 4 is a transparent, isotropic, crystalline mineral with relatively high relief which occurs in some abundance in one of the shaly sandstone layers (Fig. 3-10: -100 feet) and was not found elsewhere.

Allochems.

Intraclasts

Small intraclasts of micrite or pelmicrite composition are common in thin-sections from several limestone beds in Unit 4 (Plate 3.45-c). They have also been recognized in dolostones from the upper part of the unit where primary textures are unusually well-preserved as inclusion patterns in Section K and tentatively also in Section J (Plate 3.45-e). The intraclasts are generally scattered among much more abundant pellets and their longest dimensions rarely exceed 3 mm.

② Locations of intraclasts identified in thin-sections are shown on the detailed section logs (Figs. 3-9, 10, 11). No other intraclasts were found in Unit 4.

Pellets and Peloids

Many, though not all, of the microcrystalline limestone beds in Unit 4 are composed mainly of recognizable pellets or peloids

(Plates 3.43-h; 3.44-h). Bioturbation may have destroyed an original pelleted texture in apparently unpelleted micrites (Plates 3.42-g; 3.47-e, g, and page 3-237). Pellets or peloids were also the principal primary constituent of many beds in the upper part of the unit. They have been identified by a special microscope technique (page 1-15), in several dark-grey dolostone beds in Section K, and also in similar beds in Sections J and E (Plate 3.45-a, e). It seems likely, in view of the similarity in colour, crystal size, composition, macrofossil content and other textural features that the bulk of the upper part of the unit in all of these localities also originated as pelleted mud.

In microcrystalline limestones, pellets are commonly of the typical shape and size range (as described for Unit 2, p. 3-75). However, there is a gradation to a predominance of more angular and irregular "peloids". The latter appear to be the most common form in the dolostones.

Fossils

The variety of fossils, whole and fragmentary, occurring in Unit 4

can be divided into two groups:

1) intact fossils preserved at or near their place of origin and readily visible in hand specimen or outcrop, in the upper and middle parts of the unit; 2) delicate fragments showing no wear, found scattered in some microcrystalline limestone beds. In addition to these two groupings, sand-sized fossil fragments are found associated with group 1 and in isolated beds, and Tentaculites is abundant at the extreme top of the unit. The restriction of group 2 occurrences to limestones, and thus to the middle and lower parts of the unit, may be at least partly an artifact of preservation, since these very fine and delicate fragments apparently leave no traces after dolomitization.

Group 1 fossils include at least two kinds of cylindrical corals as well as bulbous or domal, to cylindrical and ramose stromatoporids. One kind of coral (Plate 3.46-a, b) is colonial and may belong to the genus Thamnopora which is known from Devonian rocks farther north and south (McLaren, et al., 1962, Plate III:9,10; Plate VI:7). The genus Thamnopora, is known to range from the Silurian through the Permian periods (Hill & Stumm, 1956, page F464).

The other coral recognized is a solitary tetracoral. In transverse

and longitudinal sections (Plate 3.45-f, g), the size, shape and internal structure of this coral closely resemble the genus Dendrostella, c.f. Dendrostella trigemma (Quenstedt), reported by Pedder (1964, p. 434; Plate 62:1-11) from the Middle Devonian Hume Formation of the Northwest Territories. Another species of Dendrostella has been reported from the Middle Devonian Nahanni Formation (McLaren, et al., 1962, Plate II:1,2). Both of these formations are approximately correlative with Unit 4 (the Dunedin Formation) - (Taylor and Stott, 1973, p. 20; and page 2-9, this thesis). The writer has found Dendrostella reported only from Middle Devonian rocks. However, the genus may extend through both the Eifelian and the Givetian Stages (Pedder, 1971, page 64).

At least one other probable coral occurs in some places, although it is less common than those described above (Plates 3.45-f, g; 3.46-a, b). No specimens adequately preserved for satisfactory identification were found.

The stromatoporids, although abundant, are so poorly preserved that identification of types by means of internal structure is impossible. Only rarely are any traces of internal layering or pillars visible (Plates 3.45-d, f; 3.46-a, b, c).

Most of these fossils are intact and none appear worn. Elongate specimens are most commonly oriented approximately parallel to bedding but a few generally have other orientations. In some cases, entire thin beds are uniformly rich in fossils but, in most cases, the fossils are concentrated in layers within beds, distinct from the rest of the rock only in the presence of many fossils (Plate 3.45-f). There may be an abrupt transition to rock lacking megafossils or a more gradual decrease in abundance of fossils.

At Section K, where bedding is thicker than in the upper part of Section J (Figs. 3-9 and 3-10), solitary "stick corals" (c.f. Dendrostella) occur most commonly at or near the tops of beds (Plate 3.45-f), in some cases in distinct bands which can be followed as far as the beds are exposed (175 feet in one case) and in other cases grading back-and-forth from absent to abundant laterally along a constant horizon. In several beds a sequence of layers occurs, with non-fossiliferous dolostone, commonly with patches of zebra structure, grading upward to a layer containing Thamnopora-like corals and/or numerous but not closely spaced stromatoporids (or "Thamnopora" may grade upward or downward to stromatoporids). This gives way upward, sometimes with interspersed zebra patches, to an uppermost, thin layer densely populated with Dendrostella-like corals.

Scattered crinoid columnals can be seen in some of the fossil-rich beds. Moreover, where primary microtexture is unusually well-preserved (page 3-251), the dolostone of the macrofossil-bearing beds can be seen to have originated partly as a fine, fragmental lime sand with a muddy and bituminous matrix and partly as a slightly fossiliferous and intraclastic peloid sediment. The fragmental sand is composed mostly of rather angular fossil fragments, many of which were probably monocrystalline echinoderm debris (Plate 3.47-a). The minor constituents identified are: a worn amphiporid skeleton, echinoid spines and occasional curving, thin shell fragments which may be of mollusc, brachiopod or even ostracod origin. (These details of the primary texture can be seen only with a special microscope technique devised by the writer (page 1-15). Little of the primary texture of these rocks would be seen in an ordinary microscopic investigation.)

In addition to the fossil-fragment sands just described, a few relatively light-coloured beds in the southernmost section (Fig. 3-11, about -73 to -80 feet) contain numerous well-worn fossil fragments of uncertain affinities. Occasional fossil fragments are recognizable in outcrop or hand-specimen in these layers but most are not. This part of Section E is also rich in quartz sand (15 to 30% quartz in

representative samples). Fossil fragments and intraclasts in varying percentages make up the rest of the framework. There is little evidence of micritic matrix, although extensive diagenetic alteration, including complete or partial dolomitization, makes it impossible to prove that these rocks lacked primary matrix. Plates 3.42-a; 3.43-f show a fine-grained, partially dolomitized example with well-worn, tabular fragments outlined by micrite envelopes and/or micritized exteriors. Some of the numerous micrite clasts in this sample may be micritized fossil fragments (algal plates?) as they often have a tabular shape like the coarser-crystalline (leached?) fragments. An entirely dolomitized bed contains at least a few relatively large brachiopod or mollusc fragments. The primary texture of this specimen is extremely poorly preserved (Plate 3.47-b).

The second major type of fossil occurrence (as scattered fragments in microcrystalline limestones) includes ostracod, trilobite and echinoid fragments, together sometimes forming as much as 5% of rock volume according to point counts (Plates 3.47-e, g; 3.48-a, b, c, e). Ostracod shells are commonly broken but some are intact and a rare few are articulated. Whole ostracods range from about 0.2 to 0.5 mm in longest dimension of cross-section in the thin section where they are most abundant (Plate 3.47-e). Trilobite parts are thin and delicate

and invariably occur as broken fragments, although they are thicker and generally somewhat larger than associated ostracods (Plate 3.47-g). Trilobite fragments can be seen as tiny black pieces in some hand specimens and a few larger fragments can be partly exposed by breaking the rock (Plate 3.48-a). Some trilobite fragments are riddled with borings (Plate 3.48-e).

Echinoid spines, some of them clearly derived from cidaroid echinoids, are scattered in several beds sampled (Plates 3.42-g; 3.47-g; 3.48-b). Partly corroded, monocrystalline fragments probably derived from echinoderms are also found.

Trace amounts of small gastropod fragments and delicate, probable pelecypod or brachiopod fragments occur in some microcrystalline beds, as well as a number of minute, unidentified forms (Plate 3.48-c, d). Such fragments are very rarely larger than 0.4 mm in longest dimension.

Fossil fragments are by no means uniformly abundant throughout the microcrystalline limestone parts of the unit. Plates 3.43-e, h; 3.48-d, showing "random" (regular interval) samples, are most representative of the limestones, as a whole.

A single microcrystalline limestone bed contains abundant fragments of bony fish skeletal plates (Plates 3.48-f, g, h; 3.49-a). These fragments are black and up to more than 2 cm long, so that they are noticeable in outcrop surfaces. For this reason, the one layer seen (Section J: Fig. 3-10, -119 feet) is probably the only one in the section which contains fish fragments. The fragments are now apparently composed entirely of collophane and can be removed from the limestone by acid treatment (page 1-13) but the small, broken and scattered fragments obtained do not appear to be diagnostic of a particular genus of fish.

At the extreme top of Unit 4, within a foot or two of the topmost dolostone, a thin layer in Section K (Fig. 3-9) is composed of tentaculitid tests in a matrix of bituminous, argillaceous dolostone. The tests are well displayed on numerous bedding partings in the rock. A bituminous dolostone layer from the same level in Section J (Fig. 3-10) contains white specks of the same size as the tentaculitid tests (Plate 3.49-b). In thin section, the typical conical shape can be deduced from various individuals (Plate 3.49-c, d). In this bed, the fossils form at least 30% of the rock (point count volume percent), although they are so poorly preserved as to be barely recognizable.

Textural and Structural Features.

Lamination

Internal lamination is uncommon in the beds of Unit 4. The top part of a dolostone bed at minus 56 feet in Section J is faintly laminated (Fig. 3-10) and a single thin, planar bed of microcrystalline limestone has a planar, textural lamination visible in polished surfaces and thin sections but not in the field. This lamination is due to differences in packing of the pellets forming the framework of the rock and variations in the amount of spar and microspar v.s. micrite matrix.

In the lower-middle of Section E, irregular lamination is present in parts of a sample (Plate 3.43-a), due to variations in mineral and particle composition (dolomite v.s. calcite, amount of bitumen, amount of pellets, amount of microspar, etc.). This specimen has several extremely bituminous layers containing quartz silt and other grains (Plate 3.49-e). These may represent algal mats. A micro-unconformity can be seen in the same sample (Plate 3.49-g and page 3-248).

Mudcracks

Well-developed mudcracks were found at one place in Unit 4 (Fig. 3-10: -65 feet; Plate 3.46-d). There are also early-formed, vertical or near-vertical cracks within certain beds, which were probably formed by desiccation. (See "Internal Sediments", page 3-238, "Zebra Structure", page 3-240, and "Fractures", page 3-244.) In at least one case, other textural features strongly support such an origin (Plate 3.49-e, g and see page 3-248).

Bioturbation

The tubular burrowing patterns common in Unit 3 do not occur in Unit 4. However, there is abundant evidence of bioturbation in fossiliferous and quartz-silty micrite beds. Fossil fragments are scattered at random and in all orientations in these beds, and, although almost invariably broken, the fragments are not worn (Plates 3.47-e, g; 3.48-b, c, e; 3.49-a). Delicate pieces of thin shells, which would not survive wave or current action, are common. Also, quartz silt is scattered inhomogeneously in random patches

and streaks typical of some modern bioturbate sediments (Fig. 3-6 and plates just referred to). Moreover, no lamination or any primary indication of bedding orientation is preserved within these texturally isotropic layers.

Distinct evidence of burrowing is also present in a dolomitized calcarenitic bed, in the form of tight, spherical (cylindrical?) clusters of quartz silt and fine sand among relatively evenly scattered, larger grains (Plate 3.49-f).

Internal Sediments

Small former cavities filled partly with silt-sized internal sediment are common in the microcrystalline limestone beds of Unit 4. They closely resemble the internal sediments described for Unit 2 (page 3-54) except that they are composed of calcite. The sediments commonly occur in irregularly shaped former cavities which are elongate parallel to bedding, perpendicular to it, or at other orientations (Plates 3.49-a; 3.50-a, b, c). Where early deformation has occurred, internal sediments can be found in early-formed, short, irregular cracks (desiccation cracks?--Plate 3.50-a, b).

A somewhat discontinuous row of fine, prismatic-to-blocky calcite crystals projects irregularly from upper surfaces of most internal sediments into the coarser spar above (Plate 3.50-b, c). A similar lining is sometimes distinguishable along cavity walls above the sediment. In some cases, there is evidence of deposition and then removal of parts of sedimentary fillings before the precipitation of this coating (Plate 3.50-c).

Occasionally, fractures (desiccation cracks?) or vertically elongate former cavities can be seen containing pellet sediment similar to the surrounding rock but with more, or less, intergranular spar or microspar (Plate 3.50-d,g). Also, a few fossil chambers and unidentified spar-filled shapes are partly filled with micritic sediment which probably has a very early post-depositional origin (Plates 3.48-b; 3.50-c).

Internal sediment can also be observed in some dolostone beds in the upper part of the unit. There, it generally occupies former (early?) secondary voids both lined and finally filled with white dolomite (Plate 3.50-e).

Zebra Structure

In Unit 4, as below, zebra structure is quite common. Its essential features are as described previously (page 3-57). Zebra structure in Unit 4 tends to contain less planar dark layers, with less uniform thicknesses, than that lower in the section. There is also a tendency toward relatively small patches of coarse zebra pattern ending abruptly in uniform, dark dolostone, rather than the finer layering in Units 2 and 3 that often fades in and out quite gradually. (Compare Plates 3.46-a, b, c; 3.50-f; 3.51-a; 3.52-a; 3.55-c, d, with illustrations of zebra from Units 2 and 3.)

Layered zebra (page 3-177) was not seen in Unit 4.

At a locality where primary texture is unusually well preserved, well developed zebra structure (Plate 3.51-a) can be seen to have formed in a clastic, fragmental limestone with a bituminous matrix (Plate 3.51-a, c, d, e). A similar primary texture is better preserved in a sample from higher in the same section (Plate 3.47-a). As the fragmental texture grades to a pellet-intraclast sediment, in the specimen in Plate 3.51-a, zebra cracks (white bands) fade out. In the same specimen, where primary texture is sufficiently distinct,

zebra cracks can be seen to have opened around the larger, more transparent fragments (presumably crinoid or other coarse fossil debris). On the other hand, the later fractures crossing the zebra cracks cut through these grains (Plate 3.51-b, c, d). In the same thin section, zebra cracks can be seen to wedge out and branch at their terminations, in a pattern typical of desiccation (shrinkage) cracks (Plate 3.51-e).

Soft-Sediment Deformational Structures

A local breccia of tabular fragments in a sucrosic, brownish-grey-weathering dolostone matrix occurs at about -58 feet in Section J (Fig. 3-10; Plate 3.51-f). The clastic-looking matrix suggests that this breccia was produced by deformation of a soft sediment. However, the fibrous-looking white dolomite interlayers in the argillaceous fragments are perhaps more suggestive of a tectonic origin. (See also page 3-248.)

Somewhat lower in the same section (Fig. 3-10: -102 feet), a largely dolomitized micrite layer lies atop a coarser-crystalline, sucrosic to granoblastic quartzose dolostone layer (Plates 3.51-g, h;

3.52- b; 3.55-a). The base of the micrite layer behaved rigidly and was broken and dislocated while the material below apparently flowed. A localized flexure in the same layers also involves flowage of the lower bed, apparently resulting from slumping (Plate 3.53-d).

Superficially similar mixing of two phases occurs in several other places but, there, disruption of the sediment occurred when neither phase was thoroughly lithified and the ductility contrast between phases was presumably relatively low (Plate 3.50-a, d).

Brecciation

True pseudobreccia (page 3-66) was not found in Unit 4, although textures approaching this occur locally (Plates 3.54-a, b, d; 3.55-b, c). However, in addition to the probable soft-sediment breccia already described (page 3-241), both cross-cutting and apparently localized zones and pockets of brecciation are common, particularly in Section J (Fig. 3-10). The zone of brecciation and replacement shown in Plate 3.54-a, b, d is associated with gentle warping of the beds and at least one small fault with a few inches of

vertical displacement at the outcrop surface.

Sphalerite and galena occur sporadically in the cores of white dolomite fillings in a few fractures and dissolved(?) areas of this same zone (page 3-224 and Plate 3.54-d).

In the dolostone portions of Unit 4, white dolomite is abundant in many beds, occurring in patterns varying from definite fossil forms (uncommon) to zebra patches or fracture fillings, or more commonly to some less distinctive pattern. Regardless of pattern, such zones of enrichment in white dolomite tend to be quite consistently stratigraphically controlled, within the limited exposures available for inspection. They are generally restricted to bedding-parallel horizons within beds (Plate 3.52-c).

Partly buried in the shaly talus at the top of Unit 4 at Section K are the only examples found on the Robb Lake property of solution-breccia closely resembling material the writer has seen in present-day limestone caverns. This very poorly exposed, brecciated rock is cemented with coatings of precipitated carbonate and retains considerable porosity. It is probably a very small and local occurrence, possibly of relatively recent origin.

Fractures

On the outcrop scale, joints at a high angle to bedding are common in the exposures of Unit 4, although typically not as abundant as in Units 2 and 3 (Plates 3.40; 3.41-b; 3.43). Several minor faults were also encountered in Section J (page 3-242).

More penetrative and smaller-scale fracturing are essentially as described for Units 2 and 3, including early-formed, probable shrinkage cracks and up to three generations of later, cross-cutting fractures, commonly filled wholly or mostly with coarse white dolomite (in dolostones) or sparry calcite (in limestones).

The various kinds of fractures present can be seen in Plates 3.42-h; 3.43-a, h; 3.44-h; 3.45-f, g, h; 3.47; 3.49-e, g; 3.50; 3.51; 3.54. Fracturing is unusually extensive at certain localities where tectonic stresses seem to have been concentrated (page 3-242 and Plate 3.54).

Stylolites

There are few well developed stylolites in Unit 4. Occasional poorly developed microscopic ones can be seen in thin sections of microcrystalline limestone beds.

Porosity

The bulk of Unit 4 consists of dense, crystalline dolostone and limestone lacking visible porosity both in hand specimen and in thin section. Where the dolostone is fractured or brecciated, white dolomite commonly fills most or all former voids except late joints (Plates 3.52-c; 3.54).

However, scattered vugs are found in many beds in the upper part of the unit. These consist of remnant voids in fracture or breccia fillings, often lined with bitumen (Plate 3.44-g), and also voids in the white layers of zebra texture in the upper parts of Sections K, E and H (Plate 3.50-f) and moldic vugs and patchy, finer moldic porosity in a few of the fossil casts in several fossil-rich beds in Sections J, K and H. There is also local moldic (and intergranular?) porosity in an arenitic, fossiliferous dolostone bed in Section E.

Lithotypes and Variability

As already noted under "Field Characteristics" (page 3-210), the most striking difference in lithology within Unit 4 is the diagenetically produced contrast between limestone and dolostone. Both rock types are almost entirely dark or medium-dark grey in colour but, as would be expected, there is a crystal size difference. The limestones are virtually all microcrystalline, whereas almost all dolostone beds are coarser, ranging from fine to medium-coarse crystalline (page 3-216), but mostly medium or medium-fine. Several other features of post-depositional origin (brecciation, vugs, zebra structure and white dolomite) are found only in dolostone.

There does not seem to be a significant difference in thickness between limestone and dolostone beds, as a whole, although the thickest beds are dolostone. On the other hand, another primary feature, the occurrence of megafossils, particularly of those which are intact and more or less "in situ", is almost entirely restricted to dolostone, in the outcrops available. In only one case (plate 3.47-c) were such fossils found in limestone and in this bed the bulk of the fossiliferous horizon is dolostone and the entire bed has been dolomitized a few feet laterally.

A pattern of changes in primary characteristics can be observed, from bottom to top of Unit 4, where the unit is best exposed (Figs. 3-10, 11). At the base of the unit is a small thickness (10 to 15 feet at the most) of very dark grey dolostone and calcareous dolostone, with shale partings and very argillaceous layers. Some of these beds contain a large percentage of quartz sand and one or two are actually sandstones (Plates 3.40-b; 3.43-b, c; 3.44-a, b, c, e; Fig. 3-10). Pyrite is common-to-abundant in this bottom zone, both finely disseminated and as coarser aggregates (Fig. 3-10; Plate 3.44-b, c, e). Extensive, post-depositional silicification is evident in at least one layer (Plate 3.44-a; and page 3-256).

In some places, this basal zone gives way upward to a varying thickness of microcrystalline limestone (about 20 feet at Section J, downstream segment, and 50 feet or more at Section E but apparently none at the bottom of the upstream segment of Section J - Figs. 3-10, 11). Where this limestone zone is present, the transition is gradual, with eight to ten feet of interbedded limestone, dolomitic limestone and calcareous dolostone between pure dolostone, below, and pure limestone, above. In the pure limestone zone, pellets are absent or visible only vaguely and in parts of this sections (Plates 3.47-e, g; 3.48-b, c, e; 3.49-a) and there is abundant evidence of thorough

bioturbation (page 3-237). Quartz silt and fine sand are commonly scattered in these beds.

The limestone in the downstream segment of Section J gives way abruptly to dolostone above a prominent limy shale zone (Fig. 3-10). At Section E, there is a more gradual transition, through dolomitic limestone and calcareous dolostone (Fig. 3-11). A few feet above the level of the limestone in Section J, but farther upstream, the first recognizable fossils occur in the dolostones. They are "stick" corals which, although poorly preserved, can be seen to have been deposited more or less intact, in a fine matrix. Similar richly fossiliferous beds or zones recur above this, roughly at ten feet intervals except for two wider gaps (Fig. 3-10). However, in higher fossil beds the fauna is more varied, including numerous bulbous stromatoporids and at least two kinds of corals (page and Fig. 3-10). Also, in these higher zones, fossils are clearly intact and approximately in the locations where they grew.

At about 60 to 70 feet below the top of the unit, this dolostone section can be traced a few feet laterally to an exposure that largely escaped dolomitization. The partially dolomitized "stick" coral bed already mentioned (page 3-234; Plate 3.47-c) is at the top

of this limestone outcrop. Several intervals of very thin and, in part, very planar beds occur in the limestone exposure and mudcracks were found on one of the thin beds, about mid-way between the fossiliferous layers forming the upper and lower stratigraphic limits of the limestone (Plate 3.45-d and page 3-237). Also near the middle of the limestone outcrop, a sample from a 2 to 3 inch bed consists of weakly laminated pelmicrite (grading to pelsparite) showing no evidence of burrowing but containing near-vertical cavities or cracks filled with debris similar to the host rock (Plate 3.50-g and page 3-239). The same sample also contains pelmicrite intraclasts. A local dolostone breccia that may be of sedimentary or penecontemporaneous origin was found at about the same level, at the streambed (page 3-241 and Plate 3.51-f).

At Section E, even below where the lower limestone zone gives way upward to dolostone, a dolomitic limestone bed about 90 feet below the top of the unit has bituminous layers (probably of algal origin) and cracks and cavities of evident penecontemporaneous origin, filled in part with sediment similar to the host rock (Plates 3.42-h; 3.43-a; 3.49-e and page 3-237). There is also a small-scale, local erosional surface in the same layer (Plate 3.49-g) and intraclasts of similar composition to the host rock are common

(Plate 3.45-c). A few rhombic dolomite crystals surrounded by coatings of micrite can be seen in this same bed (Plate 3.45-c).

Ten feet higher in Section E, the transition to dolostone from limestone is accompanied by the occurrence of the only light grey beds in the unit (Fig. 3-11). In thin section, these beds can be seen to consist of dolomitic limestone and dolostone with clastic primary textures and containing up to about 35% quartz sand (Plates 3.42-a; 3.43-d, f and page 3-219). Although primary textures are poorly preserved, these light-coloured beds were evidently packstones-to-grainstones, composed mainly of worn fossil fragments (shell fragments?) and rounded quartz grains. The thoroughly "churned" appearance of the bioturbate limestone lower in the section is replaced, here, by an indistinct layering due to grain-size and compositional variations. This vague layering is interrupted in places by clusters and spherical (cylindrical?) aggregates of quartz silt and very fine sand, indicating burrowing but not thorough bioturbation (page 3-238 and Plate 3.49-f).

Within a few feet upward, these dolomitic beds at Section E grade back to pelletiferous limestone with minor, scattered quartz silt (Plates 3.43-h; 3.48-d). This small limestone zone, at about

the same stratigraphic level as the similar zone adjacent to Section J (Figs. 3-10, 3-11), also contains evidence of desiccation cracks and other penecontemporaneous modifications (page 3-242 and Plate 3.50-a, b, d).

Both Sections E and J are composed entirely of dark grey dolostone above about 60 feet from the top of Unit 4. With a special microscope technique (page 1-15), the primary texture of some dolostone beds can be seen. These beds were composed mainly of pellets, with some small, probably pelmicritic intraclasts (Plate 3.45-a, e). Fossils are apparently less numerous at Section E than at Section J (Figs. 3-10, 3-11). Moreover, the one definite occurrence of fossils in the upper part of Section E differs from the other sections. It consists of an ill-preserved reticulate network and some probable brachiopod casts. At Section K, on the other hand, fossiliferous horizons are considerably more numerous than at Section J and a rich fauna of stromatoporids and several kinds of corals are present (page 3-229 and Plates 3.45-f, g; 3.46-a, b, c). Beds are also thicker at Section K than at Section J, at least in the top 45 feet of the unit, which is all that is exposed at the K location (Figs. 3-9, 10, 11).

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Primary textures of samples from Section K (again generally visible only with the writer's "paper filter" method) also differ from those of Sections J and E. Pellets are the principal constituent at some levels but pellet "muds" grade to poorly sorted sands evidently composed mainly of angular fossil-fragment grains with abundant intergranular bituminous material (page 3-232 and Plates 3.47-a; 3.51-b, c, d, e). The thin section containing the most distinct bioclastic microtexture (Plate 3.47-a) was taken from a layer containing numerous intact stromatoporids.

At this point, it is appropriate to mention the two small fossiliferous outcrops on the southwest side of the "Mississippi Creek" valley, one of which certainly belongs to Unit 4 (Location H-top, Figs. 2-6, 3-5) and the other of which probably also belongs to Unit 4 (Location S, Fig. 2-6). At Location H, four or five stratigraphic feet of dark dolostone with fossiliferous horizons are present above Unit 3 (page 3-211). The lithologies are similar in some detail to those at Section K (Plates 3.45-d; 3.50-f). At Location S, considerably farther up the valley (Fig. 2-6), a maximum of about 20 stratigraphic feet of poorly exposed, rubbly, dark-to-light grey dolostone outcrops for a length of about 1000 feet along the top of the cliff formed in this area by the top part of

Unit 3. Bedding is lacking-to-very indistinct and the bulk of the rock consists of the vestiges of an in situ organic framework of bulbous and encrusting stromatoporids (Plate 3.47-d, f) with a few favositid-like tabulate corals, and horn corals, and with a large volume of poorly sorted fossil-fragment debris. Brachiopod shells are also common.

There is no obvious stratigraphic break between this fossiliferous outcrop and the top of Unit 3. The topmost buff-weathering bed of Unit 3 grades upward to a dark grey-to-black zone a foot or two thick and somewhat discontinuous and "streaky". This, in turn, grades rapidly upward into the organic-rich rock already described, through a thin zone with numerous disarticulated brachiopod shells "floating" in a dark matrix of fine debris and/or mud (Plate 3.47-h). All but the bottom few centimetres of this thin transition zone are so altered by post-depositional changes that little primary texture can be recognized. In the fossiliferous outcrop, as a whole, post-depositional processes have affected the rock considerably, resulting in moderate-to-high visible porosity as well as partial destruction of primary texture (Plates 3.47-d; 3.55-d). All of the diagenetic and later features described for Unit 4 as a whole (page 3-262) are found here. In particular, as well as the common white dolomite,

clear quartz crystals are common here in the larger vugs, and in some cases white dolomite has filled cavities after quartz growth. Bitumen is very common as the latest cavity filling in vugs and some smaller, "intergranular" pores.

Where the top contact of Unit 4 is exposed, in Section J, and, less perfectly, in Section K, the topmost 5 feet, approximately, display a rapid change to thin, argillaceous, very bituminous and pyritic beds. Some of these beds consist of a uniform, sucrosic pattern of idiomorphic dolomite rhombs, with all intercrystalline space occupied by bitumen and pyrite (Plate 3.42-3). One or two of the topmost beds, however, are composed largely of the tests of Tentaculites, in a matrix apparently consisting almost wholly of pyrite and bitumen (Plate 3.49-b, c, d). These fossils are too poorly preserved to be identified with confidence at Section J but they are well preserved on argillaceous partings in the rubble at the top of Section K.

Several thin, black, argillaceous limestone layers are interspersed in the bottom foot or two of the Besa River Shale and the lowest 20 feet or less of the shale is black, presumably due to a high content of bitumen and pyrite, as in the top of Unit.4.

Interpretations

Environments and Their Distribution.

The distribution of lithologic variations and thickness variations in Unit 4 can be explained as the result of gradual marine flooding of a previously exposed surface on which perhaps 150 feet of topographic relief had been developed in the study area, in the form of gentle rises and hollows. Differential compaction over the rapid facies change that exists in the Silurian section in the study area (Norford, et al., 1966, p. 509) could conceivably have contributed to development of topographic relief along roughly north-south trends. However, the lithologic evidence does not support differential subsidence during the deposition of the more than 2000 feet of Lower Devonian (or older?) to Eifelian carbonates. Development of topographic relief purely by erosion, during a fairly extensive period of uplift in late (?) Eifelian time, seems a more likely, as well as a simpler explanation. A period of uplift and erosion at this time in the Robb Lake area agrees well with what is known of the sedimentary-tectonic history of the broad surrounding region of Northeastern British Columbia and Northwestern Alberta. The land mass centered on the Fort Nelson, Peace River and Alberta Arches was most extensive

in Eifelian time and probably extended as far west as the Robb Lake area (Douglas, et al., 1970, page 395, Fig. VIII 14). During Givetian time the border of the land area seems to have moved southward and somewhat eastward, implying a transgression over the area of this study (Douglas, et al., 1970, p. 399, Fig. VIII 15). Moreover, Taylor and Mackenzie (1970, p. 15) have reported an unconformity at the base of the Unit 4 equivalent (Dunedin Formation) some miles to the north of the study-area.

On the Robb Lake property, the lack of any clear evidence of truncation or erosion at the top of Unit 3 is probably due simply to the absence of exposures at this level (page 3-141). Although the apparent thinning of Unit 4 northward and, more rapidly, westward from Section E is actually well established only from Section E to Section J, the coincidence of this thinning pattern with a geographic trend (and a temporal trend in the thicker sections) of environmental change, strongly suggests that the thinning is real.

The dark-coloured, sandy dolostone interval at the bottom of Sections E and J probably represents the initial phase of marine transgression, when only the lower areas of the topography were filled, forming quiet embayments. The abundant pyrite in these

basal beds suggests stagnant muds and the high sand content reflects local reworking and erosion of the still-partly-exposed surface of Unit 3. Part way up the topographic-bathymetric profile, periods of exposure probably caused the removal of dolomite and/or calcite and replacement of silica in the thoroughly silicified former sandy carbonate rock shown in Plate 3.44-a. The thin, partly dolomitic "grey-wackes" which were found with finer-grained silty shale equivalents near the bottom of upstream Section J may be residual soils. Some beds also pinch out northward into this upstream basal part of Section J (Plate 3.53) and the base of the unit is apparently 15 feet or so higher, here, than in the downstream section, cutting out all of the lower limestone zone (Fig. 3-10). The observable pinch-out is directly into a heavily silicified, pyritic and argillaceous zone in the measured section (Plate 3.53-a) and there is evidence of penecontemporaneous disruption, alteration and erosion in some layers at this level (Plates 3.51-g, h; 3.52-b; 3.53-c, d; 3.55-a).

As the water level rose, the lower parts of the area soon began to accumulate purer lime mud and the environment became hospitable enough for the survival of mobile detritus-feeders such as trilobites, ostracods and echinoids. Soft-bodied burrowers probably also contributed to the intensive bioturbation that took place in these quiet-water subtidal muds.

With further rise of relative sea level, more open communication with the sea to the west began to develop and thin biostromes of solitary corals spread over parts of the area, probably becoming established in shallow water, following the contours of the still uneven bathymetry, because the best (firmest) substrate and the best supply of food, light and oxygen would be part way up the topographic bathymetric profile. At Section E, where the water probably remained relatively deep, biostromes are absent and the only fossils noted (high in the unit) were occasional brachiopods and an isolated, delicate, possible coral or bryozoan, probably representative of a relatively deep and quiet-water part of a less and less restricted marine environmental pattern.

← Although there is evidence of shallowing water and even occasional exposure (desiccation cracks, decreased burrowing, calcarenites) even in Section E, the distribution of high and low areas inherited from the earlier erosional surface was apparently maintained throughout deposition of Unit 4, albeit with decreasing relief. Biostromal organic communities extended periodically into what was apparently mainly a pellet-mud environment in the area of Section J, part way up the topographic-bathymetric profile, but they never developed in the lower (deeper) area of Section E. At Sections K and H, apparently

up-slope from Section J, biostromal communities more commonly covered the substrate and the faunas were more varied and populous than at Section J (page 3-250 and Figs. 3-5, 3-9, 3-10). Apparently, by the time these higher areas were submerged, a normal marine environment was well established, allowing flourishing organic communities wherever the substrate, depth, etc., were suitable. Indeed, the highest areas seem to have provided a base for the establishment, probably only locally, of a true organic framework or reef composed of tabular or encrusting stromatoporids and occasional tabulate corals in addition to the bulbous stromatoporids and small, cylindrical corals of the biostromes. Location S is an example of such a reef. It is conceivable that this outcrop is the thin edge of a larger and thicker structure lying to the west-northwest. However, the lack of significant amounts of well sorted sand in any of the sections and the lack of oolites or abundant transported reef debris suggest that no large, biohermal structure existed in the immediate area. Moreover, if such reefs did exist a bit farther away (perhaps somewhat to the west or north-west) dispersal of debris from them must have been in other directions. The stratigraphic and geographic location of this outcrop with respect to the sections already discussed also suggests that the S location merely represents a local reef-stage development late in the deposition of Unit 4. In this case, not much more thickness than is visible is

likely to have existed nearby and an essentially biostromal geometry prevailed, even though a rigid organic framework and a more typically reefal biota than elsewhere developed briefly at this locality.

It seems likely, again in view of the lack of evidence of high-energy environments, that the entire study area remained protected by a barrier or series of barriers, well to the west, from the direct force of the open sea. These barriers might have been reefs or banks or even exposed islands belonging to the pre-Unit 4 erosional surface, possibly controlled by banks or reefs developed in the westward equivalent of Unit 3 (page 3-201).

In any case, after only a relatively small thickness of fossiliferous limestone was deposited in the study area, there was a transgression of regional extent which deepened the water over the whole area considerably and relatively rapidly. This event is recorded at the top of the Unit 4 sections, where there is an abrupt change to thin, very pyritic and bituminous dolostone beds devoid of fossils except Tentaculites. This fossil was probably pelagic or nektobenthonic (Fisher, 1962, p. 104-105). Clearly, this change indicates development of stagnant bottom conditions following the rapid over-

TABLE 3-13

Diagenetic Sequence - Unit 4

Diagenetic Feature	Evidence for Position in Sequence	Illustration (Plate Number)
1) Desiccation Cracks	Mudcracked bed surfaces (penecontemporaneous by nature); vertical, down-wedging cracks filled with sediment like their walls; sheet cracks containing pelmicrite and associated with bituminous (algal?) layers.	3.46-d; 3.49-e; 3.50-d.
2) Leached cavities; local, partially lithified sediment.	Vertically cross-cutting, irregular cavities filled with pellet mud like their walls. Associated with very thin beds, mudcracks and intraclasts. Could predate (1).	3.50-g.
3) Internal sediment composed of micrite and pellet sediment.	Found in fossil chambers, desiccation cracks, and leached cavities. Closely resembles adjacent primary sediment. Probably partly predates (1) and (2).	3.48-b; 3.50-c, g.
4) Internal sediment composed of crystal silt.	Covers (3) and found in (2).	3.49-e; 3.50-a, b, c, e.
5) Deformational structures formed in partly soft sediment.	(4) is present in sheared sediment but not in sparry cavities created by shearing. These structures found only close to evidence of penecontemporaneous subaerial exposure. Probably predate (4) in some cases.	3.50-a, b; 3.51-g, h; 3.52-b; 3.53-d.
6) Spar (now calcite or dolomite) in some primary and penecontemporaneous cavities (in sediment lithified further at this time).	Spar covers (4) and fills voids caused by (5). Thin spar lining prior to (4) in some cases.	3.48-b, c, d; 3.49-e; 3.50-a, b, c, e; 3.51-g.
7) Zebra structure; most of the dolomite in the section (most of section probably lithified at this time, as dolostone).	Zebra structure formed in soft sediment and never contains internal sediment (p. 3-277). Zebra found only in dolostone; interpretations of basin geometry and lithologic patterns also indicate dolomitization at this time.	3.46-a, b, c; 3.51-a, b, c, d, e; 3.52-a.

8) Early breccia.	Zebra dark layers broken into local breccia in some cases. Had to occur prior to cementing of white layers (former cavities).	-----
9) White dolospar.	Fills (7) and (8). Thin linings could have preceded (4) locally but this is more likely to be replaced calcite spar. Could follow and/or be contemporaneous with (6). Formed in a different diagenetic environment and probably largely in different beds.	3.46-a, b, c;
3.50-f; several others.
10) Later white dolospar and breccia.	White dolomite veins and breccia fillings cross-cutting white dolomite-filled zebra and other veins show later brecciation and several stages of dolospar precipitation over a considerable time period.	3.51-d; 3.52-a, c; 3.54;
3.55-c.
11) Sphalerite and galena (Unit 4).	Found in cores of late-stage white dolospar fillings and in occasional fractures. (Contemporaneous with a late stage of (10).)	3.54-d.

Features of uncertain position:

A. Early (prior to burial of layer involved) -	
- Dolomite rhombs and dolomicrite in micrite	3.42-h; 3.45-c.
- Extensive silicification (at probable local unconformity	3.44-a; 3.55-a.
B. Late (covering zoned dolospar) -	
- Pyrobitumen in vugs	3.44-g.
- Clear quartz crystals in vugs	-----
C. Early to late -	
- Brittle fractures (several stages with dolospar or spar fillings)	(Various.)

whelming of the organism-rich, shallow marine environment. The rapid gradation to shale, upward, marks the onset of a prolonged period of deeper marine conditions in the Robb Lake area.

Diagenetic History.

Although the products of diagenesis and corresponding diagenetic processes (Table 3-13) represent a long and complex diagenetic history, there is evidence that most of the major diagenetic changes that occurred took place quite early in the post-depositional history of these rocks.

The earliest-formed group of "diagenetic" features are related to subaerial exposure of recently deposited sediment (pages 3-256, 257). These include typical mud-cracked bed surfaces; downward-wedging vertical cracks filled with sediment like that forming the walls of the cracks; sheet cracks (fischer, 1964, p. 114) filled first with pelmicrite and then with fillings of later diagenetic origin and associated with "cracked" bituminous layers, dolomicrite and micrite-coated dolomite rhombs, and finally, former cavities evidently produced by leaching close to an exposed surface (page 3-239).

Prolonged subaerial exposure at at least one level and location also produced local erosion as well as silicification and "grey-wacke" formation probably indicative of residual soil development (page 3-246). Beneath this zone and at another locality, flowage and dislocation of soft and semi-lithified sediment occurred (page 3-241), probably related in origin to the exposure of the sediment surface just above.

These features indicative of subaerial exposure are found only where most of the section remains limestone: the lower and middle parts of Unit 4. The presence of sub-vertical passages clearly produced at least partly by leaching (Plates 3.49-e; 3.50-g) and restricted to certain horizons also containing mudcracks, sheet-cracks and other signs of subaerial exposure, indicates not only subaerial exposure, but the entrance of fresh water into the surface of the exposed sediment and resulting early lithification or partial lithification. (The shapes of the leached passages, themselves, as well as of other early-formed voids, require prior development of a rigid rock.)

This lithification probably resulted from the normal inversion of the aragonite and high-Mg calcite originally composing these

sediments to low-Mg calcite upon subaerial exposure and dilution of the Mg-rich marine pore water with fresh water. The rare dolomicrite which occurs in one of these zones along with scattered dolomite rhombs, some coated with micrite, probably formed due to mixing of fresh and marine waters in proportions and volumes which locally lowered salinity while keeping the Mg/Ca ratio high, so that dolomite formation was favoured. Folk and Land (1975, p. 65) suggest this same mechanism for the formation of dolomitic beachrock in the Bahamas today. There, as at Robb Lake, no evidence has been found for the precipitation of the gypsum that must form in some quantity prior to dolomite precipitation from hypersaline water as in the well-known "sabkha" models (Folk and Land, 1975, p. 63). The dolomicrite may have formed by replacement, under these conditions, while the scattered rhombs may have been nucleated in pore space and grown by displacement and/or replacement. Some dolomite rhombs in one layer must have been formed penecontemporaneously in view of the rounded micrite coatings observed on them. These are likely to have been formed by the dilution mechanism because dolomite formed from hypersaline marine water is normally microcrystalline (Folk and Land, 1975, Fig. 2).

The internal sediment of calcite crystal silt that overlies

pelmicrite internal sediment in some of the sheet cracks and leached cavities in the partly dolomitic zone just described appears identical to the vadose cement described by Dunham (1969). Since some lithification, followed by leaching, preceded deposition of this sediment, the crystal silt was probably formed and deposited in the thin, vadose fresh water zone which the strong vertical orientation of leached passages indicates developed beneath the exposed sediment surface.

It is to be noted that almost no cement textures suggestive of marine origin are found in Unit 4. A discontinuous "row" of small blocky-to-vaguely prismatic calcite crystals projects from parts of the walls of cavities and from the surface of some internal sediments. in specimens where vadose and subaerial effects are generally visible (page 3-239). In no case was anything remotely resembling the "palisade cement" (Schroeder, 1973, p. 183) typical of marine aragonite cements observed.

Thus, it appears likely that while the original marine pore water was retained these muds had little permeability, or at least that there was little water flowing through them to form the marine cements common in Recent reefs and other permeable carbonates (Schroeder, 1973; Bathurst, 1971, p. 365).

The argillaceous-arenaceous dolostone and calcareous dolostone beds that form the bottom few feet of Unit 4 in the thicker sections must have been dolomitized either before deposition of the overlying limestone or by some later process localized in the deepest parts of the depositional basin or in the earliest beds deposited. The mechanism of this dolomitization remains uncertain. However, no cross-cutting dolostone-limestone contacts were observed and dolostone appears restricted to the bottom 15 feet or less of the formation, even though the basal unconformity apparently had considerably more than 15 feet of structural relief within the depositional basin by the time of the period of exposure and local erosion most prominently marked in Section J (about the top of the main limestone section: Fig. 3-10). The thickness of the basal dolostone section also varies from one location to another, evidently thinning toward the edges of the basin of deposition (Figs. 3-10,11).

These relationships favour dolomitization of the basal beds prior to or during deposition of the overlying limestone. The restricted, partly land-locked, relatively small areas of marine incursion in which these first beds were probably deposited (page 3-255) may conceivably have been somewhat hypersaline as well as "stagnant". Such waters may have had a Mg/Ca ratio higher

than that of normal sea water. In addition, the relatively extensive surrounding land areas existing at this time are likely to have had fresh water tables which extended under the shallow marine embayments. These meteoric waters may well have been somewhat enriched in magnesium after passage through, and along the deeply eroded surface of, the underlying dolostone unit. At the low salinities that would result from gradual mixing of a large amount of such a "fresh" water with a normal marine or somewhat hypersaline pore water in these new sediments the resulting Mg/Ca ratio should be high enough to favour precipitation of dolomite. (See Folk and Land, 1975, Fig. 1.) This is a process which might proceed concurrently with sedimentation (below the sedimentary surface) effecting a form of penecontemporaneous dolomitization.

If a decrease in local rainfall occurred concurrently with a reduction of the subaerial surface area nearby as marine water covered an increasingly large area and as the sediment fill in the basin became thicker, it might be expected that the thickening deposits of muddy sediment accumulating over the early dolostone would retain normal marine pore water, through lack of a supply of fresh water.

1 OF

Figure 3-12: Diagrammatic, Interpretative Stratigraphic Cross-Section
Unit 4, Sections E, J and K. Datum = Top of Unit 4. Horizontal scale: 1 cm

A. True scale (vertical scale: 1 cm = 500 ft.)

B. 25 times vertical exaggeration
(Vertical scale: 1 cm = 20 ft.)

2 of 2

Fig. 3-12: Diagrammatic, Interpretative Stratigraphic Cross-Section -
Sections E, J and K. Datum = Top of Unit 4. Horizontal scale: 1 cm. = 500 ft.

Scale: 1 cm = 500 ft.)

UNIT 3

SECTION J

Lower Upper

SECTION K

Aggradation
= 20 ft.)

Besa

River

Fm.

UNIT 4

UNIT 3

A number of feet of limestone overlie the basal dolostone where Unit 4 is relatively thick, over the low parts of the topography of the basal unconformity. Most of the rest of Unit 4 is dark dolostone, however, apparently consisting mainly of dolomitized pelmicrite much like the original lime sediment in the limestone sections (page 3-228). The contact between limestone and dolostone is abrupt and concordant in the downstream portion of Section J (Fig. 3-10) but it is somewhat gradational, elsewhere, with some calcareous dolostone or dolomitic limestone layers forming a transition zone (page 3-247). Moreover, a thin zone of limestone occurs above the first dolostone beds, both near Section J and in Section E (pages 3-248, 249). Although the upper limestones at these two localities cannot be shown to be exactly correlative, the measurements and field estimates upon which the stratigraphic columns (Figs. 3-10 and 3-11) are based indicate that they should be approximately correlative. Certainly, in any case, the main (lower) limestone section is much thinner at Location J than at Location E, considerably thinner than could be explained merely as an equivalent part of the thinner overall section. Thus, part of the main limestone section at Location E is replaced by dolostone at Location J. Figure 3-12 shows the diagenetic facies pattern that seemed most likely, from Location K to Location E. This pattern, with dolostone giving way laterally to an increasing amount

of limestone, moving into the basin, suggests the idea that the mechanism of dolomitization, for the lower half of the Unit, at least, involved the basin margin and the adjacent land areas that existed at least until the time of deposition of the uppermost beds of Unit 4 (page 3-257, et seq.).

Now there is no evidence of early lithification of the limestones (before further sedimentation) except immediately beneath horizons of subaerial exposure. Rather, there is evidence in several places of a former high ductility contrast between certain relatively rigid layers with features indicating subaerial exposure and penecontemporaneous lithification, and adjacent layers (page 3-241). The relatively rigid layers were able to break apart and to shear, while the adjacent layers flowed like a soft sediment.

It seems likely, then, that most of the sediment beneath the temporarily exposed surfaces retained an essentially normal marine pore water (and retained its original structure and composition) during these periods of subaerial exposure and penecontemporaneous lithification except perhaps very close to the edge of the depositional basin, where surface runoff from the adjacent land may have entered the sediment penecontemporaneously.

The supply of fresh groundwater to the edge of the sedimentary basin from the adjacent land areas may have varied greatly, in the meantime, in response to changes in amount of precipitation. However, even with a low net rate of recharge, water of meteoric origin would be continuously flowing into the sediment and ultimately entering the marine environment as a discharge probably still having a salinity at least a little lower than that of normal marine water. The relationship of dolomite distribution to the edge of the depositional basin (Fig. 3-12) evidently reflects the relationship of dolomitization to this flow of land-derived water. Dolomitization by mixing of fresh and marine waters, as must have occurred in this setting, has already been proposed to explain the dolomitization of the underlying Devonian units and of the basal beds of Unit 4. This mechanism has been cited as the cause of dolomitization on a larger scale along the Wisconsin Arch (Badiozamani, 1973). Folk and Land (1975) have shown that dolomite should form from such a mixing of waters when salinity is lowered considerably from that of sea water without significantly lowering the Mg/Ca ratio.

As the mixed water flows outward through the sediment from the basin edge, however, if dolomite is being formed from it, the Mg/Ca ratio of the water will decrease due to removal of Mg^{++} and uptake

of Ca^{++} . At the same time, an increasing amount of marine water is presumably mixed in, increasing the salinity. Both of these trends lead to eventual inability to precipitate more dolomite. Perhaps the first trend is the dominant one, as there is in the limestones little or no evidence of the present or former existence of the micritic and fibrous cements believed to be the only calcium carbonate that will form at high salinities when the Mg/Ca ratio is close to that of normal sea water (Folk, 1974, p. 45-46).

That the anhedral, sparry calcite that forms the principal cement in the limestones of Unit 4 can begin to precipitate from this mixed water where it reaches a composition at which dolomite can no longer form is implied by the model of Folk and Land (1975, Fig 2) provided that total salinity remains brackish. Inversion of aragonite and high-Mg calcite might also be expected when both the salinity and the Mg/Ca ratio were lowered in the fluid surrounding the sediment particles.

This subsurface, mixed water originating from a dolomite-forming fresh-marine mixture nearer to the basin edge of deeper beneath the surface seems to represent the simplest, most reasonable means of forming the limestones present in Unit 4 from the original

lime muds. The mixing model does require dolomitization and limestone lithification prior to burial of the region beneath the Besa River marine shales. There is also structural-textural evidence that dolomitization occurred early, in an unlithified lime-mud (see below), but it cannot be shown definitely that the limestones were lithified at the same early time. Precipitation of the sparry cement and even inversion could conceivably have occurred at a later time, when subsurface waters with a relatively low Mg/Ca ratio passed through the sediment. Folk (1974, p. 51) believes that deep subsurface waters either of marine or of meteoric derivation (or both) precipitate anhedral sparry calcite when their Mg/Ca ratios are below about 2:1. However, in addition to the simplicity of the model for early combined dolostone and limestone formation as described above, the lack of observed compaction effects in the limestones and the lack of structural or textural evidence of a ductility contrast between limestone and dolostone argue for concomitant dolomitization and limestone lithification at an early stage.

The upper part of Unit 4 is entirely dolostone, wherever it outcrops. This may be due to a considerable increase in precipitation accompanying the gradual relative rise in sea level which took place. Certainly, a pre-Unit 4 land surface seems to have existed in the north

west at least until the latest beds in Unit 4 were being deposited (page J-257). On the other hand, it is also possible that the subaerial exposure suggested by the presence of crystal silt internal sediment and apparent early (shrinkage?) cavities in a coral-rich bed about 20 feet from the top of unit 4 (Plate J.50-e) may represent a more extensive period of subaerial exposure than has been recognized, immediately prior to submergence at the end of Unit 4 time. Several richly biostromal horizons above this bed lack obvious signs of subaerial exposure, so that alternations of exposure and re-submergence would seem to be required, up to 15 feet or less from the top of the unit. If, before deep submergence and shale deposition, a fresh water lens became established periodically for extended periods over the entire area within which Unit 4 now outcrops, then mixing of this water with marine phreatic water could gradually dolomitize the whole upper part of the unit as it passed through the zone of mixing. The thickness of the upper dolostone (about 60 to 70 feet) is about twice the thickness of the fresh water zone plus "zone of diffusion" in the more permeable Pleistocene reef rock at the dry south end of Barbados today (Steinen and Matthews, 1973, p. 1013). These authors note that both the fresh water and the diffusion zones vary from about one meter to more than 10 meters in thickness. Others have suggested that spatial variations in similar lenses are due to variations in fresh

water recharge rates and tidal stimulus (ibid.). On Barbados, mineral stabilization as low Mg calcite and calcite cementation, but not dolomitization, have occurred extensively in the phreatic zone. (See also page 3-124).

The basic mechanism suggested here for the dolomitization of most of Unit 4 is strongly favoured by evidence that dolomitization occurred in an unlithified sediment but a sediment that lacked evaporite minerals. The zebra structure that is common in Units 2, 3 and 4 (page 3-240) has been found only in dolostone. Within dolostones, it occurs in every sort of primary textural rock-type, from apparently uniform, pelleted muds to bituminous, fossil-fragment packstone. It is even found very rarely within stromatoporids (Plate 3.46-a, b), although here it seems to have developed in sediment-rich pockets which might have been soft after stromatoporid growth. The formation of zebra structure thus seems to be related to dolomitization, rather than to a particular primary sediment type or environment. (If zebra structure can be shown to have developed in rigid, skeletal material in stromatoporids, then the proposed mechanism of formation will require modification.)

Detailed examination of zebra structure shows convincingly that this feature formed neither by replacement nor by displacive growth of a mineral nor by fracture of a rigid rock but rather by local compaction (or shrinkage) and separation of an unlithified sediment, as in the formation of typical desiccation cracks by

shrinkage due to water loss. In addition to the evidence from shape and details of borders of the cracks (page 3-241; Plate 3.51-a through e), this contention is supported by the intensification of colour from normal host-rock to adjacent zebra dark layers, observed in relatively light-coloured, well-developed zebra rocks (Plate 3.11-c, d, g, h). This evidently indicates a concentration of opaques in the zebra dark layers as compared to the adjacent "host", presumably due to compaction of the material forming them as it lost its originally abundant interstitial water. Flattening of peloids in the plane of the zebra layering was also observed in a sample where primary texture is unusually well-preserved.

With regard to the possibility of formation by displacive growth, the evidence from the fine structure of individual cracks (page 3-240) is supplemented by that from the shape of the zebra zones. In no case is there any evidence of the distortion that must accompany the greater than 100% increase in volume that is implied if the zebra cracks formed purely by displacive growth. At the same time, the existing dark layer material obviously cannot have filled the whole zebra volume without having since undergone compaction or shrinkage. Displacive growth strictly limited to the amount which could be compensated for by local compaction, without a bulge, seems unlikely.

Because the zebra structure does seem to have formed by shrinkage of a soft sediment, leaving voids which remained free of sediment, some means of support for these voids must have existed. In the case of subaerial mudcrack and sheet-crack formation, there is little or no overburden, and water loss, itself, causes sufficient increased cohesion and rigidity in the sediment adjacent to the cracks to support them until some are filled with sediment or vadose lithification of the carbonate sediment provides more permanent support. Zebra structure, however, is not spatially associated with surfaces of subaerial exposure (although depth of burial at the time of its formation was probably not more than a few tens of feet). Moreover, if zebra structure were a product of vadose diagenesis, the white layers (former voids) ought to contain internal sediment, such as the crystal silt associated with the known surfaces of exposure in the Robb Lake section. In no case has any internal sediment been found in zebra structure. In the rare cases where internal sediment occurs adjacent to zebra structure (known only in Unit 2), the zebra structure evidently formed after deposition of the internal sediments (Plate 3.11-d).

If, on the other hand, the zebra structure formed well below the surface, in an un-lithified lime mud with a high interstitial

water content (more than 50%), then the water might still be carrying part of the weight of the overlying sediment and an extremely loose packing of the aragonite needles, elongate, high-Mg calcite crystals and other primary constituents of the sediment would be expected, probably even within pellets. The shrinkage forming the zebra structure might involve only an aggregation or "clotting" of sediment particles in bands parallel to depositional layering as water came out from between particles and collected along otherwise invisible original depositional surfaces.

Such a local redistribution of sediment and water must have some physical or chemico-physical cause. It is suggested here that the zebra structure is associated with dolostone because the change in water chemistry that resulted in dolomitization was also responsible for forming the zebra structure.

Consider a lime sediment with a high water content but a relatively low permeability. As this sediment is gradually penetrated by mixed water partly of meteoric origin, a relatively high Mg^{++}/Ca^{++} ratio is maintained while the interference of high ion concentrations is reduced. Dolomitization can begin (following Folk and Land, 1975). It is unlikely, however, that the penetration of low-salinity water

through the low-permeability sediment would be uniform. It is quite likely that imperceptible variations in permeability and related variations in hydrodynamic patterns would result initially in stagnant "pockets" within the sediment in some places, where the original marine interstitial water would be retained. In the surrounding sediment, the beginning of dolomitization would, if anything, further lower the magnesium concentration in the interstitial water.

Now, although the future zebra pockets would be stagnant in a hydrologic sense, a chemical concentration gradient would necessarily exist, between the lower salinity and lower Mg^{++}/Ca^{++} ratio of the surrounding waters and the higher ones in the pockets. There would be a net outward diffusion of salt ions, especially Mg^{++} , and a net inward diffusion of water molecules. If, however, the permeability of the sediment were lower for the salt ions than for water molecules, there should be a buildup of osmotic pressure in the stagnant pockets. In a soft sediment not deeply buried, only a slight increase in pressure should be sufficient to separate the sediment along its weakest direction, parallel to bedding, thereby increasing permeability and destroying the osmotic pressure gradient. If the separation occurred rather abruptly, relatively rapid movement of the salt ions

in the zebra dark layer sediment into the adjacent cracks filled with dynamic fresher water might be expected. The result might be the "clotting" and shrinkage of the sediment in the zebra layers, widening the cracks. In this case, the cracks would be expected to be widest in the heart of the former stagnant zone and to pinch out at its edges where the concentration and pressure gradients decreased to zero. This is the pattern that is commonly observed in zebra structure.

An alternative explanation might also be possible, although it seems more difficult to envisage in this setting. This involves the establishment of an osmotic gradient in the opposite direction in the same stagnant zones to contain a relatively fresh pore water, trapped in surrounding marine water emplaced, perhaps, by fluctuations of fresh water supply or tides (page 3-274) causing a decrease in size of the fresh water lens. Using this model, a net outward diffusion of water molecules through a zone less permeable to salts might cause an abnormally low pressure in the pockets, resulting in actual shrinkage and separation of the sediment therein much as in desiccation cracking. It would seem that considerable lithification would have to have taken place previously in the surrounding volume of sediment so that such a low pressure zone could be supported.

Another physico-chemical effect which could play a part in triggering zebra formation is shrinkage caused by possible local mole-for-mole dolomitization resulting from local deficiency of carbonate ions. This mechanism clearly cannot, alone, account for the volume of void space generated, however. Compaction of sediment particles must also be required.

Following formation of the zebra structure, lithification apparently proceeded normally everywhere. There is no evidence of significant compaction except in the zebra layers. Dolostone evidently formed by replacement of primary material plus growth into former pore space, without notable overall volume reduction. This is supported by the state of primary textures in dolostone, where they can be seen (Plates 3.45-a, g; 3.50-e, f). The same mode of lithification (without noticeable compaction) apparently took place also in the micritic limestones, as is common (Folk, 1974, p. 50). The thin-bedded bituminous, argillaceous and pyritic dolostone that forms the upper five feet of the unit may have been dolomitized by mixing of marine water with the trapped remains of the former large volume of partly meteoric water in the underlying section. The thin limestone beds in the shale a foot or two above have not been dolomitized.

By the time Unit 4 was rapidly covered by a marine transgression and burial under terrigenous mud began, lithification of the primary sediment was probably virtually complete. Distribution of both inclusions and ferrous iron in the dolomite of stained samples indicates that the bulk of the rock is one uniform phase, whereas the coarser dolomite (mainly white in hand specimen) that projects into or fills zebra cracks and other former voids is zoned with respect to both iron and submicroscopic opaque inclusions (Table 3-12).

Similar relationships have been noted in the underlying stratigraphic units (page 3-135, 3-188). There is no reason to suppose that any other filling or cement other than the products of the original, early dolomitization and the (partly later?) white cavity-fillings now present ever existed in Unit 4. If such another cement did exist, it should probably still be in evidence because from Devonian time until quite recent time these rocks have been out of reach of meteoric waters, buried under a considerable thickness of marine shale at the least. Moreover, there is no textural evidence of leaching after burial, unless very local dissolution-replacement associated with certain late fractures and brecciation (and Zn-Pb mineralization) is considered in this category. (See below.)

An initial lining of white dolomite was precipitated in some cavities prior to a final stage of vadose silt emplacement near the top of the unit (Plate 3.50-e). Thus, some white dolomite was precipitated before Besa River Shale deposition, probably as a natural concomitant of the process of dolomitization of the bulk of the rock. However, most of the volume of the white layers in zebra structure and also of some fracture fillings consists of white dolomite crystals zoned parallel to idiomorphic boundaries facing the existing or former cavities (Table 3-12). In many cases, anhedral dolomite fills the centres of former voids, enclosing earlier idiomorphic shapes (Plate 3.42-c).

Conclusive evidence for the time of formation of this zoned dolomite is lacking. Cross-cutting white dolomite veins carrying the traces of zinc-lead mineralization that occur in Unit 4 are clearly younger than the zoned cavity-fillings. By analogy with the underlying rock units, it seems likely that, much, but not all, of these cavity fillings was precipitated under the dynamic, mixed-water regime that brought about the dolomitization. Some may have formed later, in the deeper subsurface. (See page 3.132, et seq.)

Cross-cutting relationships show that one or more stages of

fracturing and much or all of the abundant "local brecciation" (page 3-242) in Unit 4 took place after the voids in zebra structure were mostly-to-entirely filled with white dolomite (Plates 3.51-c, e; 3.55-c). Most of these late fractures and breccia-openings were also subsequently filled with white dolomite.

In Section J is a unique exposure of a more-or-less stratiform zone of disruption and emplacement of white dolomite (page 3-242 and Plate 3.54). This zone is associated with a few cross-cutting veins up to 2 or 3 inches wide, filled with white dolomite and brecciated host-rock. As well as brecciation and fracturing, considerable solution of the host dolomite is evident in the heart of this zone. "Reaction rims" of brownish (iron and bitumen-rich?) dolomite line host-rock walls and included fragments. Small clusters of sphalerite and galena crystals occur in the cores of a few of the larger volumes of white dolomite (Plate 3.54-d).

This areally restricted episode of solution and brecciation took place after the white zebra fillings were precipitated and probably after all other brecciation and most white dolomite fillings. The solution of large amounts of host-rock, locally, and the "reaction rims" indicate a chemically active solution, well out of equilibrium

with the normal pore fluids and the rock, itself. Such a fluid might have originated deep in the shale basin to the west. That the zinc and lead minerals found in Unit 4 occur in the cores of the massive white dolomite fillings deposited after this episode of solution and brecciation, suggests that the metals were carried up through fracture conduits from below, quite late in the history of the rocks. Whether they were derived from remobilization of prior deposits in Units 2 and 3 or directly from a more distant source cannot be determined. This zone of brecciation, solution and mineralization is also associated with minor faults and small warps corresponding in orientation to the larger structural features of the area (page 3-221). Thus, it seems likely that the brecciation, solutions and mineralization took place well after Middle Devonian time, under conditions of deep burial.

At some locations in Unit 4, particularly at the thin, reefal "location S" exposure, clear well-formed quartz crystals project into some remnant vugs as a latest precipitate, often growing on white dolomite crystals (page 3-221). Such crystals are typically formed slowly, from relatively dilute solutions. Possibly they were formed relatively recently, as the Devonian rocks of this area were unroofed by post-Laramide erosion. Acid groundwaters passing through or over very quartz-sandy beds in Unit 3 and below could probably have supplied silica for these crystals.

It is not clear when the hydrocarbon movement took place which left the hard pyrobitumen commonly found in vugs in Unit 4 (page 3-225). Where this bitumen has been found, it is invariably a last filling, covering the latest dolomite crystal growth (Plate 3.44-f, g). Associated pyrobitumen and quartz crystals were not observed. Where the late, mineralizing solutions penetrated the rocks (previous page) all voids have been filled and pyrobitumen is absent, at least in recognizeable form. Thus, it has not been possible to determine whether deposition of bitumen preceded, accompanied or followed this late phase of reactive solution movement.

- a. Contact between Units 3 and 4: Section J. Light grey, sandy dolostone of Unit 3 at bottom; basal, dark grey dolostone beds of Unit 4 above middle vegetated, covered zone. Covered interval is about 8 feet wide near middle of photo.
- b. Basal, dark-grey dolostone and calcareous dolostone beds of Unit 4 at stream: Section J. Hammer handle is one foot long.
- c. Limestone with shaly layer, capped by thicker dolostone beds: downstream segment, lower Unit 4, Section J.
- d. View downstream from location of (c) to Unit 3-Unit 4 contact at location of (a).

b

d

a

c

PLATE 3-40

3.41

a. Microcrystalline limestone bedding: lower-middle Unit 4, Section E. Note hammer on tree trunk at centre.

b. Typical bedding in dark grey dolostone: upper-middle Unit 4, Section J.

c. Contact between Unit 4 and the Besa River Formation: Section J. Typical shale talus on slopes in upper 2/3 of photo. Top dolostone beds in stream at lower middle.

d. Distant view of Unit 4 outcrops at Section K (centre of photo). Besa River Formation in background; Unit 3 in foreground. Most distant part of view is about one mile from camera.

b

d

a

c

PLATE 3·41

a. Quartz-sandy calcarenite: middle Unit 4, Section E. Note quartz grains (white) with overgrowths which include calcite; calcite grains and spar (dark); dolomite (light grey). Scale bar shows one millimetre; thin section, plane light.

b. Nearly opaque micrite with rhombic dolomite crystals and scattered quartz silt: lower Unit 4, Section J. Scale bar shows one millimetre; thin section, plane light.

c. Host dolomite (bottom) and zoned dolospar cavity filling (top) in a very dark grey dolostone bed: upper-middle Unit 2, Section J. Scale bar shows one millimetre; thin section, paper filter. Arrow shows stratigraphic top.

d. Same view as (c) without paper filter. Thin section, plane light (not crossed nichols). Scale and arrow as previously.

e. Rhombic dolomite with interstitial bitumen: uppermost Unit 4, Section J. Scale bar shows one millimetre. Thin section, plane light.

f. Hand specimen from which (e) was taken. Specimen is about 4 cm. tall. (Faint diagonal scoring is saw marks.)

g. Quartz grains (white, rounded) and dolomite (white to very light grey - in probable fossil fragment outlines) in fossiliferous micrite: lower-middle Unit 4, Section E. Note echinoid spine. Scale bar shows one millimetre. Thin section, plane light, stained with alizarin red.

h. Partly dolomitic micrite: middle Unit 4, Section E. Dolomitic is lighter coloured than micrite. Also note coarser (silt-sized) dolomite crystals (whitish grey), and quartz silt (white) with some visible overgrowths. Scale bar shows one millimetre; arrow shows stratigraphic top. Thin section; plane light; stained with alizarin red.

a

b

↑

c

↑

d

e

f

g

↑

h

PLATE 3·42

- a. "Lumpy", dolomitic, microcrystalline limestone with discontinuous, black, bituminous layers (bottom half): middle Unit 4, Section E. Scale shows centimetres; arrow shows stratigraphic top. Plate 3.42-h taken from this specimen.
- b. Pyritic-bituminous "eye" around dolomite-rich lens in very quartz-silty, pyritic dolostone: lower Unit 4, Section J. Brightest white grains (generally slightly rounded) are quartz. Scale shows one millimetre; arrow as previously. Thin section, plane light.
- c. Greywacke-like argillaceous sandstone: lower to lower-middle Unit 4, Section J. Note scattered pyrite (black). Scale shows one millimetre; arrow as previously. Thin section; plane light.
- d. Bimodal distribution of rounded quartz grains in light-coloured dolostone: middle Unit 4, Section E. Note rounded, then broken grain at upper right; quartz overgrowths at lower left. Scale bar shows one millimetre; arrow as previously. Thin section; plane light.
- e. Partly dolomitic micrite with quartz grains exhibiting idiomorphic overgrowths which include calcite: middle Unit 4, Section E. Scale bar shows one millimetre; arrow shows stratigraphic top. Thin section; crossed nicols.
- f. Detail of quartzose calcarenite of Plate 3.42-a, showing rounded quartz grain with rounded overgrowth: middle Unit 4, Section E. Also note partly lath-shaped calcite grains merging with intergranular spar; dolomite grains (relatively dark colour); specks of hematite-goethite (black). Scale bar shows one millimetre; thin section, plane light.
- g. Rounded quartz grains in the dolostone of (d), showing slight, welding overgrowths at contacts (top and middle) and pressure-solution contact (bottom). Scale shows 0.5 mm. between cross bars; arrow as previously. Thin section; plane light.
- h. Quartz silt grain in pelmicrosparite (to pelmicrite): upper-middle Unit 4, Section E. Note authigenic overgrowth with calcite inclusions, on quartz grain. Scale shows 0.5 mm. between cross bars; arrow as previously. Thin section; plane light.

a

b

c

d

e

f

g

h

PLATE 3·43

a. Quartz fabric in thoroughly silicified, former argillaceous and quartzose carbonate rock: lower Unit 4, Section J (interbed in "greywacke siltstone" to shale zone). Note carbonate inclusions (bright specks) surrounding detrital cores of some quartz crystals; minor sericite flakes along some crystal margins and within some overgrowths; scattered pyrite specks (black, small). Scale shows 0.5 mm. between cross bars; arrow shows stratigraphic top. Thin section; crossed nicols.

b. Very silty (to sandy) pyritic shale: lower to lower-middle Unit 4, Section J. Strong horizontal preferred orientation of fine mica grains produces relatively light matrix (45° to plane of polarization). Scale bar shows one millimetre; arrow as previously. Thin section; crossed nicols.

c. Very pyritic and argillaceous quartz sandstone (to siltstone): lower Unit 4, Section J. Black is pyrite; dark grey is clay matrix (probably now mostly sericite). Scale bar shows one millimetre; arrow as previously. Thin section, plane light. (Dark circles are bubbles in thin section.)

d. Tabular marcasite crystal pseudomorphs (now pyrite) on dark grey dolostone: upper-middle Unit 4, Section J. Specimen is about 5 cm. thick (vertical dimension in photo).

e. Pyrite lens (left middle) in very pyritic and argillaceous siltstone (to fine sandstone): lower Unit 4, Section J. Reflected light shows that most of opaques are pyrite, with only a few traces of bituminous material. Scale shows one millimetre; arrow as previously; thin section: plane, transmitted light plus reflected light.

f. Dolospar crystals projecting into former vug, with remaining cavity filled by bitumen: upper Unit 4, Section E. Note faint, darker zones paralleling the cleavage in dolomite. Both inclusion and iron zoning are actually present. Scale bar shows one millimetre; arrow as previously. Thin section, plane light.

g. Pyrobitumen, partly as bubbles, filling most of late, vuggy porosity in dolostone: upper-to-middle Unit 4, Section J. Also note white dolospar lining vugs.

h. Calcite-filled fracture in quartz-silty pelmicosparite: upper-middle Unit 4, Section E. Note residual porosity, lined with bitumen, in vein. Scale bar shows one millimetre; thin section; plane light.

PLATE 3-44

a. Pellets in dark grey dolostone: upper to middle Unit 4, Section E. Note elongation (flattening?) of some pellets parallel to bedding. Scale bar shows one millimetre; arrow shows stratigraphic top. Thin section, paper filter.

b. Approximately same view as (a) but without paper filter, showing dolomite crystal texture. Scale and arrow as in (a). Thin section, plane light.

c. Detail of part of specimen in Plate 3.43-a, showing micritic intraclasts (upper right); edge of a black, bituminous layer (lower left); microcrystalline and coarser dolomite. Note dolomite rhombs, one of which is coated with a rounded micrite layer. Scale bar shows one millimetre; arrow as previously. Thin section; plane light.

d. Nearly complete pieces of bulbous and dendroid stromatoporids in a matrix of sand-sized and smaller fossil debris: upper Unit 4, Section H. Also note stylolite (bottom). Portion of scale in view shows one cm.

e. Poorly preserved micritic intraclasts and probably pellets in dark grey dolostone: upper Unit 4, Section J. Scale bar shows one millimetre; arrow as previously. Thin section; paper filter.

f. Part of a typical fossiliferous outcrop surface: upper Unit 4, Section K. Stick corals (Dendrostella?) at top; stromatoporids and unidentified, small, dendritic coral below; scattered specimens of Thamnopora below hammer handle; more stromatoporids, etc., at bottom. Surface is approximately perpendicular to bedding, with stratigraphic top toward top of photo.

g. Stick coral (Dendrostella?) specimens in dark grey, finely clastic dolostone: upper Unit 4, Section K. Also note white dolomite-filled cracks, some cutting fossils and matrix (top) and others opening around fossils as by matrix shrinkage (lower right); traces of unidentified, small coral (upper right). Scale shows one centimetre; arrow as previously.

↑
a

↑
b

↑
c

d

↑
e

↑
g

f

PLATE 3·45

- a. Fossiliferous dolostone layer: upper Unit 4, Section K. Stromatoporids and Thamnopora; note zebra structure within stromatopod; traces of small, unidentified coral (upper right).
- b. Detail of part of (a) showing zebra within stromatopod; possible calcareous alga on right side of stromatopod; several specimens of Thamnopora.
- c. Crudely developed zebra pocket with structure suggesting shrinkage: upper Unit 4, Section K. Also note scattered stromatoporids; corals.
- d. Mudcracked bed surface (loose block essentially in place): middle Unit 4, Section J.

b

d

a

c

PLATE 3·46

3.47

- a. Clastic, fragmental matrix of a stromatoporid - rich dolostone layer, revealed by paper filter: upper Unit 4, Section K. Also note cross-cutting, dolomite-filled cracks. Scale bar shows one millimetre; thin section, paper filter.
- b. Trace of a brachiopod (pelecypod?) shell revealed by a gap in quartz grain distribution: middle Unit 4, Section E. No vestiges of primary texture remain. Scale bar shows one millimetre; arrow shows stratigraphic top. Thin section; plane light.
- c. Dolomitization "front" roughly parallelling bedding in fossiliferous (Dendrostella?), microcrystalline limestone: middle Unit 4, adjacent to Section J. Dolostone at top; limestone beneath; note differential dolomitization of fossils and matrix at contact.
- d. Large pieces of tabular stromatoporids in a hash of fossil debris (now entirely dolostone): upper Unit 4, Location S. Also note probable leached cavities. Polished surface.
- e. Ostracod, trilobite and other fragments in quartz-silty micrite: lower-middle Unit 4, Section E. Scale shows one millimetre; thin section, plane light.
- f. Nearly complete pieces of bulbous to tabular stromatoporids and probably colonial coral in a clastic, fossil debris matrix: upper Unit 4, Location S.
- g. Trilobite fragments, an echinoid spine and unidentified fossil fragments in micrite with numerous quartz grains: lower-middle Unit 4, Section E. Note random scatter of clasts (bioturbate fabric). Scale bar shows one millimetre; thin section, plane light, stained with alizarin red.
- h. Very dark dolostone with number and variety of fossil fragments (and porosity) increasing upward: bottom of Unit 4 at Location S.

a

b

c

d

e

f

g

h

PLATE 3-47

- a. Parts of two trilobites exposed in hand specimens: lower-middle Unit 4, Section E. Scale applies to both.
- b. Cidaroid echinoid spine, other fossil fragments, and quartz grains in bioturbated micrite: lower-middle Unit 4, Section E. Also note "mud" internal sediment, partial radial spar lining and anhedral spar filling inside spine; sparry patches probably representing other fossil fragments. Scale bar shows one millimetre; thin section, plane light.
- c. Gastropod, ostracod and other fossil fragments, with quartz grains, in highly bioturbated biomicrite: lower-middle Unit 4, Section E. Scale bar shows one millimetre; thin section, plane light.
- d. Probable foraminifer test in pelmicrosparite: upper-middle Unit 4, Section E. Note quartz grains; spar-filled fractures; spar-lined micrite envelope of fossil, filled with anhedral spar. Scale bar shows one millimetre. Thin section, plane light.
- e. Thoroughly bored fossil (trilobite?) fragments in very dense, quartz-silty micrite: lower to middle Unit 4, Section J. Scale bar shows one millimetre; arrow shows stratigraphic top. Thin section, plane light.
- f. Numerous phosphatic fish fragments (black) scattered in microcrystalline limestone: lower Unit 4, Section J. Scale shows two centimetres.
- g. Surface of largest fish skeletal fragment visible in (f). Right edge is the one exposed in the cut surface in (f). Bottom edge is probably a natural margin. Scale shows one centimetre. Fragment recovered as insoluble residue from acetic acid digestion.
- h. Other surface of fragment in (g). Scale shows one centimetre.

6

b

d

f

h

PLATE 3-48

- a. Fish fragments, quartz sand and silt and other small fossil fragments in micrite of specimen in Plate 3.48-f. Fish fragments have apparently been entirely replaced by collophane. Scale bar shows one millimetre; thin section, plane light.
- b. Ill-preserved tentaculitid tests in black to dark grey dolostone: top of Unit 4, Section J.
- c. Part of specimen in (b). Most of white dolomite is tentaculitid tests, although few are readily discernible. Black to very dark grey colour is pyrite and bitumin in subequal amounts. Dense, solid black is largely pyrite. Scale shows one millimetre; arrow shows stratigraphic top. Thin section, plane light.
- d. Enlargement showing a part of (b) with relatively well preserved tentaculitids. Scale and arrow as previously.
- e. Bituminous layer (black); intraclasts; internal sediment (crystal silt) and overlying spar cavity fillings (upper half); vertical, leached channels and probable micro-sheet crack (middle to bottom): middle Unit 4, Section E. Also note more usual, silty micrite host rock at bottom and top edge. Scale and arrow as previously.
- f. Quartz silt spheres or cylinders suggestive of bioturbation in light-coloured, sandy dolostone: middle Unit 4, Section E. Scale bar shows one millimetre; arrow as previously; thin section, plane light.
- g. Micro-unconformity in intraclastic, dolomitic, bituminous "micrite" of specimen in Plate 3.43-a: middle Unit 4, Section E. Also note fractures (2 sets?) and early (leached?) cavities (white, irregular shapes). Scale bar and arrow as previously. Thin section, plane light.

a

b

c

d

e

f

g

PLATE 3-49

- a. Early formed vertical and horizontal cracks in pelmicrosparite with varying amounts of inter-pellet microspar and spar: middle Unit 4, Section E. Note horizontal crack was partly filled with crystal silt and then filled with spar prior to being cut by vertical crack which, itself, seems to fade gradually into pellet sediment as if the latter were soft at bottom when cut. Scale bar shows one millimetre; arrow shows stratigraphic top; thin section, plane light. (White spots are holes in thin section.)
- b. Enlargement of part of (a), showing details of boundaries of crystal silt, host sediment and spar. Scale bar shows one millimetre; arrow as previously; thin section, plane light.
- c. Former cavity in fossiliferous micrite: lower to middle Unit 4, Section J. Note micritic internal sediment apparently partly eroded prior to superposition of crystal silt (traces of mud sediment on roof as well as floor of cavity). Also note imperfect row of small calcite crystals which lined cavity prior to precipitation of anhedral spar. Scale bar, arrow as previously. Thin section, plane light.
- d. Mudcrack separating pelmicrosparite from a largely pelmicritic phase (dark): middle Unit 4, Section E. Same specimen as (a) and (b). Arrow and scale as previously. Thin section, plane light.
- e. Early-formed (and later) cracks in dark coloured, fossiliferous dolostone: upper Unit 4, Section K. (See Plate 3.45-g) Note crystal silt internal sediment in large crack, emplaced after a thin spar lining (now white dolospar); vertical cracks which do not cut the crystal silt but do dislocate fossils; extension of silt-filled crack opening around fossil. Sequence implied is: 1) horizontal (sheet) cracking, 2) considerable lithification, 3) vertical fracturing, 4) precipitation of cavity linings and fillings of small fractures, 5) emplacement of internal sediment.
- f. Zebra structure and ill-preserved dendroid stromatoporoids and/or corals in dark dolostone: upper Unit 4, Section H.
- g. Cavities probably formed largely by leaching but filled largely by peloids and intraclasts like those of the host limestone: upper-middle Unit 4, laterally adjacent to Section J. Scale bar shows one millimetre; arrow as previously. Thin section, plane light.

↑
a

↑
b

↑
c

↑
d

↑
e

f

↑
g

PLATE 3.50

a. Zebra structure in dark dolostone: upper Unit 4, Section K. Also note later, cross-cutting fractures.

b. Detail of border of zebra crack in specimen in (a). Note that the crack opened around clasts in the host rock. Scale shows one millimetre; thin section; paper filter. (This and the following detail photos cannot be seen without paper filter.)

c. Probable zebra crack at right and later fracture, cutting cleanly across grains and matrix, at left, Same specimen as (b). Scale; paper filter, etc., as before.

d. Another part of (a), showing irregular edge of zebra crack and straighter, cross-cutting later fracture at right which also cuts white dolomite continuous with the zebra fillings. Scale, etc., as previous.

e. End of a zebra crack, splitting and fading into the host rock (upper right): same specimen as (a) through (d). Also note particularly noticeable fragmental, clastic texture; very late fracture (lower left) partly bitumen-filled. Scale, etc., as previous.

f. Probable penecontemporaneous breccia: upper-middle Unit 4, Section J.

g. Microcrystalline, dolomitic limestone with internal sediment, overlying coarser, clastic-textured, dark, siliceous rock; lower Unit 4, adjacent to bottom of upstream segment, Section J.. Note uneven contact suggesting soft deformation; white dolospar in cracks. Scale shows centimetres; arrow shows stratigraphic top.

h. Another side of same specimen as (g), showing a (penecontemporaneous) breccia of mostly fine to microcrystalline fragments, with a remnant of the microcrystalline layer projecting downward into the clastic, quartzose layer. Note vague lamination in bottom of specimen. Scale and arrow as for (g).

a

b

c

d

e

f

g

h

PLATE 3-51

a. Part of a thick dolostone bed: upper Unit 4, Section K. Note stromatoporids at top; traces of corals a little lower; zebra structure and traces of fossil fragments near bottom; scattered vugs of uncertain origin; numerous dolomite-filled fractures at high angles to bedding. Pen is about 18 cm. long.

b. Part of the disrupted, dislocated layer from which the specimen in Plate 3.51 g, h, was taken.

c. Typical dark dolostone beds with abundant white dolospar in horizontal cracks, lenses and zebra patterns, and in vertical cracks: middle to upper Unit 4, Section J.

b

c

a

PLATE 3-52

3.53

a. Poorly exposed, argillaceous, quartzose and pyritic zone: near bottom of upstream segment, Section J (Unit 4). Staff is marked in tenths of a foot.

b. View a little to right of (a), showing beds below argillaceous zone wedging out to left (by red hammer handle).

c. View a few feet to right of (b), showing more cross-cutting, uneven and wedging beds.

d. View a few feet to right of (c), showing flowage-type fold in layer shown in Plate 3.52-b.

b

d

a

c

PLATE 3-53

a. Part of an unusual zone of host dolostone solution and precipitation of brownish (ferroan?) to white, sparry dolomite: upper Unit 4, Section J. Note that a few host rock remnants have collapsed somewhat but most seem to be in original position.

b. Overall view of dissolved zone where (a) was taken. Note that the affected zone involves several beds and is cross-cutting to some extent, with effects decreasing laterally into normal dark dolostone. Also note gentle warping (doming?) of beds and small, high-angle fault cutting across from upper right to lower left, with displacement of a few inches at upper right, decreasing to zero near lower left edge of photo. Red hammer shows scale. (Color plate in original copy.)

c. Traces of zebra structure and fractures filled with white dolomite in "normal", dark grey dolostone: taken about 2 feet behind hammer in (b).

d. A portion of the partly dissolved and replaced area in the foreground of (b). Note brownish dolomite bordering host dolostone as in "reaction rims"; brown specks of altered pyrite in white dolospar. The hammer points to a pocket of reddish-brown sphalerite in the core of a white dolomite area. Traces of galena are also present in the white dolomite. Note highly irregular but distinct borders of the host rock against white dolomite.

b

d

a

c

PLATE 3.54

3.55

a. Largely dolomitized, silty micrite (dark) in abrupt, planar contact with diagenetic quartzite (thoroughly silicified probable former quartzose carbonate rock). These are the upper and lower phases, respectively, of Plate 3.51-g. Scale bar shows one millimetre; arrow shows stratigraphic top; thin section; plane light.

b. Dark grey dolostone with white dolomite "pockets" in a pattern approaching that of pseudobreccia: upper Unit 4, Section J.

c. Zebra-structured dolostone with cross-cutting, later pod of layered dolospar (bituminous at centre?): upper to middle Unit 4, Section J.

d. Zebra structure in the edges of a series of tabular-encrusting stromatoporid layers: upper Unit 4, Location S. Dark, elliptical cross-sections may be corals.

↑
a
|

b

c

d

PLATE 3-55

Thesis
M.Sc.
1977
T39
V.2

FIGURE 2-5 : STRATIGRAPHIC CORRELATION DIAGRAM SH

Legend: see Figure

SECTION → Y

P

G

K

Thickness
in feet

1 OF

BESA R

• 1200

UN

• 1000

• 800

UNIT 3

GRAM SHOWING SECTIONS MEASURED

See Figure 3-13

V H J E

BESA RIVER FM.

UNIT 4

2 of

+600

+400

+200

0

-200

-400

limestone

limestone

limestone

Approximately this interval
is microcrystalline limestone
several hundred feet to
the east.

3 OF

J-

stone

-400

-600

-800

-1000

-1200

-1400

5 OF 1

UNIT 1

SILURIAN

UNIT 2

UNIT 1

6 OF 1

LURIAN

UNIT

- 1200

- 1400

- 1600

- 1800

- 2000

SILURIAN

7 OF

UNIT 1

LURIAN

FIGURE 3-1: SECTION P

Theod
 m. 36.
 1977
 T39
 V. 2

Thickness
in feet

Crystal
size

MIC.
 FN.
 MED.
 CSE.

| 1 OF 1 |

L-F

L-F

Slightly L-F

720

Dark streaks in some places
(desiccated?).

680

Intraclasts and fossil fragments.

Coguinoid layers: fossils, fossil
fragments, intraclasts and quartz
grains.

L-F. (approx. location).

2 of

640

600

560

Quartz vein network and local breccia.

Many L-F. beds in this part but extent and location not recorded.

Small-scale cross-bedding.

Minor bedding plane thrust fault with small drag fold. Probably little or no section repeated or lost but could be significant internal displacement.

Carbonate pebbles and coral fragments.

3 OF

fragments.

4 OF 1

440

Graphic log generalized within
units of similar lithology above this
level (from field notes).

Graphic log copied from bed-by-
bed graphic log in field notebook
below this level.

This part brecciated a few feet
from line of section.

400

Small soft-sedimentary breccia.

L-F.

Extremely platy to shaly; also
silty and sandy.

C

Intraclasts: granule-size and
smaller.

L-F.

L-F.

L-F.

360

Intraclasts.

Internal sediment.

L-F.

5 OF 1.

6 OF

240

C

C

Sucrose.

Bioturbate.

200

Limestone (partially dolomitized).

Bioturbate.

7 OF

155 feet of section measured without description or sampling. Mainly light grey dolostone; numerous sandy, thin to medium beds.

CRYSTAL SIZE

MC FN MED CSE

COLOUR (fresh surface)

OK MED LT BUFF

Thickness in feet

CRYSTAL SIZE

MIC
FN
MED
CSE

COLOUR
(fresh surface)

OK
MED
LT
BUFF

Thickness
in feet

Emergent
Inter-tidal
Subtidal

UNIT 3

UNIT 2

8 OF

9 OF 1

10 OF 1

11 OF

Measured without logging from here to bottom of Unit 2 (695 feet). Regular interval samples collected to -440 feet; occasional samples and notes below.

SEE FIGURE 2-5 AND TEXT

12 OF

Major storm
deposit?

1120

Thick-bedded to massive quartz
sandstone.

Off shore shoal
deposits?

1160

NOTE: Bedding
generalized from limited
notes and thickness
measurement accuracy
lower than for overlying
units.

13 OF

Dolomitic quartz sandstone
grading to very quartz-sandy
dolostone. Carbonate sand grains
visible in thin section. Considerable
amount of planar, coarse lamination
(grain-size type) in lower part.

1200

Probable
increasing
water depth.

Probable
increasing
water depth.

Shoreline sheet
deposits?

1200

1240

1280

Unconformity

UNIT 1

NONDA FORMATION

Medium-gray dolostone.

14 of 14

FIGURE 3-2: SECTION V

Thesac
m.s.c.
1977
T39
V.2

+160

C

L-F

Very fissile

C

+120

Internal sediment.
(2 phase).

Very recessive parting.

Weakly bioturbate.

+80

Mudcracks.

Black; carbonaceous.
Mudcracks.

Heavy shale.

2 of

3 OF

Unit 3

Unit 2

-40-

-80-

4 of 4

These
M.Sc.
1977
T39
V.2

FIGURE 343 SECTION Y

300

Internal sediment.

Mostly pelletoid intracasts.

X—Trace galena in breccia.

260

Internal sediment.

Gastropod casts (vague).

XX—Good Zn-Pb in talus.

220

Mudcracks and rhombic crystal casts.

Pyrite along bedding plane.
Poorly developed L.F.

2 of

6

3 of 1

4 OF 1

UNIT 3

UNIT 2

Typical med. to thick-bedded, medium-crystalline, light-coloured dolostone.

-20-

Fossil-rich "debris bed" containing brachiopods, horn corals, high-spined gastropods and fine fragments.

5 of 5

FIGURE 3-4: SECTION G

These
M.S.
1977
739
V.2

440

C

C

400

C

360

C

C

320

280

240

4 OF

200

Iron oxides

Ripple Marks.

160

Quartz crystals in vugs.

120

5 OF 1

Bedding: 40°, 20° S.E.

UNIT 3

UNIT 2

Breccia blocks up to 15 feet across occur in places, surrounded by smaller fragments and white dolomite.

7 OF

Breccia fragments are mostly medium and medium-fine crystalline, light grey dolostone but fine crystalline and very fine-to-microcrystalline fragments are numerous in some places. Some of the relatively fine-crystalline fragments are medium to dark grey in colour.

8 of 1

Brachiopod casts in local breccia fragments. Also internal sediments.

← Approximately 80 ft offset - (upper part NE.)

- Accuracy of correlation of sections: $\pm \approx 5$ ft. or better.

Minor sphalerite in white dolomite fillings

- N.E. Section
- Bitumin in vugs in white dolomite. Also quartz crystals
- Fragments include graded dolosiltite w. flame struct's.
- N.E. section
- Probable disrupted algal layering (bituminous) in frags.
- Tr. sphalerite in white dolomite fillings in N.E. section.

-280

About 75 feet offset here. Upper part S.W.

Minor calcite as last filling in dolomite-lined vugs.

Tr. sphalerite?

About 30 feet offset here. Upper part S.W.

-440

-480

x — Tr. sphalerite in breccia fillings.

-520

11 OF 1

-520

Intercrystalline bitumin
in some fragments

-560

C

-600

C

12 OF

-640

C

-680

-720

C

13 OF

-680-

-720-

C

C

C

-1040-

C

Approximately
290 feet stratigraphic
thickness between
these outcrops,
based on altimeter
readings and dip
estimate.

14 of 14

LARGE SCALE BRECCIAS AND ZINC-LEAD MINERALIZATION

DISTRIBUTION AND NATURE OF BRECCIAS

Large volumes of brecciated rock, cutting across as much as 700 feet of stratigraphic section, are found in a number of places on the Robb Lake Property. Although the writer was able to devote only very little time to the study of these breccias in the course of his overall stratigraphic and sedimentological study, they deserve special attention not only because they are a particularly dramatic result of diagenesis in these rocks, but also because they contain all but an insignificant percentage of the zinc-lead mineralization, the discovery of which led to this study.

Based on distribution in outcrop, these large-scale breccias seem to be limited stratigraphically to a broad zone between about 600 feet above the bottom of Unit 2 and 200 or 300 feet below the top of Unit 3. The breccias seem to achieve their greatest lateral extent in certain parts of this zone which must have been particularly susceptible to brecciation. One of these particularly susceptible intervals is from about 230 to 320 feet above the bottom of Unit 3 (page 3-199). Chaotic

breccia occurs within this interval in two measured sections (Y and P), it is suspected in two others, where covered, (G and K) and it was observed in a number of exposures elsewhere that are at about the same stratigraphic level. A second particularly susceptible interval seems to be the upper 300 feet or so of Unit 2, although not the topmost few beds. The first 100 feet or so below the thin-bedded interval at 400 feet below the top of Unit 2 may also be preferentially brecciated to some degree. However, this part of the section is not exposed for inspection in most accessible locations (Fig. 2-5). All three of these apparently particularly susceptible intervals contain massive or thick-bedded, mainly subtidal deposits (Fig's. 3-1, 3-5).

The large-scale breccias are irregular in shape. The bottom parts of a number of them are covered, but the shapes of several large ones can be outlined on the southwest side of Tennessee Mountain (Fig. 2-6). There, the largest bodies of brecciated rock seem to be elongate perpendicular to bedding, at least in the surface exposed (Plate 1.1-b). Another relatively well exposed major breccia extends most or all of the way down the south side of Texas Ridge at the head of Mississippi Valley (Fig. 2-6; Plate 1.1-b). The exposed portion of this breccia is elongate more parallel to bedding.

than across it. Brecciation extends more than one thousand feet along bedding while cutting across 200 or more feet of section, moving up-section as it descends the mountain.

The fragments composing the large breccias range in size from a millimetre or less to several metres in longest dimension. In some cases, considerable volumes of consistently relatively fine or coarse breccia can be observed but in many cases a wide size range occurs within a few square feet of outcrop (Plates 4.1-a, b, c; 4.2-a, b, d, f; 4.3-g). A few fragments show slight rounding but most show none. The most distinct and extensive rounding observed by the writer is exhibited by subangular-to-angular, cobble-sized fragments in a matrix of much finer, very angular fragments and cement in a side "pocket", not typical of the bulk of the adjoining large breccia (Plates 4.2-a through g, and see below).

The cores of the major breccias are polymictic, containing a mixture of fragments of a great variety of dolostone lithologies. Most of these lithologies can be recognized as occurring at one or more stratigraphic levels in the measured sections, stratigraphically higher, than the level of the breccia fragments. Particularly noticeable in

certain places, however, are fragments of shale and finely laminated, very shaly carbonate rock. While these lithologies are known in Unit 3, above the level of their location in the breccias, they are rare. In a few cases, such shaly fragments have been bent or squeezed between other fragments, showing that they were somewhat plastic at the time of emplacement in the breccias (Plates 4.1-b, 4.3-e).

Sparry white dolomite most commonly fills the interstices between fragments, particularly in relatively coarse breccia (Plates 4.1-a, b; 4.2-h; 4.3-h). However, a black-looking matrix takes the place of the white dolomite cement in a number of places (Plate 4.1-c). On close inspection, this matrix is seen to be composed of innumerable very fine fragments, cemented by overgrowths and a limited amount of interstitial dolospar and quartz (Plates 4.2-f; 4.3-a through e). Some of the very fine fragments are black and nearly to entirely opaque in thin section (bituminous shale?) but much of the dark colour of this matrix can be accounted for by dark and medium-dark grey, fine to microcrystalline dolostone fragments and occasional shale fragments of similar colour. Interstitial and fragment-coating pyrite specks and other (bituminous?) opaques also contribute to the dark colour. In the lower parts of at least two breccias, this kind of matrix grades in places to what appears to be a sedimentary, fine-crystalline dolostone matrix, commonly containing abundant fine dolostone fragments.

Near the tops of the breccias inspected by the writer, as well as at their edges and where they narrow in resistant horizons, the fragments become less varied, grading to fragments of a single lithology, evidently only a little out of their bedded locations (Plate 4.2-h). In some places, this simpler breccia takes on a "crackled" appearance, with fragments essentially in their bedded positions. This pattern grades to white dolomite veins in intact dolostone, with some brecciation of vein wall material.

The large-scale collapse of bedded rock into the tops of the large breccias can be seen at and near the top of the southwest face of Tennessee Mountain (Plates 1.1-b; 4.1-d; 4.3-g).

ORIGIN OF BRECCIAS

The major breccias (containing most of the zinc-lead mineralization) cut across hundreds of feet of stratigraphic section and contain juxtaposed fragments which must have originated a considerable stratigraphic distance apart. The tops of several large breccias are no more than about 300 feet below the top of Unit 3 (perhaps less, outside the cross-sections viewed); the polymict core zones of these breccias are well within Unit 3, and at least two breccias (probably more) cut

across the contact between Units 2 and 3. These facts point to development of the breccias after the deposition of Unit 3.

All the common forms of white dolospar found in the bedded sequence are found in breccia fragments and are cut off at fragment borders. These include zebra structure, in many cases entirely filled with the usual dolospar pattern (grown gradually from the walls of the cracks). Thus, large-scale brecciation occurred after the formation of zebra structure and the precipitation of most of the white dolomite in the normal, bedded sequence.

Evidence from Unit 4 (page 3-254) indicates that a considerable amount of relief (on the order of 150 feet, at least) developed on the top of Unit 3 during what must have been a prolonged period of subaerial exposure. Moreover, the higher parts of this topographic profile remained exposed during deposition of much of Unit 4 in the course of a very gradual, halting marine transgression.

On the basis of both modern and ancient examples, the fresh water phreatic zone which existed beneath the land surface and adjacent coastal zone during this long period of emergence could easily have extended deeper than the 1800 feet or less between the top of Unit 3

and the lowest known large-scale brecciation in Unit 2, even without the occurrence of particularly high rainfall. It is reported, for example, that the fresh water lens in the dry, low-lying, Houston-Galveston area of the Texas Gulf Coast is as much as 2500 feet thick (Dunham, 1969, p. 162).

With the establishment of an entirely fresh and actively circulating pore water in the rocks in question during this period of emergence, conditions must have become more favourable for the dissolution of relatively susceptible parts of the stratigraphic section than at any other time in the history of these rocks. This is true regardless of what the composition of the dissolved rocks may have been and regardless of whether initial relative permeability differences played an important role.

The combination, then, of geometric and lithologic evidence (pages 4-1 to 4-6) and hydrologic considerations strongly supports the contention that, 1) the major breccias on the Robb Lake Property formed between the end of Unit 3 deposition and the burial of most of the area beneath marine deposits late in Unit 4 time, 2) these breccias formed mainly by solution of rock and collapse of overlying and adjacent

rock, 3) the fresh pore water that must have existed at this time was the dissolving agent involved.

In spite of the evidence cited above, other mechanisms which might be suggested as capable of producing these breccias deserve further comment. First, tectonic brecciation is said to have been suggested by some who have visited the Robb Lake area. To the writer, the negative evidence in regard to this idea is impressive. Regardless of the orientation of their longest dimensions, the larger breccias are cross-cutting on a large scale: that is, they are not localized in a particular zone or zones where bedding-parallel relative movement might have taken place during deformation. At the same time, although the breccias are commonly well-fractured, there is a notable absence of any evidence of major, cross-cutting faults or of widespread shearing. In this regard, it should be remembered that these rocks were lithified and received at least most of their white dolomite cement during Middle Devonian time, well before the first orogenic tectonics began in this region. The normally bedded dolostones are also quite well-fractured (page 2-2). However, more thorough fracturing might be expected in the breccias, after their complete cementation, due to their isotropy during deformation (as a result of lack of bedding).

With these facts in mind, it is difficult to imagine how such irregularly shaped breccias, with such highly polymict core zones, could have formed tectonically. In addition, the major breccias are not positioned along the axial planes of folds (although at least one does occur in this location), nor are they arranged in any other recognizable pattern with respect to the structural framework. On the other hand, on the basis of the limited paleogeographic information available, the distribution of the breccias does seem to be related to the topography of the post-Unit 3 unconformity (page 4-16).

It is true that after their formation and prior to the filling of much of their porosity, the breccias were mechanically weak and also provided open passages where fluids under high pressure could collect under certain circumstances (page 4-18). There is evidence that a limited amount of structural modification did take place at this time (page 4-18).

Certain breccias in the Robb Lake area have been described, at least informally, as penecontemporaneous "slump breccias". The bottom parts of at least two breccias containing ore-grade mineralization higher up (the TG breccia and the Cascade Showing breccia) have been included in this category. This interpretation has probably been suggested

because some of the matrix of these basal parts of breccias consists of grey, very fine-crystalline dolostone (grading in part to the dark, finely fragmental matrix already described: page 4-4). However, the fragments generally appear to be just as angular and undeformed as those in the "normal" breccias (as described on page 4-3), suggesting lithification prior to brecciation. The fine dolostone matrix was obviously emplaced by a sedimentary process. In part, it contains abundant fine, angular dolostone fragments and in part it appears quite uniform.

These so-called slump breccias are not widespread in any of the stratigraphic units; nor do they appear to favour any particular stratigraphic horizon. Rather, they seem to be restricted to the lower parts of large breccias. Moreover, the evidence from this study indicates that Units 2 and 3 were deposited on very gently sloping to level mudflats in an environment which was both tectonically and depositionally quiet. Slumping on the scale of these breccias is highly unlikely in such an environment.

The writer believes that the above considerations, taken together with the evidence previously stated for the origin of the large breccias as a whole, lead to the conclusion that the so-called "slump breccia"

portions of the large breccias on the Robb Lake Property were formed not as penecontemporaneous slumps which might provide weak zones leading to later brecciation but rather as accumulations of collapsed and sedimented debris in the bottoms of already-formed, coarsely, perhaps cavernously porous solution breccias. Some of the fine dolostone matrix resembles some of the lithologies found in Unit 4 (q.v.), particularly certain of those deposited in the early, relatively restricted phase of Unit 4 deposition. It is possible that there was communication with the depositional surface at the time of the Unit 4 transgression and that some marine and/or surface-residual sediment found its way into the breccia porosity, which was certainly considerable at that time. However, it is perhaps more likely that the fine crystalline dolostone matrix, commonly argillaceous, was sedimented (as carbonate, silt, clay minerals and some coarser debris) from the waters which apparently filled the voluminous cavity space of the breccias continuously from the time of their formation to the time of their virtually complete cementation. (See page 4-15 .)

As far as the writer is aware, fossils are not found in this matrix material. Although the writer has not seen any sedimentary structures indicative of slumping in the breccias, such structures would surely be more likely to develop in the already-formed breccias,

where steeply sloping cavities might occur and late collapse events could disrupt sediment on collapsing blocks, than on the near-level, stable surface of the original mudflats.

Once it is accepted that the bulk of the large-scale brecciation was caused by solution and collapse of rock under the influence of "ground water" of meteoric origin, then another question arises: are the breccias the result of the presence of some particularly soluble rock-type where brecciation took place? This question is of special interest due to, 1) a common tendency to ascribe non-tectonic, post-depositional breccias in carbonate rocks to the former presence of evaporite minerals (on evidence varying from nil to conclusive), 2) an increasingly well-publicized and evidently somewhat successful attempt to genetically relate carbonate-hosted zinc-lead mineralization resembling that at Robb Lake in many respects, to gypsum and/or anhydrite (e.g., Pine Point, N.W.T., - Jackson and Beales, 1967; Tri-State District, Mississippi Valley - Beales, 1976).

Certainly it would not be surprising to find that some gypsum had been precipitated, at least locally and occasionally, in a carbonate mudflat environment such as that in which Units 2 and 3 were deposited. On the other hand, it is clear that the highly hypersaline pore or

surface waters that are required for gypsum (or anhydrite) precipitation are by no means characteristic of all such shallow water to supratidal carbonate environments.

Actually, in a few places in Unit 3, textures can be observed which are probably best explained as resulting from penecontemporaneous growth of gypsum or anhydrite in a desiccating, soft sediment (page 3-207). However, if so, the evaporite minerals must also have been removed either by solution or replacement well before the formation of the major breccias, as typical, early white dolomite now takes their place (ibid.). It is perhaps possible, too, that minor amounts of scattered gypsum or anhydrite crystals were precipitated penecontemporaneously at a number of stratigraphic horizons; that they were dissolved or replaced soon after, and that they have left no traces of their existence that have been recognized thus far. The abundant evidence of the repeated, extensive effects of fresh water, however, and the evidence for a brackish, rather than hypersaline, lagoonal water argue very strongly against extensive evaporite precipitation in the sediment (pages 3-103; 3-118, et seq.; 3-204).

It was suggested to the writer during his field work that zebra structure (page 3-57) was formed by evaporite mineral growth. There

is textural and structural evidence that this was not the case (pages 3-240 and 3-276). Moreover, even if the zebra structure were formed in this manner, it was filled, instead, with white dolomite before the large breccias were formed, as was nearly all other porosity present earlier (pages 3-133; 4-6). Even supposing this fact could be ignored, it must be recognized that, common though patches of zebra structure are, and although they are occasionally disrupted into small "pocket breccias" (formed much earlier than the large breccias), they simply are not large or continuous enough to have caused the large-scale collapse-brecciation by solution of their white-layers.

There is, then, no evidence at all that massive or bedded evaporites, the solution of which could cause the major breccias, ever existed in Units 2 and 3. There is, on the other hand, considerable evidence that they did not. Moreover, the evidence suggests that any minor gypsum or anhydrite that may have been formed was removed and replaced by white dolomite prior to formation of the large breccias.

As the major breccias were not formed by the solution of evaporites, was there some other relatively soluble rock involved? This question cannot be answered conclusively on the basis of the evidence available. Limestone remnants, small or large, are found in parts of the most

commonly brecciated stratigraphic intervals (Fig. 2-5 and page 4-1) and close to at least two large, mineralized breccias (the North Face Breccia and the T-G Breccia). The writer has noted no limestone breccia on the property, however, and the limestone remnants, where observed, pass to un-brecciated dolostone at their borders. It is thus possible that preferential solution of limestone led to the large-scale brecciation, but convincing evidence is lacking. By analogy with the extensive cavern systems which have developed in dolostones under the present land surface in several parts of the world, it is certainly possible for major solution features to form in dolostone, itself, presumably controlled mainly by permeability differences, and unknown, minor differences in solubility.

In conclusion, the evidence indicates formation of the major breccias by solution of carbonate rock, with solution probably favouring the most permeable, and perhaps most soluble, layers. The notable lack of deposits indicating fluvial transport in the breccias and, equally, the lack of travertine and associated rapidly precipitated "cave deposits" point to the formation of these breccias by "intrastratal" karstification (Quinlan, 1972, p. 159), with phreatic water always filling all porosity and without the opportunity for the development of underground streams or rapid currents that could transport material

larger than silt size. Such a hydrologic regime is not surprising, if the study area never rose far above sea level and were never far from a sinuous, perhaps partly surrounding marine shoreline. This kind of setting seems indicated for early Unit 4 deposition (page 3-235) and a much greater thickness of Unit 4 equivalent (Dunedin Formation) at Mount Bertha, a few miles to the north, suggests that the Robb Lake area may have remained emergent much longer than neighboring parts of the outcrop belt, prior to Unit 4 deposition.

As the sea gradually transgressed into the study area during Unit 4 time, a point must eventually have been reached where the fresh water lens began to be displaced by marine phreatic water. This process must have continued, perhaps with minor reversals, until the entire area was submerged at the beginning of Besa River time (in this area) or shortly before. It may be that cementation of the breccias with white dolomite began during this period, contemporaneously with, and by the same mechanism as the dolomitization-lithification of Unit 4 rocks (page 3-271). Cementation might have begun in this way in some breccias, while other breccias, still beneath emergent parts of the area, were still forming.

It is not demonstrable from available evidence, however, that

cementation of the breccias did begin as early as this. Certainly, there is clear evidence of later precipitation of white dolomite (with minor sphalerite and galena) in fractures and small brecciated and/or dissolved-replaced zones cutting across white dolomite cement and pre-lithified dark dolostone in upper Unit 4 (Plates 3.54-a, b, d; 3.55-c). Also, the lack of iron or inclusion zoning in most of the breccia-cementing dolomite studied in thin-section suggests that this white dolomite may have a different origin from the sparry cavity fillings in the un-brecciated section.

As these rocks were deeply buried beneath marine sediments after Unit 4 time and remained buried beneath a seal of relatively impermeable shales until Tertiary or even Quaternary time, the later white dolomite probably precipitated from subsurface fluids not in communication with either marine or meteoric waters. A likely source of such subsurface fluids is the overlying shales and whatever laterally equivalent shales were close enough so that fluids from them would follow this route out of the deepening basin. Unlike the early-lithified limestones, the shales would have trapped great volumes of water upon burial and this water must have been expelled during compaction or lithification of the shales to their present state. Lithification presumably began as soon as a significant amount of sediment accumulated over the shales in

question. However, it is now well known among petroleum geologists that abnormally high fluid pressures, sometimes approaching lithostatic pressure, can develop and be maintained over long periods of geologic time in deeply buried sections containing thick, sealing shales (e.g., Bradley, 1975). Such conditions exist today, for example, in the Gulf Coast Area of the U.S.A. (Early Tertiary), in the Mackenzie Delta (Tertiary) and on the continental shelf of Nova Scotia (Late Jurassic-Early Cretaceous).

If, as seems likely, a significant amount of porosity remained in the breccias when buried deeply and sealed by shales, then water in the breccia porosity could develop much higher pressures than the normal hydrostatic ones. Hydraulic fracturing caused by such pressures locally exceeding lithostatic has been cited as an important process in some areas (e.g., Masson, 1972). This hydraulic fracturing by formational water seeking release may explain the white dolomite-filled "crackle" breccia and breccia veins which were observed near the tops of several large breccias as well as the white dolomite veins and local dissolved-to-brecciated zones (some of them mineralized) in Unit 4. The formational water may have contained an abundance of dissolved hydrogen sulphide at least during a certain period its history. This, along with elevated subsurface temperatures, may explain the evidently

corrosive nature of the fluid which either preceded or carried some of the white dolomite (and traces of sphalerite and galena) precipitated in Unit 4 (Plate 3.54).

NATURE AND ORIGIN OF ZINC-LEAD MINERALIZATION

As the study of the zinc-lead mineralization, itself, was not among the purposes of this thesis project, the following will necessarily be a brief and incomplete account. However, the implications of the evidence and interpretations from this project with regard to the zinc-lead mineralization require some comment.

The principal zinc and lead minerals on the Robb Lake Property are the sulphides: sphalerite and galena. Minor amounts of oxidation products of these minerals, probably including hydrozincite, are common on weathered exposures.

As far as the writer is aware, all zinc and lead on the property occur in breccias or in white dolomite veins or pods either cross-cutting or following bedding. The bulk of the sphalerite and galena occur as coarse crystals in white dolomite cementing the breccias. Locally, all inter-fragment space is cemented by sphalerite, with minor galena. Fractured to brecciated sphalerite

is not uncommon and may be due to hydraulic fracturing after precipitation (page 4-18). Geopetal sphalerite textures (the so-called "snow on roof texture" occur in some places, both in the major breccias and in brecciated pods associated with mineralized veins (Plate 4.3-f). These show gravitational settling of crystals in the precipitating brine.

In a few places, a limited amount of replacement of breccia fragments by sphalerite and lesser galena has occurred. This sphalerite tends to be finer-grained than that in the cement. Clustering of sphalerite around breccia fragments, particularly dark-coloured ones, is quite common and suggests that the effect of the fragments on the chemistry of the precipitating solution was often such as to encourage the precipitation of sphalerite. It may be that abundant interstitial organic material (and lesser pyrite?) in the fragments caused a film of chemically more reducing solution around them. Certainly such interstitial material is abundant today in many of the dark-coloured beds, particularly in Unit 4 (q.v.).

The abundant, densely clustered sphalerite in the best showings in the cores and lower parts of breccias tends to be honey-coloured to very slightly greenish. Minor occurrences in veins and pods, generally above the stratigraphic level of the better showings, tend to consist

of brownish-red or reddish-brown sphalerite, however. Pyrite, some of which was formerly marcasite (page 3-222), occurs near or with the ore minerals in some places.

From the Unit 4 equivalent at other localities on trend with the Robb Lake Property, the writer has seen fine-grained, brownish sphalerite which is said to be of syngenetic origin. Although discussion of this mineralization is beyond the scope of this thesis, the writer has good reason to believe that it is not actually syngenetic and that it probably had a similar origin to the Robb Lake mineralization. In any case, no sphalerite of this type occurs at Robb Lake, to the writer's knowledge.

What, then, is the origin of the zinc-lead mineralization at Robb Lake? Clearly the sphalerite and galena were not emplaced until after the formation of the breccias. The (minor) mineralization in upper Unit 4 was not emplaced until after lithification of that part of the section. Thus, none of the mineralization could have been emplaced before some time during Unit 4 deposition and that in Unit 4 must have been emplaced after Unit 4 time, whether by remobilization from below or by introduction from an external source.

In view of the lack of any evidence of syngenetic mineralization in any of the stratigraphic units; in view of the lack of any obvious mechanism or source for mineralization contemporaneous with or immediately following formation of the breccias (in Unit 4 time), and in view of the likelihood of the passage of considerable volumes of ion-rich waters from overlying (and adjacent?) shales after burial of the carbonates (page 4-17), precipitation of the metal sulphides (and much or all of the breccia-cementing dolomite) from metal-rich formational waters derived from basinward shales of younger and/or equivalent age seems by far the most likely mode of origin for the mineralization. Shales as a whole are known to be metal-enriched as compared to other sedimentary rocks and certain shale horizons can be highly enriched, as several studies have shown (e.g., Jackson and Beales, 1967). Moreover, volcanic activity is more likely to have affected the basinal shales than the carbonate platform, providing the possibility of enrichment of the shales from volcanic sources. The writer has seen volcanic material in the northern extension of this shale basin, in the Yukon Territory, both in Ordovician and in Middle to Upper Devonian parts of the sequence. It is rumored that volcanics have also been identified in Devonian shales to the west of the Robb Lake Area.

It is uncertain whether sufficient sulphide could have been present

in these rocks or moved from down-dip to the west, to allow the precipitation of the amount of sphalerite, galena and pyrite present. The writer is inclined to think that there was a sufficient amount and that the amount available was a major limiting factor controlling the amount of metal sulphide precipitated. It is perhaps also conceivable, however, that sulphate-bearing waters from the east could have made their way to the area under the shale seal, as in the model of Jackson and Beales (1967). Abundant sulphate-reducing bacteria could well still have been present at this time in the organic-rich Unit 4 rocks.

IMPLICATIONS FOR ZINC-LEAD EXPLORATION

The most important implications of the foregoing interpretations for exploration elsewhere in this region are as follows:

- 1) The occurrence of significant amounts of zinc-lead mineralization depends upon the existence of significant amounts of connected porosity in the carbonates at the time of mineralization. This means secondary porosity in breccias and fractured zones, as very little primary porosity remained at the time of mineralization. Development of further porosity by hydraulic fracturing required the prior existence of considerable porosity caused by solution collapse or, later, by tectonic stresses (a possibly important factor at some localities other than Robb Lake).

2) The large solution breccias at Robb Lake, which seem to have provided a larger amount of porosity at the proper time than any other known feature of the Devonian rocks of Northeastern B.C., are controlled in their geographic distribution by the distribution of the significant unconformity which overlies them. They would be expected to be best developed under areas which remained emergent longest, following deposition of Unit 3 (the upper Stone Formation). Indeed, even on the Robb Lake Property, the major breccias seem to occur in an area never covered by more than a few feet of Unit 4 beds and in part possibly never covered in Unit 4 time at all (page 3.259, et seq.).

3) The amount of zinc and lead sulphides precipitated in available porosity probably depends to an important degree on the amount of reduced sulphur available. If, as may be the case, this is controlled in large part by the amount of organics present in the area of precipitation, then this places a severe limit on the amount of mineralization that can be expected in any one locality and perhaps suggests that an ore deposit of large tonnage is unlikely in this setting.

4) Providing the requirements of porosity and proper chemistry can be met, however, supply of metals does not seem to be a problem, i.e.,

contrary to the theories of those who would derive the metals from the dolostones, themselves: trapping, rather than supply, seems to be the critical factor for these deposits.

With regard to detailed exploration on the Robb Lake Property, the following implications of this study are probably most important:

1) As the distribution of the breccias does seem to be related to the Unit 2 - Unit 3 unconformity, it is reasonable to look for more orebodies in the direction of thinnest Unit 4 and not where Unit 4 thickens. Unfortunately, paleogeographic control is very limited. However, major breccias would be much less likely under the Halfway River Valley, to the south, than to the west of Mississippi Valley, even well under the thrust plate of older rocks, on this basis.

2) Very irregularly shaped breccia bodies, intermittently and variably mineralized from one part to another, are to be expected.

3) There seems to be no reason to think that the best of the known mineralization consists of satellite or remobilized deposits indicative of a larger and/or higher-grade orebody yet to be found.

All three of these implications have apparently become clear or been tested to a large degree in the course of exploration on the property.

4.1

a. Polymict breccia with wide fragment size range: lower-middle Unit 3, southwest side of Tennessee Mountain. Staff is five feet long, marked in tenths of a foot.

b. Polymict breccia with a bent, carbonate-rich shale fragment (very argillaceous dolostone?) and locally very quartzose cement: lower-middle Unit 3, southwest side of Tennessee Mountain.

c. Black "matrix" of very fine fragments and cement in large-scale breccia: lower-middle Unit 3, southwest side of Tennessee Mountain. (See text.)

d. Collapsed block of bedding (centre, middle distance) at top of a large breccia body: top of southwest side of Tennessee Mountain (middle to upper Unit 3).

b

d

a

c

PLATE 4-1

4.2

- a. Conglomerate-like breccia in a side "pocket" in a large-scale breccia: close to Unit 2-Unit 3 contact, near "Waterfall Showing", southwest side of Tennessee Mountain. Note crude rounding of largest fragments (clasts). The boulder marked with an "x" is approximately 15 inches (38 cm.) in longest dimension.
- b. Closeup of part of breccia outcrop in (a), showing rounded, large clasts; wide fragment size range; angular small fragments.
- c. View uphill to the breccia exposure in (a) and (b). Note remnants of bedding at top edge of photo; breccia below.
- d. Another closeup of the breccia exposure in (a) through (c): hammer head is in a rounded mold which surrounded a boulder now removed.
- e. Uphill view from well below top of Unit 2. Breccia outcrop in (a) through (d) is shown by arrow at upper left.
- f. Typical matrix material from breccia shown in (a) through (d). Note presence of a variety of the common lithologies of Units 3 and 2. Some fragments have corroded, dissolved-looking borders but a majority have more even, angular borders. Sizes range continuously down to the finest visible sizes. Note dark overall colour of fine-sized material. (Polished surfaces.)
- g. View downward and westward toward the outcrops in (a) through (d). Arrow at lower left points to outcrops in (a) through (d). Note abnormally steeply dipping (collapsed) beds just to right of breccia exposure.
- h. "Crackle"-type breccia with pure, white dolospar filling and fragments of uniform composition: from top of a large breccia body, at the bottom laminoid-fenestral zone of Unit 3, Section G.

a

b

c

d

e

f

g

h

PLATE 4·2

- a. Matrix material in specimens of Plate 4.2-f. Note quartz cement (white); dolomite cement and overgrowths; fragments of coarse to fine-crystalline dolomite; dark, bituminous(?), microcrystalline carbonate fragment with very irregular borders (upper right); other dark fragments (possibly somewhat soft when emplaced?); black to very dark grey, bituminous coatings on many clasts; a few scattered pyrite specks (black). Thin section, plane light; scale bar shows one millimetre.
- b. Another part of same breccia matrix as (a). Note coarse-crystalline dolomite fragments distinguishable from overgrowths by slightly darker colour; discontinuous coating of opaques on fragments; scattered quartz crystals (probably grains with small overgrowths); abundant fine fragmental material (mostly dolomite) as well as dolomite cement. Thin section, plane light; scale bar shows one millimetre.
- c. Another part of breccia matrix in (a). Coarse dolomite fragment is a single crystal, including the piece broken away and slightly separated from the main fragment, at top. Also note several fine-crystalline dolomite fragments; matrix composed mainly of fine dolomite fragments with a few quartz grains and minor cementing quartz and dolomite. Thin section, plane light; scale bar shows one millimetre.
- d. Another part of breccia matrix in (a). Note oblong, pyritic shale fragment (bottom-middle); unidentified black fragment (upper left); extensive quartz and dolomite cements; coarse and fine-crystalline dolomite fragments. Thin section, plane light; scale bar shows one millimetre.
- e. "Smeared out" shale fragment (horizontal) and undeformed probable calcareous shale fragment (right-middle); quartz and dolomite cements; dolomite fragments of varying crystal sizes: same breccia matrix as (a). Thin section, plane light; scale bar shows one millimetre.
- f. Locally brecciated "pocket" adjacent to a large, cross-cutting white dolomite vein: upper Unit 3, Location S. Note reddish brown sphalerite emplaced geopetally atop host rock fragments but separated from the fragments by a thin layer of white dolomite. (See especially the upper right part of photo.)
- g. Largely brecciated exposure near top of southwest side of Tennessee Mountain; vestiges of bedding, with dips reversed back into hill, in middle; assistant at lower left shows scale.
- h. Large breccia blocks exposed in streambed on southwest side of Tennessee Mountain, above the "Waterfall Showing." Hammer at centre has handle one foot long.

a

b

c

d

e

f

g

h

PLATE 4.3

SUMMARY AND CONCLUSIONS

At the Robb Lake Property, in the front range of the Rocky Mountains in Northeastern British Columbia, approximately 2,400 feet of carbonate rocks lie between the top of the Silurian Nonda Formation and the bottom of the mainly Upper Devonian Besa River Formation. Although the bulk of this thick carbonate section consists of initially monotonous-looking dolostone beds, the section can be subdivided into four locally mappable units which can be correlated lithologically with three formations defined farther north (Taylor and Mackenzie, 1970).

LITHOLOGIC PATTERNS AND DEPOSITIONAL HISTORY

The lowermost unit is correlatable with the Wokkash Formation, believed to be of Lower Devonian age. It disconformably overlies the Nonda Formation and grades from moderately to extremely quartz-sandy dolostone, upward, in the bottom part. The middle portion of the unit consists mainly of layers of large, planar cross-beds formed of extremely quartz-sandy dolostone to dolomitic sandstone also containing carbonate sand grains. The upper portion of the unit consists of a variable thickness (thirty feet where measured) of thick, massive

orthoquartzite layers, grading upward to lenses and layers of quartz sandstone in very quartz-sandy dolostone. Irregularly distributed but extensive quartz cement and clay matrix at the top of the unit suggest a period of emergence and erosion prior to deposition of the next unit.

The rocks of Unit 1 were probably deposited during a gradual transgression over the emergent Nonda surface, followed by a period of time in a belt of bars and shoals along an exposed shoreline and then a new shallowing and decrease in current activity, perhaps in an increasingly sheltered area landward of increasingly extensive shoals. Petrographic data suggest derivation of at least part of the quartz sand from an older sandstone. Potential sources are the sands in the Silurian section and the Cambrian and older clastics exposed at this time to the southeast and perhaps to the east. Longshore currents are the most likely means of transport into the study area.

Unit 2 begins with several thin, fine-crystalline, laminated beds lying on the surface of Unit 1. The rest of the bottom fourth of the unit consists mainly of fine-to-medium-fine crystalline, thick-to-medium beds of quartz-sandy dolostone. At least near the bottom of the unit, these beds contain traces of small, rather delicate fossil fragments, probably somewhat worn.

About 250 feet above the bottom of Unit 2, there is an abrupt disappearance of quartz sand (except for traces found in insoluble residues). In the next 400 to 500 feet, viewed from bottom to top, an alternating pattern gradually appears, consisting of one or more thick layers of medium or medium-fine crystalline dolostone followed by one or more thin layers of fine-crystalline, commonly fenestral dolostone. This pattern is well-developed in the upper 300 to 400 feet of the unit.

Zebra structure is common in the thick layers and many of the thin, fine-crystalline layers contain formerly micritic intraclasts, laminoid-fenestral fabric, discontinuous, fine laminae and/or micro-unconformities. Above about 360 feet from the bottom of the unit, large terebratulid brachiopods (but not Stringocephalus) are dispersed in many thick, medium-crystalline beds. These ill-preserved fossils are intact, commonly bivalved, and apparently occur approximately where they lived. They are particularly abundant in the top 250 feet of the unit. Less common are smaller, even more poorly preserved brachiopods, probably a different kind, and large gastropods, both in the same kind of medium-crystalline, thick beds.

Thick, medium-to-medium-fine crystalline dolostone beds can be traced into local remnants of microcrystalline limestone in the top

200 feet or more of the unit. There the large terebratulid brachiopods can be seen to occur in a matrix of pelmicrite or pelmicrosparite, commonly with numerous intact amphiporid skeletons and a few scattered fine fragments of delicate fossils such as ostracodes and trilobites.

The cyclic alternation of lithologies is interrupted in several places by thicker than usual intervals of thin beds. Some beds in such intervals are coarse crystalline and show other evidence of a particularly strong overprint of early diagenetic effects. Mudcracks were also found in one such interval.

An intertidal to lower supratidal mudflat environment of deposition is indicated for the fine crystalline, thin part of the cyclothems developed in the upper part of Unit 2. The thicker, coarser crystalline portion of the cyclothems must have been deposited subtidally, in a shallow, lagoonal environment sheltered by a seaward barrier system to the west or northwest. Minor disconformities and associated diagenetic effects indicate a period of subaerial exposure, of variable but relatively short duration, in most cycles. Disconformities occur most commonly at the top of the subtidal member so that most intertidal deposits were formed during the transgressive phase.

The cyclical, relative rise and fall of sea level implied by this depositional pattern was clearly superimposed on an overall subsidence of the area, allowing the deposition of a considerable thickness of sediments. Although other explanations are possible, it seems most likely that the cyclical pattern is due to widespread cyclical changes in sea level unrelated to local tectonics.

Although the data are relatively scanty, the lower half of Unit 2, which is not noticeably cyclic, appears to have been deposited under sheltered, perhaps highly restricted, lagoonal conditions where the principal organisms were numerous soft-bodied burrowers. The abundant quartz sand in the bottom 230 feet of the unit is likely to have been derived from the landward side of the area and the abrupt disappearance of quartz sand above this level probably marks the time when transgressing lagoonal and supratidal deposits finally covered the nearby areas of exposure of Unit 1.

The top of Unit 2 probably marks a somewhat more prolonged period of subaerial exposure than between normal cycles. However, a disconformity of more than local significance and short time span does not seem to be indicated.

Unit 3 begins with a distinctive bioturbate zone and a number of laminoid-fenestral, dark-coloured, fine-crystalline beds. These are overlain by a variable, but considerable, thickness of predominantly thin and fine-crystalline beds showing considerable lithologic variety as compared to Unit 2. Mudcracks and ripple marks occur in a number of places in this basal zone.

There is a gradual transition, upward, to predominantly thick, generally coarser crystalline beds, with numerous interspersed thin, generally finer crystalline, sandy beds. This transition takes place lower in the section on the northwest side of the property than elsewhere. Two or more particularly thick zones of thin beds occurring above the basal part of the unit appear to be correlatable across most or all of the property. In the upper half or less of Unit 3, a distinctly cyclical pattern like that in upper Unit 2 occurs in the eastern part ~~of the~~ property.

Occasional dolomitized, pebbly calcarenite layers composed of a variety of fossil fragments and abundant quartz sand, commonly with oolitic coatings, are found in the middle to upper parts of the unit on the northwest side of the property. Quartz sand is present in varying amounts in a majority of beds throughout Unit 3. Intact, large fossils like the terebratulid brachiopods in Unit 2 are not found in Unit 3.

The basal beds of Unit 3 evidently represent a prolonged period of intertidal and supratidal deposition following a transgression over the previously emergent surface of Unit 2. Subtidal deposition apparently began again earliest on the northwest side of the property. This, along with the occurrence of fossil debris beds and differences in lithologic pattern higher in the section, indicates that the open sea lay in that direction.

Gradual transgression eventually resulted in deposition of subtidal, lagoonal beds like those in Unit 2, throughout the study area. Several particularly well established periods of predominantly subtidal deposition occurred, separated by particularly prolonged periods of intertidal-supratidal deposition and subaerial exposure. A simple, cyclical pattern of deposition like that in upper Unit 2 existed in middle-upper Unit 3 time on the east side of the property but even there it was complicated by relatively prolonged periods of regression.

The overall lithologic pattern of Unit 3 suggests a regular, widespread rise and fall of sea level, as for Unit 2, after the initial prolonged transgressive phase. However, this must have been complicated by irregular local variations in subsidence rate and perhaps variations in sediment supply.

A seaward source of sediment is indicated for all of Unit 3, with sand being supplied by longshore currents to dunes along a seaward barrier zone on the west or northwest. The general pattern of deposition outlined here probably prevailed until a fairly rapid, major regression of the sea occurred at the end of Unit 3 time.

Unit 4 begins with a few feet of dark grey, fine crystalline, partly sandy and pyritic dolostone in the thicker sections measured. Where the section is somewhat thinner, similar beds can be seen to wedge out locally in one direction and must pass laterally into limestone in another direction. Greywacke-like siltstone and shale layers and diagenetically silicified quartzites are also associated with these basal beds.

In places where Unit 4 is relatively thick, the basal dolostones pass upward to a number of feet of thin and medium-bedded, microcrystalline limestone. This limestone consists largely of micrite and pelmicrite containing scattered delicate fragments of ostracodes, trilobites, echinoids and unidentified fossils, homogeneously distributed as a result of bioturbation. Quartz silt and very fine sand are also common. In the upper part of the limestone section, several beds containing desiccation cracks and other evidence of subaerial exposure are present, as well as occasional calcarenite layers.

The limestones give way upward to mainly medium-bedded and medium-fine crystalline, dark grey dolostone in which an increasing number of biostromal horizons appear, upward. These dolostones overlie the basal dolostones where the unit is somewhat thinner and there is some inter-tonguing of limestone with dolostone from the thickest sections towards thinner ones. The biostromal horizons contain bulbous stromatoporids, stick corals (Dendrostelia?), Thamnopora and occasional unidentified forms, all essentially intact and fossilized approximately where they grew. Enough primary texture can be seen in some thin sections to suggest that the bulk of these dolostones were deposited as pellet "muds" like the limestones, except for certain beds near the top of the unit in the thinnest and most fossiliferous sections. These latter beds have a matrix composed mainly of sand-sized fossil fragments and intergranular bituminous matter. There is an increasing abundance and diversity of fossils both upward in the unit and laterally toward the thinner exposures. A small exposure on the west side of the property exhibits disrupted pieces of organic framework, including tabular stromatoporids and occasional colonial corals.

The topmost few beds of Unit 4 are black, thin-bedded, bituminous and highly pyritic dolostone, with numerous tests of Tentaculites in one top bed at each of two eastern localities.

Thickness and facies variations in Unit 4, and petrographic details, indicate that an emergent surface with local relief on the order of 150 feet existed at the beginning of Unit 4 time. The dark-coloured, sandy and pyritic dolostone beds at the bottom of the unit were probably deposited in quiet-water embayments in the low areas of the topography during the initial marine transgression over the emergent surface. Periods of exposure and soil development at the margins of the new depositional basin are probably indicated by the siltstone, shale and silicified layers.

As the sea level rose further, purer lime muds were deposited, except at the shorelines, and the still-restricted environment became hospitable enough for mobile detritus-feeding organisms. With yet further rise in sea level and more open communication with the sea to the west, biostromes of sessile organisms intermittently colonized the shallow waters near the margins of the gradually enlarging basin of deposition.

By latest Unit 4 time, reefs or reefoid barriers had probably developed on high parts of the buried Unit 3 surface (largely west of the study area) and debris from them was transported into the adjacent parts of the lagoonal basin.

This pattern of shallow-water deposition, with occasional subaerial exposure, was terminated abruptly by a major transgression (pulse of regional subsidence?). A rapid increase in water depth killed the abundant shallow-water organisms and resulted in stagnant bottom conditions and the beginning of Besa River shale deposition.

DIAGENESIS

As the bulk of the thick Devonian carbonate section was deposited near sea level, it is not surprising that leached cavities, crystal silt internal sediment, and other evidence of the effects of meteoric water are common at many levels in Units 2 through 4. However, petrographic details indicate that lithification of the sediment as limestone, under the influence of meteoric water alone, was relatively minor, except locally. Most of the sediment seems to have been lithified concurrently with dolomitization. This occurred early, probably during periods of relatively high sea level, cyclical or otherwise, during Unit 2 and Unit 3 deposition, and while adjacent areas were subaerially exposed during much of Unit 4 deposition. Early dolomitization under these conditions can be explained as a result of the production of low-salinity, high magnesium pore waters by the dynamic mixing of marine

and meteoric waters within the sediment (Folk and Land, 1975). Aside from the positive evidence favouring this mode of dolomitization, the principal arguments against dolomitization by the popular hypersaline "sabkha" model are the lack of evidence of evaporite minerals and the abundant evidence of the availability of fresh water.

Precipitation of white dolomite as a continuation (and repetition) of the dolomitizing process probably accounts for most or all of the white dolospar which entirely fills most early-formed cavities, although some later precipitation of white dolomite in cross-cutting veins and breccias also occurred.

Formation of pyrobitumen in vugs took place after all dolospar precipitation in primary and early diagenetic cavities and probably occurred following migration of petroleum through these rocks after they were deeply buried. Well formed quartz crystals projecting into vugs in all units are of late diagenetic origin, either during deep burial or after more recent uplift.

BRECCIAS AND ZINC-LEAD MINERALIZATION

Large volumes of brecciated rock occur in a number of places in

Units 2 and 3. Although they do follow bedding in places, they are also cross-cutting on a very large scale. These breccias seem to attain their greatest lateral extent in certain intervals which were probably relatively susceptible to brecciation. These intervals appear to have been composed mainly of thick subtidal deposits.

The cores of the large breccias are polymict but the margins, particularly at the tops, grade to monomictic "crackle" breccia and ultimately to in-place bedded dolostone thoroughly veined with white dolomite. White dolomite cement is the most common inter-fragment filling in the breccias but a matrix of poorly sorted, very fine fragments and minor cementing quartz and dolomite can also be found in a number of places. Partially rounded breccia boulders occur in at least one locality.

The collapse of large blocks of bedded rock into the upper parts of large breccias can be observed in several places.

Consideration of the depositional and diagenetic history of these rocks, as interpreted by this study, along with observations of the breccias, themselves, leads to the conclusion that the breccias were formed as intrastratal karst breccias in carbonate rock during the

period of emergence between the end of Unit 3 deposition and late Unit 4 time. There is no evidence for the former existence of the extensive evaporite layers which would have been required to form the breccias by evaporite solution, while the shape, position and internal characteristics of the breccias are difficult to explain as a result of tectonic brecciation. Penecontemporaneous slump brecciation can also be ruled out as a significant mechanism. It does seem likely however, that minor enlargement of the breccias occurred under deep subsurface conditions by means of hydraulic fracturing.

The sphalerite and galena on the Robb Lake Property occur largely in the matrix of parts of the large breccias. Minor amounts of the same minerals are also found in white dolomite veins and pods in un-brecciated strata.

It is clear that none of the zinc-lead mineralization was emplaced until after the formation of the breccias. The writer has seen no evidence on the property for syngenetic mineralization. The most likely source of metals is formational waters derived from overlying (and laterally adjacent?) shales during compaction, deep in the subsurface. The breccias would form natural conduits for such waters and the extension of the breccias by hydraulic fracturing probably also occurred at

this time. Availability of sulphur for fixing the metals was probably an important limiting factor in the amount of zinc and lead precipitated.

CONCLUSIONS

Of the three primary purposes of this thesis study, the first was to describe the petrographic characteristics and stratigraphic patterns of the rocks studied. This descriptive work is summarized in the foregoing paragraphs. In brief, the stratigraphic section between the Silurian Nonda Formation and the Devonian Besa River Formation on the Robb Lake Property consists of four locally mappable lithologic units as follows:

- 1) -a thin, bottom unit of quartz-sandy dolostone grading to dolomitic sandstone, with cross-bedding in the middle part and much relatively pure quartz sandstone in the upper part.
- 2) -a very thick, disconformably overlying unit composed of quartz-sandy, largely fine-crystalline and bioturbate, light-coloured dolostone in the lower part, giving way upward to a cyclical alternation of thick, medium-crystalline beds, commonly with zebra structure and/or brachiopod casts, and thin, fine-crystalline beds, commonly with fenestral fabric, intraclasts, fine laminae and/or micro-erosional structures.

3) -a second very thick, largely light-grey dolostone unit with many thin, fine-crystalline beds, common mudcracks and some quartz sand and silt, at the bottom, grading upward to irregularly interspersed thin beds like those below and thick beds like those in upper Unit 2 but lacking brachiopods and generally containing some quartz sand.

4) -a thin, upper unit unconformably overlying the previous unit and consisting partly of dark grey dolostone and partly of micro-crystalline limestone. Biostromal fossil assemblages occur in places in the upper part of this unit and fragments of thin-shelled, vagile, sediment-ingesting organisms are found in bioturbate limestones lower down.

The second primary purpose of this thesis was to reconstruct the geologic history represented by the rocks studied. The following conclusions, summarized in greater detail in the previous several pages, can be made in this regard:

1) The oldest rock unit described represents a major transgression over the emergent surface of the Nonda Formation, followed by a relatively short period of shallow marine and shoreline deposition (by comparison with the units above) and then (probably) a period of emergence, with at least minor erosion.

2) The lower part of the second unit was probably deposited under sheltered (restricted?) lagoonal conditions, with sand probably supplied from a land source which was abruptly cut off, probably by burial beneath transgressive deposits.

3) The cyclical pattern in the upper part of Unit 2 is due to a cyclical rise and fall in relative sea level resulting in deposition in the intertidal-supratidal zones (thin, fine to microcrystalline beds), then deposition in quiet, shallow, subtidal waters, commonly followed by a short emergence. Extensive overall subsidence of the study area continued at this time, allowing a great thickness of sediment to be deposited under this régime.

4) A somewhat more prolonged emergence than in normal cycles is probably represented by the top of the second unit. However, a disconformity of more than local significance and short time span does not seem to be indicated.

5) Unit 3 time began with a prolonged period of intertidal and supratidal deposition in the study area.

6) Subtidal deposition evidently re-appeared earliest on the northwest side of the property. This, along with several other forms of evidence, indicates that the open sea lay in that direction.

7) Subtidal deposits similar to those of upper Unit 2 account for much of the bulk of Unit 3, with several particularly well established periods of predominantly subtidal deposition. However, several prolonged periods of intertidal-supratidal deposition and some subaerial exposure also occurred. A basic, cyclical pattern of sea level rise and fall evidently did exist, at least much of the time, but its effects were complicated by irregular, local variations in subsidence rate and perhaps in sediment supply.

8) A seaward source of sediment is indicated for all of Unit 3, with quartz sand probably supplied by longshore currents to dunes along a seaward barrier zone on the west or northwest.

9) A major regression of the sea, probably fairly rapid, occurred at the end of Unit 3 deposition. By the beginning of Unit 4 deposition, local erosional relief on the order of 150 feet had developed on the emergent surface. Thus, an unconformity of considerable significance exists in the study area at this stratigraphic level.

10) Unit 4 was deposited during a gradual and somewhat halting marine transgression which first flooded only the low areas of the erosion surface, forming quiet embayments. An increasing percentage of the area was flooded, with time, resulting in better communication with the open sea and a more normal marine environment. Eventually,

biostromal communities of sessile marine organisms (principally corals and stromatoporids) were able to colonize the shallow margins of the local basins intermittently. By very late Unit 4 time, reefs or reefoid barriers must have developed on high parts of the Unit 3 surface (largely a little to the west of the study area) as debris from them was transported into adjacent parts of the lagoonal basin in the study area.

11) The shallow marine, coastal depositional pattern was abruptly terminated by a rapid major transgression which created stagnant bottom conditions at the submerged surface of Unit 4 and was followed by the beginning of Besa River shale deposition.

12) Most (probably all) of the carbonate rocks studied were deposited as calcium carbonate (aragonite, Mg-calcite and normal calcite), largely in the form of lime mud (commonly pelleted) but also including considerable amounts of skeletal sand at certain levels.

13) A minor percentage of the section was lithified as limestone. Most of this probably remains as limestone today.

14) Most of the sediment was lithified concurrently with dolomitization, changing from un-lithified, watery sediment to dolostone.

15) Dolomitization of the bulk of the sediment occurred early, probably during relatively high stands of sea level (subtidal deposition), in the course of Unit 2-Unit 3 deposition. Dolomitization of Unit 4 rocks probably occurred during much of Unit 4 time, while adjacent areas remained emergent.

16) Early dolomitization under these conditions is best explained as resulting from circulation of large volumes of low-salinity, high-magnesium pore waters produced by dynamic mixing of marine and meteoric waters within the sediment. In addition to the positive evidence favouring this model, the principal arguments against dolomitization by the popular "sabkha" model are the lack of evidence of abundant evaporite precipitation and the abundant evidence of the availability of fresh water.

17) White dolomite filled most early-formed or primary voids at an early stage. It probably precipitated as a continuation of the dolomitizing process. Some white dolomite was also precipitated much later, however, in breccias and veins.

18) Pyrobitumen was probably emplaced in pores during migration of petroleum after these rocks were deeply buried.

19) The evidence from this study leads to the conclusion that the large-scale breccias on the Property were formed by intrastratal karstification during the period of emergence between deposition of Units 3 and 4 and continuing until late Unit 4 time. Minor enlargement of the breccias probably occurred under deep subsurface conditions by means of hydraulic fracturing.

20) The zinc-lead mineralization in the study area was probably precipitated in the breccias after deep burial, with metals derived from formational waters issuing from compacting shales.

21) Availability of sulphide for fixing the metals may have been an important limiting factor in the amount of metals precipitated.

The third primary purpose of this thesis study was to set forth the implications of the results of the study for mineral exploration. The following conclusions can be drawn in this regard:

1) Exploration should be influenced by the requirement of adequate connected, late, secondary porosity for the occurrence of significant amounts of this kind of zinc-lead mineralization.

2) The distribution of relatively high areas of the Unit 3-Unit 4 unconformity surface may be expected to control maximum development of breccias and where no unconformity exists breccias of this type

REFERENCES

- Abraham, H., 1966, Asphalts and allied substances (6th edition), Vol. 1: Historical review and natural raw materials: Van Nostrand, Princeton and New York, 370 p.
- Radiozamani, Khosrow, 1973, The Dorag dolomitization model-application to the Middle Ordovician of Wisconsin: J. of Sedimentary Petrology, V. 43, pp. 965-984.
- Bathurst, R.G.C., 1971, Carbonate sediments and their diagenesis: Developments in Sedimentology, No. 12, Elsevier; Amsterdam, N.Y., 620 pp.
- Bonham-Carter, G.F., 1965, A numerical method of classification using qualitative and semi-quantitative data, as applied to the facies analysis of limestones: Bull. Can. Pet. Geol., V. 13, #4, pp. 482-502.
- Bradley, J.S., 1975, Abnormal formation pressure: Am. Assoc. Petrol. Geol. Bull., V. 59, No. 6, p. 957-973.
- Clifton, H.E., and Hunter, R.E., 1973, Bioturbational rates and effects in carbonate sand, St. John, U.S. Virgin Islands: Jour. Geol., V. 81, No. 3, pp. 253-268.
- Collins, J.A. and Smith, L., 1972, Sphalerite as related to the tectonic movements, deposition, diagenesis and karstification of a carbonate platform, in Stratigraphy and Sedimentology, Section 6, International Geological Congress, 24th session, Canada, 1972, Montreal, pp. 209-216.
- Crickmay, C.H., 1960, Studies of the Western Canada Stringocephalinae: J. Paleo., V. 34, pp. 874-889.
- Crickmay, C.H., 1954, Paleontological correlation of Elk Point and equivalents, in Symposium, Western Canada Sedimentary Basin: A.A.P.G., Tulsa, pp. 143-158.
- Deer, W.A., Howie, R.A., and Zussman, J., 1966, An introduction to the rock-forming minerals: Longmans, Green and Co., London, 528 p.
- Douglas, R.J.W., Gabrielse, H., Wheeler, J.O., Stott, D.F., and Balyas, H.R., 1970, Geology of Western Canada, in Douglas, R.J.W., ed., Geology and economic minerals of Canada: Geol. Surv. Can., Economic Geol. Rept. No. 1, p. 365-546.

- Dunham, R.J., 1969, Early vadose silt in Townsend Mound (Reef), New Mexico, in Depositional Environments in Carbonate Rocks, G.M. Friedman, ed., S.E.P.M. Spec. Pub. No. 14, pp. 139-181.
- Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture, in A.A.P.G. Mem. #1, pp. 108-121.
- Fischer, A.G., 1964, The Lofer cyclothems of the Alpine Triassic: Kansas Geol. Surv. Bull. 169, V. 1, pp. 107-149.
- Fisher, D.W., 1962, Small conoidal shells of uncertain affinities, in Moore, R.C., ed., Treatise on Invertebrate Paleontology, Part W (Miscellanea): G.S.A. Press & U. of Kansas Press, pp. 98-143.
- Folk, R.L., 1974, The natural history of crystalline calcium carbonate: Effect of magnesium content and salinity: J. of Sedimentary Petrology, V. 44, pp. 40-53.
- Folk, R.L., 1973, Carbonate petrography in the post-Sorbian age, in Ginsburg, R.N., ed., Evolving concepts in sedimentology: Johns Hopkins University Press, Baltimore, p. 118-158.
- Folk, R.L., 1968, Petrology of sedimentary rocks: Hemphill's, Austin, 170 p.
- Folk, R.L. and Land, L.S., 1975, Mg/Ca ratio and salinity: two controls over crystallization of dolomite: A.A.P.G. Bulletin, V. 59, pp. 60-68.
- Friedman, G.M., 1965, Terminology of crystallization textures and fabrics in sedimentary rocks: J. Sed. Pet., V. 35, pp. 643-655.
- Friedman, G.M., 1959, Identification of carbonate minerals by staining: Jour. Sed. Pet., V. 29, p. 87-97.
- Gebelein, C.D., and Hoffman, P.F., 1971, Algal origin of dolomite in interlaminated limestone - dolomite sedimentary rocks, in Bricker, O.P., ed., Carbonate Cements: Johns Hopkins University Studies in Geology, No. 19, The Johns Hopkins Press, Baltimore & London, p. 319-326.
- Gebelein, C.D., and Hoffman, P.F., 1968, Intertidal stromatolites and associated facies from Lake Ingraham, Cape Sable, Florida (abstract), in Abstracts for 1968: Geol. Soc. America, Spec. Paper No. 121, p. 109.

Griffin, D.L., 1967, Devonian of Northeastern British Columbia, in Oswald, D.H., ed., International Symposium on the Devonian System, V. 1: A.S.P.G., Calgary, pp. 803-826.

Griffin, D.L., 1965, The Devonian Slave Point, Beaverhill Lake, and Muskwa Formations of Northeastern British Columbia and adjacent areas: B.C. Dept. Mines & Petrol. Res., Bull. #50, 90 pp. + plates and maps.

Ham, W.E., 1954, Algal origin of the "birdseye" limestone in the McLish Formation: Oklahoma Acad. Sci. Proc., V. 33, pp. 200-203.

Harrison, R.S., Steinen, R.P., and Matthews, R.K., 1972, Subaerial, vadose, and phreatic diagenesis in Pleistocene reef tracts of Barbados: recognition and application to economic exploration, in Stratigraphy and Sedimentology, Section 6, International Geological Congress, 24th session, Canada, 1972, Montreal, pp. 138-143.

Hill, D., and Stumm, E.C., 1956, Tabulata, in Moore, R.C., ed., Treatise on Invertebrate Paleontology, Part F: Coelenterata: Geol. Soc. America and Univ. of Kansas Press, p. F444-F476.

Hoffman, Paul, 1973, Recent and ancient algal stromatolites: seventy years of pedagogic cross-pollination: Evolving concepts in sedimentology, Johns Hopkins Univ. Press, Baltimore, pp. 178-191.

Irish, E.J.W., 1969, Halfway River, British Columbia: Geol. Surv. Can. Paper 69-11.

Jackson, S.A., and Beales, F.W., 1967, An aspect of sedimentary basin evolution: the concentration of Mississippi Valley-type ores during late stages of diagenesis: Bull. Can. Petrol. Geol., V. 15, pp. 383-433.

James, N.P., 1972, Holocene and Pleistocene calcareous crust (caliche) profiles: criteria for subaerial exposure: Jour. Sed. Petrology, V. 42, No. 4, p. 817-836.

Jamieson, E.R., 1967, The Alexandra Reef Complex (Frasnian), Hay River Area, N.W.T., Canada: stratigraphy, sedimentology and paleoecology: unpublished Ph.D. thesis, University of Reading, England.

- Kendall, C.G. St. C., and Skipwith, P.A., 1968, Recent algal mats of a Persian Gulf lagoon: *J. Sed. Pet.*, V. 38, pp. 1040-1058.
- Kidd, F.A., 1962, The Besa River Formation: *Edmonton Geol. Soc.*, 4th Ann. Field Trip Guide, pp. 97-101.
- Kingston, D.R., 1956, Paleozoic stratigraphy of the Tetsa-Halfway Rivers area, northeastern British Columbia, Canada: unpublished Ph.D. thesis, University of Wisconsin.
- Krumbein, W.C., and Sloss, L.L., 1963, *Stratigraphy and sedimentation*: W.H. Freeman and Company, San Francisco, 660 p.
- Land, L.S., 1973, Holocene meteoric dolomitization of Pleistocene limestones, north Jamaica: *Sedimentology*, V. 20, p. 411-424.
- Land, L.S., Salem, M.R.I., and Morrow, D.W., 1975, Paleohydrology of ancient dolomites: geochemical evidence: *A.A.P.G. Bulletin*, V. 59, pp. 1602-1625.
- Laudon, L.R., and Chronic, B.J., 1949, Paleozoic stratigraphy along Alaska Highway in northeastern British Columbia: *Bull., A.A.P.G.*, V. 33, No. 2, pp. 189-222.
- MacQueen, R.W., and Taylor, G.C., 1974, Devonian stratigraphy, facies changes, and zinc-lead mineralization, southwestern Halfway River Area (94B), northeastern British Columbia: *Geol. Surv. Can. Paper 74-1, Part A*, p. 327-331.
- Masson, H., 1972, Sur l'origine de la cornieule par fracturation hydraulique: *Ecolgae Geol. Helv.*, V. 65, No. 1, p. 27-41.
- McGillivray, J.G., and Mountjoy, E.W., 1975, Facies and related reservoir characteristics, Golden Spike reef complex, Alberta: *Bull. Can. Petrol. Geol.*, V. 23, No. 4, p. 753-809.
- McLaren, D.J., Norris, A.W., and McGregor, D.C., 1962, Illustrations of Canadian fossils: Devonian of Western Canada: *Geol. Surv. Can., Paper 62-4*.
- McLearn, F.H., and Kindle, E.D., 1950, Geology of northeastern British Columbia: *Geol. Surv. Can., Mem.* 259.

- Meyers, William J., 1974, Carbonate cement stratigraphy of the Lake Valley Formation (Mississippian) Sacramento Mountains, New Mexico: *J. of Sedimentary Petrology*, V. 44, pp. 837-861.
- Muir-Wood, H.M., Stehli, F.G., Elliott, G.F., and Hatai, K., 1965, Terebratulida, in Moore, R.C., ed., *Treatise on Invertebrate Paleontology*, Part H: Brachiopoda, Vol. 2: Geol. Soc. America and Univ. of Kansas Press, 1965, p. H728-H857.
- Norford, B.S., Gabrielse, H., and Taylor, G.C., 1967, Stratigraphy of Silurian carbonate rocks of the Rocky Mountains, northeastern British Columbia: *Bull. Can. Pet. Geol.*, V. 14, No. 4, pp. 504-519 (dated 1966).
- Parks, J.M., 1966, Cluster analysis applied to multivariate geologic problems: *Jour. Geol.*, V. 74, No. 5, p. 703-715.
- Pedder, A.E.H., 1971, Middle Devonian coelenterates from the Nahanni Formation of H.B., Amerada Camsell A-37 well, District of Mackenzie: *Geol. Surv. Can., Bull.* 192, p. 63-73.
- Pedder, A.E.H., 1964, Correlation of the Canadian Middle Devonian Hume and Nahanni Formations by tetracorals: *Palaeontology*, V. 7, p. 430-451.
- Pettijohn, F.J., 1957, *Sedimentary rocks*: Harper & Row, New York, 718 p.
- Powers, M.C., 1953, A new roundness scale for sedimentary particles: *J. Sed. Pet.*, V. 23, p. 117-119.
- Quinlan, J.F., 1972, Karst-related mineral deposits and possible criteria for the recognition of paleokarsts: a review of preservable characteristics of Holocene and older karst terranes, in *Stratigraphy and Sedimentology*, Section 6, International Geological Congress, 24th session, Canada, 1972, Montreal, pp. 156-168.
- Read, J.F., 1973, Carbonate cycles, Pillara Formation (Devonian), Canning Basin, Western Australia: *Bull. Can. Pet. Geol.*, V. 21, No. 1, pp. 38-51.
- Sangster, D.F., 1973, Geology of Canadian lead and zinc deposits: *Geol. Surv. Can., Paper* 73-1, Part A, p. 129-130.

- Schroeder, J.H., 1973, Submarine and vadose cements in Pleistocene Bermuda reef rock: *Sedimentary Geol.*, V. 10, p. 179-204.
- Shinn, E.A., 1968, Practical significance of birdseye structure in carbonate rocks: *J. Sed. Pet.*, V. 38, p. 215, et seq.
- Siedlecka, A., 1972, Length-slow chalcedony and relicts of sulphates-evidences of evaporitic environments in the Upper Carboniferous and Permian beds of Bear Island, Svalbard: *J. of Sedimentary Petrology*, V. 42, pp. 812-816.
- Spry, Alan, 1969, *Metamorphic textures*: Pergamon Press, Oxford, New York, 350 p.
- Steinen, R.P., and Matthews, R.K., 1973, Phreatic v.s. vadose diagenesis: stratigraphy and mineralogy of a cored borehole on Barbados, W.I.: *Jour. Sed. Pet.*, Vol. 43, No. 4, pp. 1012-1020.
- Taylor, G.C., 1973, Devonian facies and relationship to lead-zinc mineralization in northeastern British Columbia, in *Sedimentary geology and mineral deposits of the Canadian Cordillera*: *Geol. Assoc. Can., Cordilleran Section, program and abstracts*, p. 18-19.
- Taylor, G.C., and MacKenzie, W.S., 1970, Devonian stratigraphy of northeastern British Columbia: *Geol. Surv. Can., Bull. No. 186*, 62 pp.
- Taylor, G.C., MacQueen, R.W., and Thompson, R.I., 1975, Facies changes, breccias, and mineralization in Devonian rocks of Rocky Mountains, northeastern British Columbia (94B, G, K, N): *Geol. Surv. Can. Paper 75-1, Part A*, p. 577-585.
- Taylor, G.C., and Stott, D.F., 1973, Tuchodi Lakes Map Area, British Columbia: *Geol. Surv. Can., Memoir 373*, 37 pp. + 2 maps.
- Tebbutt, G.E., Conley, C.D., and Boyd, D.W., 1965, Lithogenesis of a distinctive carbonate rock fabric: *Univ. of Wyoming Contrib. to Geology*, V. 4, pp. 1-13.
- Thompson, R.I., 1973a, Robb Lake Property, in *Geology, Exploration and Mining in British Columbia, 1972*: *B.C. Dept. Mines & Pet. Res.*, pp. 463-476.

Thompson, R.I., 1973b, Zinc-lead occurrences near Robb Lake, Northeastern British Columbia: Geol. Assoc. Can., Cordilleran Section, "Sedimentary Geology and Mineral Deposits of the Canadian Cordillera": Program and Abstracts, p. 19-20.

Wells, A.J., 1956, Cyclic sedimentation: Geol. Mag., V. 97, pp. 389-403.

Williams, M.Y., 1944, Geological reconnaissance along the Alaska Highway from Fort Nelson, B.C., to Watson Lake, Yukon: Geol. Surv. Can., Paper 44-28.

Williams, M.Y., and Bocock, J.B., 1932, Stratigraphy and paleontology of the Peace River Valley of British Columbia: Trans. Roy. Soc. Can., 3rd ser., V. 26, Sec. 4, pp. 197-224.

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APPENDIX I

Size, Composition and Roundness Data

TABLE 1

F-13 COLO SIZE

PAGE 0

PHI MIDPOINT	FREQUENCY	PERCENT
2.375	1.00	2.39
2.625	2.00	4.78
2.875	1.00	2.39
3.125	1.00	2.39
3.375	4.10	9.81
3.625	9.10	21.77
3.875	2.30	5.50
4.125	1.70	4.07
4.375	1.00	2.39
4.625	1.40	3.25
4.875	3.60	8.61
5.125	3.76	9.00
5.375	2.49	5.96
5.625	1.73	4.19
5.875	1.50	3.59
6.125	1.06	2.54
6.375	.84	2.01
6.625	.63	1.63
6.875	.60	1.44
7.125	.52	1.24
7.375	.40	.96

7-2

PHI MEAN	4.383	PHI STANDARD DEVIATION	1.166	PHI MEDIAN	4.059
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F-13 ARTZ SIZE

PH ₇ MIDPOINT	FREQUENCY	PERCENT
0.125	1.00	1.37
0.375	6.00	8.22
0.625	3.00	4.11
0.875	2.50	3.42
1.125	7.00	9.59
1.375	10.00	13.70
1.625	8.00	10.96
1.875	14.50	19.36
2.125	10.00	13.70
2.375	6.50	9.32
2.625	2.20	3.01
2.875	.00	.00
3.125	.00	.00
3.375	.00	.00
3.625	1.10	1.51
3.875	.90	1.23

ALL YEAR 1.625

PHI STANDARD DEVIATION

• 712

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1.7.9

7-3

TABLE 3

5-13 32CR SIZE (Quartz grains in coarse layer.)

5A3E

PHI MIDPOINT	FREQUENCY	PERCENT
.125	1.00	2.38
.375	4.00	9.52
.625	4.00	9.52
.875	8.00	20.24
1.125	5.00	13.10
1.375	5.00	13.10
1.625	1.00	2.38
1.875	7.00	17.86
2.125	2.00	4.76
2.375	2.00	4.76
2.625	1.00	2.38

PHI MEAN 1.265

PHI STANDARD DEVIATION .634

PHI MEDIAN 1.159

TABLE 4

Z-13 JZFG SIZE (Quartz grains in fine layer.)

PAGE

PHI MIDPOINT	FREQUENCY	PERCENT
.275	1.00	2.19
1.125	.00	.00
1.375	4.00	8.75
1.625	4.00	8.75
1.875	8.00	17.51
2.125	7.50	16.41
2.375	9.30	20.35
2.625	4.40	9.63
2.875	2.80	6.13
3.125	3.00	6.56
3.375	.00	.00
3.625	1.70	3.72

PHI MEAN	2.211	PHI STANDARD DEVIATION	.574	PHI MEDIAN	2.195
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TABLE 5

F-13 CLST SIZE (Carbonate clasts)

PAGE 6

PHI MIDPOINT	FREQUENCY	PERCENT
1.375	2.00	14.29
1.625	2.00	14.29
1.875	3.00	21.43
2.125	1.00	7.14
2.375	.80	5.71
2.625	1.20	8.57
2.875	1.00	7.14
3.125	3.00	21.43

PHI MEAN	2.218	PHI STANDARD DEVIATION	.633	PHI MEDIAN	2.000
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7-6

Approved for Release

TABLE 6

Mineral Percentage Composition
Specimen P-1070

<u>Mineral</u>	<u>Volume Percent</u>
Quartz	82.8
Clays and fine mica	14.1
Pore space (partly artificial)	2.3
Opaque (whitish-yellowish-brown)	0.8
Muscovite	trace
Hematite	trace
Tourmaline?	trace

Total points counted : 128

TABLE 6

7-8

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1070 3RTZ RNDN (Roundness)

TABLE 8

PAGE 8

MIDPOINT	FREQUENCY	PERCENT
1.500	3.00	3.13
2.000	5.00	5.21
2.500	2.00	2.08
3.000	8.00	8.33
3.500	8.00	8.33
4.000	15.00	15.62
4.500	22.00	22.92
5.000	23.00	23.96
5.500	10.00	10.42

MEAN 4.172

STANDARD DEVIATION 1.028

MEDIAN 4.455

7-9

1070 3RTZ RNDN (Roundness)

TABLE 9

PHI MIDPOINT	FREQUENCY	PERCENT
-.875	3.00	2.91
-.625	4.00	2.68
-.375	4.00	2.68
-.125	8.00	5.37
.125	7.00	4.70
.375	6.00	4.03
.625	9.00	5.04
.875	12.50	8.39
1.125	18.00	12.08
1.375	21.00	14.09
1.625	12.50	8.39
1.875	15.50	10.40
2.125	7.50	5.03
2.375	7.00	4.70
2.625	2.60	1.74
2.875	1.40	.94
3.125	3.00	2.91
3.375	2.40	1.61
3.625	1.60	1.07
3.875	.25	.17
4.125	.95	.64
4.375	.80	.54
4.625	.00	.00
4.875	.40	.27
5.125	.47	.32
5.375	.13	.09

7-10

PHI MEAN 1.280

PHI STANDARD DEVIATION 1.055

PHI MEDIAN

1.286

Approved for Release by NSA on 08-11-2013 pursuant to E.O. 13526

TABLE 10

P-80 Crystal size distribution of dolomite
excluding internal sediment.

<u>PHI MIDPOINT</u>	<u>FREQUENCY</u>	<u>PERCENT</u>
.375	6.50	4.78
.625	15.50	11.40
.875	3.50	2.57
1.125	11.50	8.46
1.375	10.00	7.35
1.625	12.50	9.19
1.875	17.00	12.50
2.125	11.00	8.09
2.375	6.10	4.49
2.625	9.20	6.76
2.875	8.20	6.03
3.125	7.00	5.15
3.375	3.70	2.72
3.625	5.60	4.12
3.875	3.20	2.35
4.125	1.90	1.40
4.375	1.70	1.25
4.625	.70	.51
4.875	.20	.15
5.125	.00	.00
5.375	.29	.21
5.625	.35	.26
5.875	.30	.22
6.125	.06	.04

Phi Mean 2.00

Standard Deviation 1.07

Phi Median 1.875

TABLE 11
 P-21 Combined crystal size distribution of "host" and
 cavity-filling dolomite. Borderline material of
 uncertain affinity omitted.

<u>PHI MIDPOINT</u>	<u>FREQUENCY</u>	<u>PERCENT</u>
.125	8.00	9.50
.375	13.50	16.02
.625	7.50	8.90
.875	3.00	3.56
1.125	5.00	5.93
1.375	10.00	11.87
1.625	5.00	5.93
1.875	3.50	4.15
2.125	5.50	6.53
2.375	6.40	7.60
2.625	3.80	4.51
2.875	1.80	2.14
3.125	6.00	7.12
3.375	2.70	3.20
3.625	.40	.47
3.875	1.40	1.66
4.125	.75	.89

Phi Mean 1.511 Phi Standard Deviation 1.140

TABLE 12

PHI MIDPOINT	FREQUENCY	PERCENT
1.875	1.00	4.76
2.125	2.00	9.52
2.375	3.60	17.14
2.625	3.60	17.14
2.875	1.80	8.57
3.125	5.00	23.81
3.375	2.70	12.86
3.625	.30	1.43
3.875	.25	1.19
4.125	.75	3.57

PHI MEAN 2.818 PHI STANDARD DEVIATION .524 PHI MEDIAN 2.792

7-13

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P-21 CAV SIZE (Cavity Filling dolomite) TABLE 13

PAGE 8

PHI MIDPOINT	FREQUENCY	PERCENT
.125	8.00	12.65
.375	13.50	21.34
.625	7.50	11.86
.875	3.00	4.74
1.125	5.00	7.91
1.375	10.00	15.81
1.625	5.00	7.91
1.875	2.50	3.95
2.125	3.50	5.53
2.375	2.80	4.43
2.625	.20	.32
2.875	.00	.00
3.125	1.00	1.58
3.375	.00	.00
3.625	.10	.16
3.875	1.15	1.82

PHI MEAN 1.077 PHI STANDARD DEVIATION .819 PHI MEDIAN .969

7-14

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TABLE 14

34.2 COLH SIZE (Host dolomite)

PAGE 8

PHI MIDPOINT	FREQUENCY	PERCENT
2.875	1.00	.94
3.125	1.00	.94
3.375	9.90	9.29
3.625	5.20	4.88
3.875	12.65	11.87
4.125	10.25	9.62
4.375	9.60	9.01
4.625	11.20	10.51
4.875	9.20	8.63
5.125	7.05	6.62
5.375	7.46	7.00
5.625	6.65	6.24
5.875	5.70	5.35
6.125	2.65	2.67
6.375	1.89	1.77
6.625	1.53	1.44
6.875	1.35	1.27
7.125	1.17	1.10
7.375	.90	.84

PHI MEAN 4.685

PHI STANDARD DEVIATION .955

PHI MEDIAN 4.582

7-15

TABLE 15

34.2 DCAV SIZE

PAGE 8

PHI MIDPOINT	FREQUENCY	PERCENT
.875	1.00	3.57
1.125	.00	.00
1.375	.50	1.79
1.625	2.00	7.14
1.875	7.00	25.00
2.125	1.00	3.57
2.375	2.30	8.21
2.625	2.80	10.00
2.875	2.40	8.57
3.125	2.00	7.14
3.375	3.40	12.14
3.625	.80	2.86
3.875	1.80	6.43
4.125	.00	.00
4.375	.10	.36
4.625	.70	2.50
4.875	.20	.71

PHI MEAN	2.572	PHI STANDARD DEVIATION	.853	PHI MEDIAN	2.518
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7-16

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1065 2RTZ SIZE

PHI MIDPOINT	FREQUENCY	PERCENT	PHI MEAN	PHI MEDIAN	PHI STANDARD DEVIATION
3.375	.70	2.51	5.007	4.963	
3.625	.30	1.08			
3.875	.25	.90			
4.125	1.35	4.84			
4.375	2.90	10.39			
4.625	3.50	12.34			
4.875	5.20	20.79			
5.125	5.64	20.22			
5.375	2.72	9.75			
5.625	1.40	5.02			
5.875	1.20	4.30			
6.125	.62	2.22			
6.375	.42	1.51			
6.625	.34	1.22			
6.875	.30	1.08			
7.125	.26	.93			
7.375	.20	.72			

7-17

1050 3RTZ SIZE

TABLE 17

PHI MIDPOINT	FREQUENCY	PERCENT	PHI MEAN	PHI STANDARD DEVIATION	PHI MEDIAN
.375	1.00	4.38			
.625	2.50	12.20			
.875	.50	2.44			
1.125	5.00	24.39			
1.375	.50	2.44			
1.625	2.50	12.20			
1.875	1.00	4.38			
2.125	3.00	14.63			
2.375	2.00	9.76			
2.625	.00	.00			
2.875	1.00	4.38			
3.125	.00	.00			
3.375	.00	.00			
3.625	.10	.49			
3.875	1.40	6.83			
PHI MEAN	1.679		.899		1.575

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TABLE 18

Specimen	P-20.7			P-33			P-55			P-35.4		
	Total points counted	Intraclasses	% Intraclasses	Total points counted	Intraclasses	% Intraclasses	Total points counted	Intraclasses	% Intraclasses	Total points counted	Intraclasses	% Intraclasses
1	48	16	33.3	45	9	20.0	59	10	16.9	82	16	19.5
2	69	27	39.1	71	12	16.9	71	16	22.5	82	23	28.8
3	74	21	28.4	74	11	14.8	---	--		73	14	19.2
Combined	191	64	33.5	190	32	16.8	130	26	20.0	237	53	22.4

Traverse

TABLE 19

Particle Composition - Specimen AC-4

<u>Particle or Matrix Component</u>	<u>Volume Percent</u>
Pellets	23.8
Intracrystals	2.6
Non-pelleted micrite	15.9
Micrite which <u>may</u> belong to pellets	18.5
Microspar ($> 5 \mu$ and $< 20 \mu$)	21.9
Spar ($> 20 \mu$)	14.6
Unidentified light-coloured opaque	0.7
Internal sediment (calcite crystal silt)	2.0
Total number of points counted :	151

AC-4 PLTS SIZE (Pellets)

TABLE 20

PAGE 1

PHI MIDPOINT	FREQUENCY	PERCENT
2.375	1.00	3.03
2.625	1.60	4.85
2.875	.40	1.21
3.125	3.00	9.09
3.375	4.50	14.55
3.625	6.60	20.00
3.875	4.35	13.18
4.125	2.65	8.03
4.375	2.10	6.36
4.625	3.50	10.61
4.875	1.80	5.45
5.125	.94	2.85
5.375	.26	.79

PHI MEAN 3.799

PHI STANDARD DEVIATION .669

PHI MEDIAN 3.716

7-21

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7

TABLE 21

Particle Composition - Specimen P-15
(all points are dolomite)

<u>Particle or Component</u>	<u>Volume Percent</u>
Intracrystals	20.8
Pellets	12.5
Unidentified coarse clast	2.1
Dolospir	14.6
Internal sediment (now dolomite silt)	2.1
Dolomite of uncertain origin between recognizable clasts	47.9

Total points counted : 48

7-23

TABLE 22

Specimen P-216.4

Mineral Composition		Particle Composition	
	Percent		Percent
Dolomite	80.3	Quartz-cored oolites	10.3
Quartz	19.7	Non-oolitic quartz grains	12.6
		Carbonate-cored oolites	.5
		Intraclasts	5.1
		Echinoderm fragments	.9
		Coral fragments	5.6
		Mollusc and brachiopod fragments	1.9
		Unidentified carbonate clasts	17.8
		Dolomitized micrite (mostly coatings on grains)	20.6
		Spar (dolomite)	15.4
		Silt-sized matrix (dolomite)	8.4
		Dolomite of uncertain origin	.9

Total number of counts: 214

TABLE 23

E352 MIN (Mineral Composition)

SUM OF COUNTS EQUALS 332.0	Quartz	8.4	1.8	13.0	73.2	.3	3.3
SUM OF PERCENTS 100.0	Dolo. > 5%						
	Calc. > 5%						
	Calc. (5% white)						
	Pore space						
	Dolo. < 5%						

7-24

E-22 MIN (Mineral Composition)

TABLE 24

1	SUM OF COUNTS EQUALS 301.0	Quartz	32.9	1.3	11.6	47.5	6.0	0.7
	SUM OF PERCENTS 100.0	Pore space						
		Dolo. > 5%						
		Calc. > 5%						
		Calc. < 5% (micrite)						
		Dolo. < 5%						

CONSTITUENT PERCENTS IN ORDER COUNTED

7-25

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TABLE 25

Specimen J-91 - Composition

Traverse Set #1 (4 short traverses 1 mm apart, counted at 6 points per millimetre)

	<u>Percent</u>
Micrite	60.9
Dolomite	25.5
Calcite > 5 microns	10.7
Quartz	2.2
Open fractures	.4
Unidentified	.4

Traverse Set #2 (Same traverses as above, counted at 3 points per millimetre.)

Micrite	62.7
Dolomite	25.1
Calcite > 5 microns	9.1
Quartz	1.9
Open fractures	.8
Unidentified	.4

E315 MIN (Mineral Composition) TABLE 26

1
 SUM OF COUNTS EQUALS 139.0
 SUM OF PERCENTS 100.0
 CONSTITUENT PERCENTS IN ORDER COUNTED 10.1 2.2 87.8
 Quartz Pore space Dolomite

2
 SUM OF COUNTS EQUALS 144.0
 SUM OF PERCENTS 100.0
 CONSTITUENT PERCENTS IN ORDER COUNTED 18.1 0.7 81.2

7-27
 ALL TRAVERSES COMBINED
 SUM OF PERCENTS 100.0
 CONSTITUENT PERCENTS IN ORDER COUNTED 14.1 1.4 84.5
 Quartz Pore space Dolomite

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J-89 MIN

TABLE 27

SUM OF COUNTS EQUALS 198.0 (all counts are twice true value in this printout due to counting procedure)

SUM OF PERCENTS 100.0

CONSTITUENT PERCENTS IN ORDER COUNTED 12.1 0.0 46.5 41.4

TOTAL COUNT 198 PERCENT ERROR .0

SUM OF COUNTS EQUALS 202.0

SUM OF PERCENTS 100.0

CONSTITUENT PERCENTS IN ORDER COUNTED 8.9 0.0 54.5 36.6

TOTAL COUNT 202 PERCENT ERROR .0

SUM OF COUNTS EQUALS 492.0

SUM OF PERCENTS 100.0

CONSTITUENT PERCENTS IN ORDER COUNTED 9.8 1.6 60.2 28.5

TOTAL COUNT 492 PERCENT ERROR .0

ALL TRAVERSES COMBINED

SUM OF PERCENTS 100.0

CONSTITUENT PERCENTS IN ORDER COUNTED 10.1 .9 55.8 33.2

7-28

Quartz
Feldspar
Mica
Olivine

ALL TRAVERSES COMBINED
SUM OF PERCENTS 100.0

TABLE 28

5332 CALC SIZE (not including the predominant micrite)

PHI MIDPOINT	FREQUENCY	PERCENT
3.125	2.00	5.33
3.375	3.10	8.26
3.625	1.10	2.93
3.875	2.80	7.46
4.125	4.20	11.19
4.375	5.10	13.58
4.625	2.10	5.69
4.875	1.80	4.79
5.125	1.41	3.76
5.375	1.34	4.90
5.625	1.75	4.66
5.875	1.50	3.99
6.125	2.01	5.35
6.375	1.89	5.03
6.625	1.53	4.07
6.875	1.35	3.60
7.125	1.17	3.12
7.375	.90	2.40

PHI MEAN	4.905	PHI STANDARD DEVIATION	1.193	PHI MEDIAN	4.557
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7-29

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DATE 10-1-80 BY 1044 JMS/SP

TABLE 29

E-32 CALC SIZE (not including minor micrite)

PHI MIDPOINT	FREQUENCY	PERCENT
1.875	1.50	6.62
2.125	3.00	13.25
2.375	.50	2.21
2.625	.60	2.65
2.875	.40	1.77
3.125	2.00	8.83
3.375	.00	.00
3.625	1.00	4.42
3.875	.25	1.10
4.125	.95	4.19
4.375	.80	3.53
4.625	.00	.00
4.875	.40	1.77
5.125	.47	2.08
5.375	1.29	5.70
5.625	1.40	6.18
5.875	1.20	5.30
6.125	1.57	6.93
6.375	1.47	6.49
6.625	1.19	5.25
6.875	1.05	4.64
7.125	.91	4.02
7.375	.70	3.09
		<u>Σ 100.02</u>

This accounts for 94 %
of the rock. The rest
is micrite.

7-30

PHI MEAN 4.561

PHI STANDARD DEVIATION 1.824

PHI MEDIAN 4.953

4.953

REPRODUCED FROM
ORIGINAL DATA
1950-1951

TABLE 30

J-35 SOLO SIZE (Total of all traverses)

PHI MIDPOINT	FREQUENCY	PERCENT
1.125	1.00	.38
1.375	15.00	1.83
1.625	2.00	.75
1.875	9.00	3.40
2.125	13.00	5.66
2.375	38.20	14.42
2.625	38.00	14.34
2.875	38.80	14.64
3.125	32.00	12.08
3.375	25.10	9.47
3.625	20.80	7.85
3.875	11.10	4.19
4.125	10.00	3.77
4.375	4.50	1.70
4.625	3.50	1.32
4.875	3.00	1.13
5.125	2.35	.89
5.375	1.81	.68
5.625	1.40	.53
5.875	1.20	.45
6.125	.43	.16
6.375	.21	.08
6.625	.17	.06
6.875	.15	.06
7.125	.13	.05
7.375	.10	.04

7-31

PHI MEAN 3.025 PHI STANDARD DEVIATION .827 PHI MEDIAN 2.906

TABLL 31

5032 CRTZ SIZE

N = 20

PHI MIDPOINT	FREQUENCY	PERCENT
1.625	.50	2.50
1.875	.50	2.50
2.125	3.50	17.50
2.375	4.30	21.50
2.625	6.20	31.00
2.875	1.00	5.00
3.125	4.00	20.00

PHI MEAN 2.553

PHI STANDARD DEVIATION

.380

PHI MEDIAN

2.548

7-32

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

DATE 10-11-88 BY SP-8

TABLE 32

N = 28

E332 3RTZ SIZE

PHI MIDPOINT	FREQUENCY	PERCENT	PHI MEAN	PHI STANDARD DEVIATION	PHI MEDIAN	PHI MODUS
1.375	1.00	3.40				
1.625	.00	.00				
1.875	1.50	5.10				
2.125	1.50	5.10				
2.375	1.80	6.12				
2.625	5.30	19.73				
2.875	8.40	28.57				
3.125	2.00	6.80				
3.375	3.10	10.34				
3.625	1.90	6.46				
3.875	.25	.85				
4.125	2.15	7.31				
PHI MEAN	2.873		.611		2.84	

7-33

ALL INFORMATION CONTAINED
HEREIN IS UNCLASSIFIED
DATE 11-11-2011 BY 60322

TABLE 33

J-59 CRTZ SIZE

PHI MIDPOINT	FREQUENCY	PERCENT
3.125	1.00	5.60
3.375	.00	.00
3.625	2.10	11.76
3.875	1.15	6.47
4.125	1.35	7.56
4.375	2.40	13.43
4.625	.00	.00
4.875	2.40	13.43
5.125	2.82	15.80
5.375	1.07	5.99
5.625	.35	1.96
5.875	.30	1.68
6.125	.63	3.53
6.375	.63	3.53
6.625	.51	2.86
6.875	.45	2.52
7.125	.39	2.18
7.375	.30	1.68

PHI MEAN 4.831

PHI STANDARD DEVIATION 1.042

PHI MEDIAN 4.8

TABLE 34

E315 CRTZ RNCN

MIDPOINT FREQUENCY PERCENT

1.000	1.00	2.63
1.500	1.00	2.63
2.000	1.00	2.63
2.500	3.00	7.89
3.000	3.00	7.89
3.500	3.00	7.89
4.000	5.00	13.16
4.500	10.00	26.32
5.000	9.00	23.68
5.500	2.00	5.26

MEAN 4.013

STANDARD DEVIATION 1.097

MEDIAN 4.425

7-35

TABLE 35

5-32 CRTZ RNDN

N = 21

MIDPOINT	FREQUENCY	PERCENT	MEAN	STANDARD DEVIATION	MEDIAN
1.000	1.00	4.76	3.357	1.135	3.531
1.500	2.00	9.52			
2.000	1.00	4.76			
2.500	2.00	9.52			
3.000	2.00	9.52			
3.500	4.00	19.05			
4.000	4.00	19.05			
4.500	3.00	14.29			
5.000	2.00	9.52			

APPENDIX II
Matching Coefficients

EXPLANATORY NOTES

- 1) Where the word, "Merged", appears, the results for the variables, Dark, Medium, Light, Fine, Medium and Coarse, are computed by combining the data from these with adjacent categories: "Dark" includes Dark and Medium-dark, "Fine" includes Microcrystalline and Fine, etc.
- 2) The numbered variables in several matrices are accessory and thin-section-observed characters which turned out to be of little value in this semi-quantitative analysis, in some cases due to insufficient data and in others simply to irrelevance. These include presence of bitumen, sand (quartz) visible in hand specimen, internal sediment, white dolomite greater than 5 volume percent, etc.
- 3) The numeral "-9.00" in the two coefficient matrices indicates that neither of the two characters being compared is present in any of the cases for which presence-absence is known.

4) The numeral "-8.00" in the matrix based on presence of the less common character indicates that the less common of the two characters being compared is not present in any of the cases where presence-absence is known.

5) The numeral ".00" in the matrix of less common characters indicates that neither of the characters being compared is present in any of the cases for which presence-absence is known.

8-4

Unit 2

PLCM SECT
UNIT 2, SECTION P

NO. OF SAMPLES: 194

COEFFICIENTS

MERGED?: NO

	DK	MD	H	ML	LT	BF	MI	FN	MF	Y	MC	CS	FE	VU	IV	FD	LA	ZE	Z3
<1P	-1.00	-.85	-.66	-.85	-.80	-1.00	-.75	-.72	-.87	-.81	-1.00	-1.00	-.67	-.97	-.94	-.94	-.84	-.94	-.93
>2P	-.98	-.84	-.98	-.70	-.03	-1.00	-1.00	-.87	-.64	-.03	-1.00	-1.00	-.92	-.58	-.96	-.96	-.06	-1.00	-.03
>3P	-1.00	-.87	-1.00	-.72	-.06	-1.00	-1.00	-.91	-.68	-.11	-1.00	-1.00	-.98	-.56	-.95	-.95	-.02	-1.00	-.03
>5P	-1.00	-1.00	-1.00	-.88	-.55	-1.00	-1.00	-1.00	-.74	-.67	-1.00	-1.00	-1.00	-.52	-1.00	-.44	-1.00	-.50	-.84
QARK																			
MED DK																			
MEDIUM																			
MED LT																			
LIGHT BY																			
BUFF																			
MICROCRYST																			
FINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
FENESTRAE																			
VUGS																			
INTRACLASTS																			
MEGAFOSSILS																			
LAMINATION																			
ZERRA																			

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UNIT 2, SECT. P.

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

DK	YD	M	ML	LT	BF	MI	FN	MF	Y	MC	CS	FE	VU	IN	FO	LA	ZE	ZS	
<1F	1.00	.30	.20	-.70	-.16	8.00	1.00	-.38	-.74	.05	1.00	8.00	-.16	-.93	-.50	-.95	1.50	-.90	-.76
>2FT	1.00	.22	-.80	.19	1.43	8.00	1.00	.38	.16	1.43	1.00	8.00	-.47	1.66	.00	1.72	1.00	1.65	1.65
>3F	1.00	-.48	1.00	-.04	1.52	8.00	1.00	-.62	-.11	1.42	1.00	8.00	-.29	1.45	.00	1.12	1.00	1.50	.29
>5FT	1.00	1.00	1.00	-.78	1.78	8.00	1.00	1.00	.50	1.50	1.00	8.00	1.00	.21	1.00	1.43	1.00	1.43	.65
DARK																			
MED DK																			
MEDIUM																			
MED LT																			
LIGHT BY																			
BUFF																			
MICROCRYST																			
FINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
FENESTRAE																			
VUGS																			
INTRACLASTS																			
MEGAFOSSILS																			
LAMINATION																			
ZERRA																			

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UNIT 2, SECT. P.

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

OK	45	M	HL	LT	BF	MI	FN	WF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	
<41F	5.00	6.00	7.00	8.00	1.0010.0011.0012.0013.00	1.0015.0016.0017.0018.0019.00	1.0021.00	1.0023.00											
>2FT	5.00	6.00	7.00	8.00	2.0010.0011.0012.0013.00	2.0015.0016.0017.0018.0019.00	2.0021.00	2.0023.00											
>3F	5.00	6.00	7.00	8.00	3.0010.0011.0012.0013.00	3.0015.0016.0017.0018.0019.00	3.0021.00	3.0023.00											
>5F	5.00	6.00	7.00	8.00	4.0010.0011.0012.0013.00	4.0015.0016.0017.0018.0019.00	4.0021.00	4.0023.00											
DARK					5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00														
MED OK					11.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00														
MEDIUM					11.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00 7.00														
MED LT					11.0012.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00														
LIGHT BY					11.0012.0013.0014.0015.0016.0017.0018.0019.00	11.0020.0021.0022.0023.00													
BLUE					10.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.0010.00														
MICROCRYST																			
FINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
FENESTRAE																			
VUGS																			
INTRACLASTS																			
MEGAFOSILS																			
LAMINATION																			
ZERRA																			

UNIT 2, SECT. P.

WEIGHTS 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	OK	YD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	Z3
<1F	.19	.27	.21	.32	.75	.18	.21	.30	.39	.73	.22	.22	.26	.36	.24	.54	.22	.58	.30
>2FT	.57	.65	.62	.64	.80	.57	.59	.64	.63	.78	.56	.56	.64	.58	.55	.60	.58	.61	.56
>3F	.47	.56	.52	.55	.75	.44	.48	.56	.55	.74	.43	.45	.55	.49	.44	.52	.47	.54	.47
>5FT	.17	.30	.22	.31	.66	.16	.17	.28	.31	.66	.15	.14	.25	.24	.15	.37	.16	.41	.20
DARK							.04	.16	.22	.58	.01	.01	.11	.12	.03	.38	.03	.38	.08
MED OK							.15	.20	.34	.69	.14	.14	.19	.25	.15	.49	.15	.50	.22
MEDIUM							.07	.21	.26	.62	.06	.06	.17	.17	.09	.44	.08	.44	.13
MED LT							.19	.26	.32	.69	.16	.16	.25	.25	.19	.48	.18	.47	.21
LIGHT OY							.67	.78	.75	.72	.65	.64	.73	.68	.65	.72	.65	.72	.67
BUFF							.03	.15	.22	.57	.01	.00	.11	.12	.02	.38	.02	.38	.08
MICROCRYST											.0		.13	.18	.05	.36	.04	.40	.12
FINE													.15	.27	.16	.43	.14	.51	.23
MED FINE													.29	.32	.22	.47	.22	.45	.25
MED CRYST.													.71	.68	.62	.71	.64	.74	.66
MED COARSE													.11	.15	.03	.34	.03	.38	.09
COARSE													.10	.15	.02	.33	.02	.37	.09
FENESTRAE														.25	.12	.44	.12	.48	.19
VUGS															.18	.40	.17	.45	.21
INTRACLASTS																.37	.04	.39	.12
MEGAFOSILS																	.35	.49	.38
LAMINATION																		.39	.11
ZEBRA																			.39

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
.22	.56	.45	.14	.01	.14	.06	.14	.44	.00	.03	.14	.20	.62	.01	.00	.10	.15	.02	.33	.02	.37	.09

UNIT 2, SECT. P.

WEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

OK	MO	M	ML	LT	BF	HI	FN	MF	M	MC	CS	FE	VJ	IN	FO	LA	ZE	23
<1F	.12	.12	.12	.12	.12	.01	.01	.02	.02	.02	.00	.02	.00	.04	.00	.00	.00	.02
>2FT	.12	.12	.12	.12	.12	.01	.01	.02	.02	.02	.00	.02	.00	.04	.00	.00	.00	.02
>3F	.12	.12	.12	.12	.12	.01	.01	.02	.02	.02	.00	.02	.00	.04	.00	.00	.00	.02
>5FT	.12	.12	.12	.12	.12	.01	.01	.02	.02	.02	.00	.02	.00	.04	.00	.00	.00	.02
DARK						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MED OK						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MEDIUM						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MED LT						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
LIGHT QY						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
BUFF						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MICROCRYST												.03	.01	.05	.01	.01	.01	.03
FINE												.03	.01	.05	.01	.01	.01	.03
MED FINE												.04	.02	.06	.02	.02	.02	.04
MED CRYST												.04	.02	.06	.02	.02	.02	.04
MED COARSE												.02	.00	.04	.00	.00	.00	.02
COARSE												.02	.00	.04	.00	.00	.00	.02
FENESTRAE												.02	.02	.04	.02	.02	.02	.04
VUGS														.04	.00	.00	.00	.02
INTRACLASTS															.04	.04	.04	.06
MEGAFOSSELS																.00	.00	.02
LAMINATION																.00	.00	.02
ZERRA																.00	.00	.02

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	.00	.00	.00	.00	.12	.12	.12	.12	.12	.12	.01	.01	.02	.02	.00	.00	.02	.00	.04	.00	.00	.00	.02

200

MERGE07: YES

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Unit 2, Section P (merged)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	DK	YD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VJ	IN	FO	LA	ZE	ZE
<1F	.33	.33	.35	.70	.16	8.00	1.00	.16	.74	.29	1.00	1.00	.16	.93	.50	.95	.53	.90	.76
>2F	.17	.22	.08	.19	.44	8.00	1.00	.48	.16	.33	1.00	1.00	.47	.65	.00	.73	.1.00	.62	.55
>3F	.50	.48	.30	.04	.52	8.00	1.00	.68	.11	.33	1.00	1.00	.89	.45	.00	.59	1.00	.50	.29
>4F	1.00	1.00	.79	.74	.79	8.00	1.00	1.00	.50	1.00	1.00	1.00	1.00	.21	1.00	.31	1.00	.73	.45
DARK																			
MED DK																			
MEDIUM																			
MED LT																			
LIGHT BY																			
BLUE																			
MICROCRYST																			
FINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
FENESTRAE																			
VUGS																			
INTRACLASTS																			
MEGAFOSFELS																			
LAMINATION																			
ZEBRA																			

Unit 2, Section P (merged)

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

OK	YD	M	ML	LT	BF	MI	FN	WF	M	MC	CS	FE	VU	IN	FD	WA	ZE	Z3							
<1F	5.00	6.00	1.00	8.00	1.00	10.00	0.011	0.012	0.013	0.00	1.00	15.00	0.016	0.017	0.018	0.019	0.00	1.00	0.021	0.00	1.00	0.023	0.00		
>2FT	5.00	6.00	7.00	8.00	2.00	10.00	0.011	0.012	0.013	0.00	2.00	15.00	0.016	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.00	0.022	0.023	0.00	
>3F	5.00	6.00	7.00	8.00	3.00	10.00	0.011	0.012	0.013	0.00	3.00	15.00	0.016	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.00	0.022	0.023	0.00	
>5FT	5.00	6.00	4.00	8.00	4.00	10.00	0.011	0.012	0.013	0.00	4.00	15.00	0.016	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.00	0.021	0.022	0.023	0.00
DARK																									
MED OK																									
MEDIUM																									
MED LT																									
LIGHT GY																									
BUFF																									
MICROCRYST																									
FINE																									
MED FINE																									
MED CRYST																									
MED COARSE																									
COARSE																									
PENESTRAE																									
WUOS																									
INTRACLASTS																									
MEGAFOSILS																									
LAMINATION																									
ZEBRA																									

Unit 2, Section P (merged)

HEIGHTS 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	DK	HD	M	ML	LT	BF	HI	FN	HF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23
<1F	.28	.27	.34	.32	.75	.18	.21	.30	.39	.90	.22	.22	.26	.36	.24	.54	.22	.58	.30
>2FT	.65	.65	.69	.64	.80	.87	.59	.68	.63	.86	.56	.56	.64	.58	.55	.60	.58	.61	.56
>3F	.57	.56	.61	.85	.78	.46	.48	.89	.55	.85	.45	.45	.55	.49	.44	.52	.47	.54	.47
>5FT	.31	.32	.34	.31	.64	.14	.17	.21	.31	.82	.15	.15	.25	.24	.15	.37	.16	.11	.20
DARK							.16	.23	.34	.90	.14	.14	.19	.25	.15	.50	.15	.51	.22
MED DK							.15	.23	.34	.90	.14	.14	.19	.25	.15	.49	.15	.50	.22
MEDIUM							.23	.33	.36	.87	.22	.22	.31	.31	.25	.54	.24	.53	.27
MED LT							.19	.29	.32	.85	.16	.16	.25	.25	.19	.48	.18	.47	.21
LIGHT BY							.67	.81	.75	.82	.65	.65	.73	.68	.65	.72	.65	.72	.67
BUFF							.02	.18	.22	.80	.01	.01	.11	.12	.02	.38	.02	.38	.08
MICROCRYST													.13	.18	.05	.36	.04	.40	.12
PINE													.18	.29	.18	.46	.17	.53	.26
MED FINE													.29	.32	.22	.47	.22	.45	.25
MED CRYST													.90	.84	.82	.86	.84	.83	.82
MED COARSE													.11	.15	.03	.34	.03	.38	.09
COARSE													.11	.15	.03	.34	.03	.38	.09
PENESTRAE														.25	.12	.44	.12	.48	.19
VUGS															.18	.40	.17	.45	.21
INTRACLASTS																.37	.04	.39	.12
MEGAFOSSILS																	.35	.49	.38
LAMINATION																	.39	.11	
ZERRA																			.39

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
.22	.56	.45	.14	.14	.14	.22	.16	.44	.00	.02	.16	.20	.12	.01	.01	.10	.15	.02	.33	.02	.37	.09

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carleton university computing centre

Unit 2, Section P (merged)

WEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

DK	4D	M	ML	LT	BP	MI	FN	MF	Y	YC	CS	FE	VU	IN	FO	LA	ZE	23
<1F	.12	.12	.12	.12	.12	.01	.01	.02	.02	.00	.00	.02	.00	.04	.00	.00	.00	.02
>2FT	.12	.12	.12	.12	.12	.01	.01	.02	.02	.00	.00	.02	.00	.04	.00	.00	.00	.02
>3F	.12	.12	.12	.12	.12	.01	.01	.02	.02	.00	.00	.02	.00	.04	.00	.00	.00	.02
>5FT	.12	.12	.12	.12	.12	.01	.01	.02	.02	.00	.00	.02	.00	.04	.00	.00	.00	.02
DARK						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MED DK						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MEDIUM						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MED LT						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
LIGHT BY						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
BUFF						.13	.13	.14	.14	.12	.12	.14	.12	.16	.12	.12	.12	.14
MICROCRYST												.03	.01	.05	.01	.01	.01	.03
PINE												.04	.02	.06	.02	.02	.02	.04
MED FINE												.04	.02	.06	.02	.02	.02	.04
MED CRYST												.02	.00	.04	.00	.00	.00	.02
MED COARSE												.02	.00	.04	.00	.00	.00	.02
COARSE												.02	.00	.04	.00	.00	.00	.02
PENESTRAE													.02	.06	.02	.02	.02	.04
VUGS														.04	.00	.00	.00	.02
INTRACLASTS														.04	.00	.00	.00	.02
MEGAFOSILS															.04	.00	.00	.02
LAMINATION																.04	.00	.02
ZEBRA																	.00	.02

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
.00	.00	.00	.00	.12	.12	.12	.12	.12	.12	.01	.01	.02	.02	.00	.00	.02	.00	.04	.00	.00	.00	.02

Unit 2, Section V

VLCDH SECT NO. OF SAMPLES: 52

COEFFICIENTS

MERGED?: NO

(Note that colour data is largely lacking and several other characters are wholly or largely absent.)

DK	HD	H	ML	LT	BF	MI	PN	MF	Y	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SELF	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
ST	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
ST	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
ST	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
DARK	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED DK	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MEDIUM	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED LT	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
LIGHT GY	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
BUFF	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MICROCRYST	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
FINE	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED FINE	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED CRYST	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED COARSE	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
COARSE	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
FENESTRAE	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
VUGS	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
INTRACLASTS	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MEGAFOSILS	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
LAMINATION	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
ZEBRA	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
23																			

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carleton university computing centre

Unit 2, Section V

(Note limitations of data.)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

DK	WD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IV	FO	LA	ZE	23	24
<1F	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
>2FT	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
>3F	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
>5FT	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
DARK	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED DK	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MEDIUM	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED LT	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
LIGHT GY	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
BUFF	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MICROCRYST	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
FINE	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED FINE	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED CRYST	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MED COARBE	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
COARSE	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
FENESTRAE	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
VUGS	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
INTRACLASTS	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
MEGAFOSSILS	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
LAMINATION	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
ZERRA	9.00	8.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
23																			

carleton university computing centre

Unit 2, Section V

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

DK	MD	M	ML	LT	BF	MI	FN	MF	Y	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
<1F	.00	1.00	.00	.00	.00	.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>2F	.00	2.00	.00	.00	.00	.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>3F	.00	3.00	.00	.00	.00	.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>5F	.00	4.00	.00	.00	.00	.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK																			
MED OK																			
MEDIUM																			
MED LT																			
LIGHT GY																			
BUFF																			
MICROCRYST																			
FINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
PENESTRAE																			
VUGS																			
INTRACLASTS																			
MEGAFOSSILS																			
LAMINATION																			
ZERRA																			
23'																			

(.00 indicates that there are no cases where both characters are known and at least one is present.)

Unit 2, Section V

HEIGHTS 1: POSITIVE AND MISMATCHES V-S. TOTAL MATCHES

OK	4D	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FD	LA	ZE	23	24
<1F	.00	1.00	.00	.00	.00	.00	.02	.04	.88	.02	.02	.02	.02	.02	.42	.02	.42	.02	.02
>2F	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
>3F	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
>4F	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
DARK	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MED OK	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MEDIUM	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MED LT	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
LIGHT BY	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
BUFF	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MICROCRYST	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
FINE	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MED FINE	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MED CRYST	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MED COARSE	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
COARSE	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
FENESTRAE	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
VUGS	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
INTRACLASTS	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
MEGAFOSILS	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
LAMINATION	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
ZEBRA	.00	1.00	.00	.00	.00	.00	.94	.87	.88	.85	.85	.85	.85	.85	.85	.86	.87	.85	.85
23																			

Note

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.02	.85	.85	.48	.00	1.00	.02	.00	.00	.00	.02	.00	.02	.88	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

carleton university computing centre

Unit 2, Section V

WEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

	OK	YD	M	HL	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
<1F	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
>2FT	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
>3F	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
>5FT	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
DARK	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MED OK	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MEDIUM	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MED LT	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
LIGHT QY	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
BUFF	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MICROCRYST	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
FINE	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MED FINE	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MED CRYST	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MED COARSE	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
COARSE	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
FENESTRAE	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
VUGS	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
INTRACLASTS	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
MEGAFOSILS	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
LAMINATION	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
ZEBRA	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98

Note →

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	.00	.00	.00	.00	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98

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Unit 3

Unit 3, Section P (Section log data)

STCO SECT NO. OF SAMPLES: 314

COEFFICIENTS MERGE09: NO

OK	MD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
<5F=1.00	-0.5	-0.58	1.00	-0.31	1.00	-0.85	-0.18	-0.68	-0.52	-0.81	1.00	-0.74	-0.97	-0.92	-1.00	-0.64	-0.82	-0.1	-0.94	-0.92
>2FT=1.00	-0.90	1.00	1.00	-0.28	1.00	1.00	-0.94	-0.27	-0.72	1.00	1.00	-0.93	-0.50	-0.92	1.00	-0.88	-0.35	-0.91	-0.92	1.00
>3F=1.00	-0.80	1.00	1.00	-0.25	1.00	1.00	-0.93	-0.24	-0.78	1.00	1.00	-0.93	-0.51	-0.91	1.00	-0.88	-0.41	-0.91	-1.00	1.00
>5FT=1.00	-0.87	1.00	1.00	-0.28	1.00	1.00	-0.90	-0.60	1.00	1.00	1.00	-0.88	-0.50	1.00	1.00	-0.71	-0.71	-1.00	1.00	1.00
DARK	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
MED DK	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
MED LT	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
LIGHT BY	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
BUFF	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
MICROCRYST	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
FINE	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
MED FINE	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
MED CRYST	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
MED COARSE	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
COARSE	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
FENESTRAE	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
VUGS	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
INTRACLASTS	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
MEGAFOSSILS	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
LAMINATION	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
ZERRA	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
23	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00
24	-1.00	1.00	1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	-1.00	-1.00	1.00	1.00	1.00

Unit 3, Section P

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	DK	4D	M	HL	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
<127-8.00	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
>257-8.00	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
>257-8.00	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
>257-8.00	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
DARK	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MED DK	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MED QK	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MED LT	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
LIGHT QY	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
ALFF	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MICROCRYST	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
FINE	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MED FINE	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MED CRYST	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MED COARSE	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
COARSE	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
FENESTRAE	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
VUGS	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
INTRACLASTS	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
MEGAFOSSILS	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
LAMINATION	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
ZEBRA	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
23	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
24	1.27	1.00-8.00	1.00	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27

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2579078

Unit 3, Section P

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

DK	MD	M	ML	LT	BF	MJ	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
<1F	5.00	8.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00
>2FT	5.00	8.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00
>3F	5.00	8.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00
>5FT	5.00	8.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00	5.00	6.00	7.00	8.00
DARK																				
MED DK																				
MEDIUM																				
MED LT																				
LIGHT QY																				
BUFF																				
MICROCRYST																				
FINE																				
MED FINE																				
MED CRYST																				
MED COARSE																				
COARSE																				
FENESTRAE																				
VUGS																				
INTRACLASTIC																				
MEGAFOSILS																				
LAMINATION																				
ZERRA																				
23																				
24																				

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Unit 3, Section P

#13-76 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	OK	40	M	4L	LT	BF	HI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
SEIF	.62	.72	.62	.62	.20	.62	.56	.58	.77	.74	.59	.54	.58	.64	.59	.57	.60	.75	.64	.58	.57
>2FT	.26	.31	.38	.26	.62	.26	.28	.43	.41	.49	.32	.23	.33	.26	.27	.25	.37	.37	.48	.26	.27
>3F	.26	.31	.38	.26	.62	.26	.26	.42	.40	.49	.30	.22	.32	.25	.26	.24	.36	.37	.47	.26	.26
>2FT	.15	.41	.28	.15	.62	.15	.12	.28	.34	.41	.16	.08	.19	.12	.14	.11	.25	.31	.36	.13	.13
CARK							.03	.21	.34	.42	.00	.00	.13	.24	.04	.04	.08	.30	.15	.05	.04
MED OK							.15	.29	.42	.48	.12	.12	.14	.29	.10	.10	.14	.35	.21	.12	.10
MEDIUM							.15	.28	.44	.57	.15	.15	.21	.35	.14	.14	.16	.40	.25	.16	.14
MED LT							.04	.22	.34	.43	.01	.01	.11	.21	.01	.01	.05	.28	.12	.03	.01
LIGHT OY							.76	.83	.81	.78	.73	.73	.80	.74	.72	.72	.75	.75	.74	.72	.72
BUFF							.03	.21	.34	.42	.00	.00	.00	.10	.21	.00	.00	.04	.27	.12	.00
MICROCRYS													.08	.17	.02	.02	.04	.31	.37	.03	.02
FINE													.16	.25	.11	.10	.11	.38	.43	.11	.10
MED FINE													.51	.61	.54	.54	.56	.69	.62	.55	.54
MED CRYS													.71	.41	.34	.33	.35	.48	.63	.33	.33
MED COARSE													.09	.18	.04	.03	.05	.32	.38	.04	.03
COARSE													.06	.16	.02	.00	.03	.30	.36	.02	.01
FENESTRAE														.20	.08	.07	.14	.36	.36	.08	.07
VUGS															.14	.12	.19	.32	.54	.13	.13
INTRACLASTS															.02	.08	.27	.42	.03	.03	.03
MEGAFOSSILS																.07	.25	.42	.02	.01	.01
LAMINATION																	.32	.43	.08	.08	.08
ZERRA																		.66	.24	.24	.24
23																			.43	.43	.43
24																					.02

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FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
.58	.25	.24	.11	.04	.10	.14	.01	.72	.00	.01	.10	.54	.32	.02	.00	.06	.12	.02	.00	.07	.25	.42	.01	.01

Unit 3, Section P

WEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

OK	NO	M	ML	LT	BF	MI	FN	WF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
<LF	.23	.82	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88
>2FT	.58	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88
>3F	.58	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88
>5FT	.28	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88
DARK						.70	.70	.70	.70	.70	.70	.70	.64	.64	.64	.64	.64	.64	.64	.64
MED OK						.70	.70	.70	.70	.70	.70	.70	.64	.64	.64	.64	.64	.64	.64	.64
MED LUM						.70	.70	.70	.70	.70	.70	.70	.64	.64	.64	.64	.64	.64	.64	.64
MED LT						.70	.70	.70	.70	.70	.70	.70	.64	.64	.64	.64	.64	.64	.64	.64
LIGHT OY						.70	.70	.70	.70	.70	.70	.70	.64	.64	.64	.64	.64	.64	.64	.64
BLUE						.70	.70	.70	.70	.70	.70	.70	.64	.64	.64	.64	.64	.64	.64	.64
MICROCRYST										.37	.22	.23	.22	.23	.22	.23	.23	.22	.22	.22
PINE										.37	.22	.23	.22	.23	.22	.23	.23	.22	.22	.22
MED FINE										.36	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22
MED CRYST										.36	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22
MED COARSE										.36	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22
COARSE										.36	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22
FENESTRAE										.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
VUGS										.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
INTRACLASTS										.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
MEGAFOSILS															.01	.01	.01	.01	.01	.01
LAMINATION															.01	.01	.01	.01	.01	.01
ZEARA															.01	.01	.01	.01	.01	.01
23																		.01	.01	.01
24																				.01

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
.70	.71	.71	.71	.64	.64	.64	.64	.64	.64	.22	.22	.22	.22	.22	.22	.15	.01	.01	.01	.01	.01	.01	.01	.01

EXIT

carleton university computing centre

2579081

Unit 3, Section P (Regular interval hand specimen data, only.)

STOP H SP NO. OF SAMPLES: 56

COEFFICIENTS MERGED: NO

Unit 3, Section P (Regular interval hand specimen data, only.)

STOP H SP NO. OF SAMPLES: 56
COEFFICIENTS MERGED?: NO
OK 40 M ML LT BF MI FN MF M HC CS FE VU IN FO LA ZE 23 24 25 26 27
Sand present
>10% white dolomite
Internal sediment
* Diffuser
>5% Insoluble residue

S&P-1.00	-.67	-.71	1.00	-.56	-.75	-.33	-.25	1.00	1.00	-.71	1.00	-.60	-.75	-.43	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>2FT-1.00	1.00	-.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
>3FT-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
>5FT-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
DARK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED DK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MEDIUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED LT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
LIGHT GY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
BUFF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MICROCRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED CRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
FENESTRAE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
VUGS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
INTRACLASTS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MEGAFOSILS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
LAMINATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
ZERRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
23	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

Insoluble residue
Siltstone
Internal sediment
Sand present
dolomite
>10% white

Unit 3, Section P (Hand specimen data)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

OK	YD	M	ML	LT	BF	HI	FN	HF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27
5-1F-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2-1F-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2-2F-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2-3F-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2-4F-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2-5F-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK																						
MED DK																						
MEDIUM																						
MED LT																						
LIGHT BY																						
BUFF																						
MICROCRYST																						
PINE																						
MED FINE																						
MED CRYST																						
MED COARSE																						
COARSE																						
FENESTRAE																						
VUGS																						
INTRACLASTS																						
MEGAPOSSILS																						
LAMINATION																						
ZERRA																						
23																						
24																						
25																						
26																						

Unit 3, Section P (Hand specimen data)

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

OK	4D	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27	
<1E	5.00	5.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00
>2FT	5.00	5.00	7.00	8.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
>3FT	5.00	5.00	7.00	8.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
>5FT	5.00	5.00	7.00	8.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
DARK																							
MED DK																							
MEDIUM																							
MED LT																							
LIGHT GV																							
BUFF																							
MICROCRYST																							
FINE																							
MED FINE																							
MED CRYST																							
MED COARSE																							
COARSE																							
FENESTRAE																							
VUGS																							
INTRACLASTIC																							
MEGAFOSFELS																							
LAMINATION																							
ZEPHYRA																							
23																							
24																							
25																							
26																							

Unit 3, Section P (Hand specimen data)

WEIGHTS 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	OK	QD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27
<1E	.46	.46	.54	.50	.62	.62	.46	.42	.69	.54	.54	.46	.45	.62	.58	.46	.46	.46	.54	.55	.54	.50	.50
>2F1	.25	.33	.42	.27	.42	.50	.42	.58	.25	.33	.42	.25	.40	.42	.45	.25	.50	.25	.33	.60	.42	.27	.75
>3F	.18	.27	.36	.20	.36	.45	.36	.55	.18	.27	.36	.18	.33	.36	.40	.18	.45	.18	.27	.56	.36	.20	.67
>5F1	.00	.28	.15	.08	.38	.23	.15	.38	.23	.08	.15	.00	.18	.23	.25	.00	.23	.00	.08	.36	.23	.00	.50
DARK							.09	.43	.30	.14	.20	.04	.19	.41	.40	.07	.18	.16	.28	.59	.12	.08	.47
MED OK							.14	.41	.36	.20	.25	.09	.25	.44	.47	.13	.25	.18	.30	.67	.12	.13	.47
MEDIUM							.18	.48	.39	.20	.27	.12	.23	.48	.47	.16	.25	.22	.35	.65	.21	.15	.59
MED LT							.38	.64	.45	.42	.42	.33	.42	.51	.55	.37	.47	.41	.49	.63	.41	.35	.65
LIGHT BY							.32	.62	.43	.32	.39	.27	.44	.50	.54	.29	.41	.38	.46	.70	.29	.28	.65
BUFF							.27	.68	.43	.30	.32	.20	.33	.56	.44	.29	.34	.33	.41	.61	.27	.25	.53
MICROCRYST												.19	.44	.44	.40	.11	.20	.20	.31	.61	.13	.11	.47
FINE												.40	.76	.56	.56	.42	.48	.51	.59	.72	.42	.47	.65
MED FINE												.44	.48	.60	.60	.31	.43	.36	.44	.70	.33	.25	.45
MED CRYST												.29	.41	.44	.44	.13	.29	.22	.33	.61	.19	.13	.47
MED COARSE												.35	.41	.49	.420	.34	.24	.35	.65	.23	.21	.65	
COARSE												.17	.37	.37	.37	.04	.18	.13	.26	.57	.08	.04	.47
FENESTRAE												.57	.41	.21	.27	.32	.41	.61	.23	.22	.22	.57	
VUGS													.67	.67			.56	.40	.48	.73	.45	.37	.82
INTRACLASTS													.36	.36			.44	.50	.59	.53	.42	.42	.79
MEGAFOSSILS																	.22	.17	.30	.56	.12	.08	.47
LAMINATION																		.31	.41	.63	.28	.23	.59
ZERRA																		.28	.44	.20	.47	.17	.53
23																		.73	.30	.25	.25	.59	
24																			.61	.78	.64	.10	.44
25																							.47
26																							

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
.46	.25	.18	.00	.04	.08	.12	.33	.27	.20	.07	.41	.27	.11	.16	.00	.17	.37	.37	.04	.18	.13	.24	.57	.08	.04	.47

Unit 3, Section P (Hand specimen data)

HEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

	OK	NO	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27	
<1F	.77	.77	.77	.79	.77	.77	.77	.77	.77	.77	.77	.77	.80	.77	.79	.77	.77	.77	.77	.77	.80	.77	.79	.93
>2FT	.79	.79	.79	.80	.79	.79	.79	.79	.79	.79	.79	.79	.82	.79	.80	.79	.79	.79	.79	.79	.82	.79	.80	.93
>3F	.80	.80	.80	.82	.80	.80	.80	.80	.80	.80	.80	.80	.84	.80	.82	.80	.80	.80	.80	.80	.84	.80	.82	.95
>5FT	.77	.77	.77	.79	.77	.77	.77	.77	.77	.77	.77	.77	.80	.77	.79	.77	.77	.77	.77	.77	.80	.77	.79	.93
DARK							.00	.00	.00	.00	.00	.00	.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
MED DK							.00	.00	.00	.00	.00	.00	.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
MEDIUM							.00	.00	.00	.00	.00	.00	.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
MED LT							.02	.02	.02	.02	.02	.02	.14	.05	.25	.04	.02	.04	.05	.05	.18	.09	.07	.70
LIGHT QY							.00	.00	.00	.00	.00	.00	.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
BUFF							.00	.00	.00	.00	.00	.00	.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
MICROCRYST													.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
FINE													.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
MED FINE													.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
MED CRYST													.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
MED COARSE													.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
COARSE													.14	.04	.23	.02	.00	.02	.02	.04	.18	.07	.05	.70
FINESTRAE													.18	.18	.30	.16	.14	.16	.18	.18	.27	.21	.20	.78
VUGS													.25	.25	.25	.05	.04	.05	.07	.21	.09	.09	.70	
INTRACLASTS													.25	.25	.25	.25	.23	.25	.27	.27	.39	.29	.29	.75
MEGAPOSSIBLES													.02	.04	.05	.04	.02	.04	.04	.05	.20	.09	.07	.70
LAMINATION													.02	.02	.04	.04	.02	.02	.04	.04	.18	.07	.05	.70
ZEBRA													.20	.20	.20	.03	.03	.03	.04	.04	.20	.11	.09	.70
23																					.20	.11	.09	.70
24																					.25	.21	.21	.71
25																					.11	.11	.11	.71
26																								.70

8-30

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
.77	.79	.80	.77	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.00	.14	.04	.23	.02	.00	.02	.04	.18	.07	.05	.70

Unit 3, Section P (Regular-interval hand specimen data, only.)

PTSD H SP NO. OF SAMPLES: 56

COEFFICIENTS																						MERGED: YES									
DA	QD	H	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27									
<1F	.67	.67	.71	1.00	.45	.75	.33	1.25	1.00	1.00	.71	.60	.75	.43	1.00	.00	1.00	1.00	.33	.43	1.00	.00									
>2FT	1.00	1.00	.60	.33	.80	1.00	1.00	.78	1.33	.00	1.00	1.00	.50	.60	1.00	1.00	1.00	1.00	.67	.60	1.00	1.00									
>3F	1.00	1.00	.50	.00	.71	1.00	1.00	.75	.00	.33	1.00	1.00	.33	.50	1.00	1.00	1.00	1.00	.60	.50	1.00	1.00									
>5FT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00									
DARK																															
MED OK																															
MEDIUM																															
MED LT																															
LIGHT BY																															
BUFF																															
MICROCRYST																															
PINE																															
MED FINE																															
MED CRYST																															
MED COARSE																															
COARSE																															
FENESTRAE																															
VUGS																															
INTRACLASTS																															
MEGAFOSILS																															
LAMINATION																															
ZENRA																															
23																															
24																															
25																															
26																															

8-31

Unit 3, Section P (Hand specimen data) - Merged

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	5C	4D	M	ML	LT	BF	MI	FN	MF	N	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27
<1F	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>2FT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>3FT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>5FT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED DK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEDIUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED LT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LIGHT BY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BUFF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MICROCRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED CRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FENESTRAE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VUGS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INTRACLASTS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEGAFOSILS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAMINATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZEBRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

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Unit 3, Section P (Hand specimen data) - merged.

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

OK	YD	M	ML	LT	BF	HI	FN	MF	M	MC	CS	FE	VJ	IN	FD	LA	ZE	23	24	25	26	27
<1P	8.00	8.00	7.00	8.00	1.00	10.00	0.01	1.00	13.00	0.01	4.00	0.01	5.00	0.01	9.00	0.02	0.02	0.02	0.02	0.02	0.02	1.00
>2P	5.00	6.00	2.00	8.00	2.00	1.00	1.00	2.00	13.00	0.01	3.00	0.01	7.00	0.01	2.00	0.02	0.02	0.02	0.02	0.02	0.02	2.00
>3P	5.00	6.00	3.00	8.00	3.00	3.00	3.00	3.00	13.00	0.01	3.00	0.01	7.00	0.01	3.00	0.02	0.02	0.02	0.02	0.02	0.02	3.00
>5P	5.00	6.00	4.00	8.00	4.00	4.00	4.00	4.00	13.00	0.01	4.00	0.01	7.00	0.01	4.00	0.02	0.02	0.02	0.02	0.02	0.02	4.00
DARK																						
MED DK																						
MEDIUM																						
MED LT																						
LIGHT GY																						
BUFF																						
MICROCRYST																						
FINE																						
MED FINE																						
MED CRYST																						
MED COARSE																						
COARSE																						
FENESTRAE																						
VUGS																						
INTRACLASTS																						
MEGAPOSSILS																						
LAMINATION																						
ZEBRA																						
23																						
24																						
25																						
26																						

Unit 3, Section P (Hand specimen data)

HEIGHTS 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	OK	YD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27
CREE	.16	.16	.58	.50	.85	.42	.16	.42	.16	.42	.16	.42	.16	.42	.16	.42	.16	.42	.16	.42	.16	.42	.16
DEFT	.33	.33	.45	.27	.67	.50	.42	.75	.25	.33	.42	.42	.40	.42	.40	.45	.25	.50	.25	.33	.60	.42	.27
DEFT	.27	.27	.40	.20	.64	.45	.36	.73	.18	.27	.36	.36	.33	.36	.40	.18	.45	.18	.27	.54	.36	.20	.67
DEFT	.28	.28	.25	.108	.42	.23	.15	.54	.23	.31	.15	.15	.18	.23	.25	.00	.23	.00	.08	.16	.23	.00	.50
DARK							.16	.46	.39	.50	.29	.29	.27	.48	.49	.16	.25	.22	.31	.70	.15	.17	.47
MED OK							.14	.45	.34	.46	.25	.25	.25	.44	.47	.13	.25	.18	.30	.67	.12	.13	.47
MEDIUM							.19	.75	.58	.54	.53	.53	.48	.62	.64	.50	.55	.50	.58	.72	.55	.44	.76
MED LT							.38	.69	.45	.55	.42	.42	.42	.51	.55	.37	.47	.41	.49	.63	.41	.35	.65
LIGHT SY							.52	.73	.59	.64	.55	.55	.60	.69	.63	.49	.57	.58	.61	.74	.48	.49	.71
BUFF							.27	.54	.42	.54	.32	.32	.33	.54	.44	.20	.34	.33	.41	.41	.27	.25	.53
MICROCRYST													.19	.44	.40	.11	.20	.20	.31	.61	.13	.11	.47
PINE													.42	.81	.58	.47	.48	.56	.65	.74	.48	.53	.65
MED FINE													.44	.48	.60	.31	.43	.36	.44	.70	.33	.25	.65
MED CRYST													.56	.52	.67	.40	.54	.45	.52	.74	.44	.34	.65
MED COARSE													.35	.41	.49	.20	.34	.24	.35	.65	.23	.21	.65
COARSE													.35	.41	.49	.20	.34	.24	.35	.65	.23	.21	.65
FENESTRAE													.87	.41	.21	.21	.27	.32	.41	.61	.23	.22	.57
VUGS													.67	.40	.56	.40	.48	.73	.45	.37	.45	.37	.82
INTRACLASTS													.36	.44	.44	.50	.59	.53	.42	.42	.42	.42	.79
MEGAFOSILS													.22	.17	.30	.56	.12	.08	.47	.47	.47	.47	.47
LAMINATION													.31	.31	.41	.63	.23	.59	.23	.23	.23	.23	.59
ZEBRA													.28	.64	.20	.17	.53	.53	.53	.53	.53	.53	.53
23													.73	.30	.25	.59	.73	.30	.25	.59	.73	.30	.25
24													.44	.61	.75	.44	.61	.75	.44	.61	.75	.44	.61
25													.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
26													.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
.44	.25	.18	.00	.12	.09	.45	.31	.46	.20	.07	.46	.27	.37	.16	.16	.17	.37	.37	.04	.18	.13	.24	.57	.08	.08	.47

carleton university computing centre

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Unit 3, Section P

WEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

[illegible]

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

FORTRAN RJN-TIME ERROR IN '9BCDREAD' CALLED AT LOC X'0E629'.
P1 2 2 1 1 1 1 2 1 1 2 1 1 1 1 1 2 1 1
P2 2 2 1 1 1 1 2 1 1 2 1 1 1 1 1 2 1 1

carleton university computing centre

347119

[illegible][illegible]

COEFFICIENT BASED ON PRESENCE OF THE LESS COMMON CHARACTER

[illegible]

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

[illegible]

Unit 3, Section 6

HEIGHTS IN POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

OK	40	M	ML	LT	8F	MI	FN	MF	Y	MC	CS	FE	VU	IN	FO	LA	7E	23	24
S&P	.39	.39	.48	.49	.40	.38	.70	.55	.46	.49	.41	.45	.55	.41	.41	.64	.50	.66	.42
>2FT	.35	.45	.54	.67	.38	.77	.85	.33	.36	.33	.33	.36	.35	.32	.32	.64	.36	.76	.33
>3F	.28	.40	.48	.68	.31	.73	.52	.30	.30	.28	.28	.29	.30	.25	.28	.59	.30	.71	.26
>8FT	.09	.09	.21	.44	.10	.63	.39	.19	.18	.13	.12	.15	.20	.11	.10	.48	.21	.61	.11
DARK						.70	.15	.07	.06	.00	.00	.10	.11	.01	.00	.38	.05	.50	.00
MED DK						.70	.15	.07	.05	.00	.00	.10	.11	.01	.00	.38	.05	.50	.00
MEDIUM						.70	.30	.24	.25	.19	.19	.22	.29	.19	.18	.51	.21	.65	.18
MED LT						.75	.28	.28	.27	.20	.20	.26	.29	.21	.20	.48	.25	.58	.20
LIGHT OY						.94	.71	.67	.67	.57	.57	.69	.60	.58	.58	.74	.58	.74	.58
BUFF						.66	.14	.08	.07	.00	.00	.11	.12	.01	.00	.32	.04	.47	.00
MICROCRYST												.67	.70	.55	.54	.74	.59	.74	.57
FINE												.36	.40	.30	.30	.58	.34	.63	.30
MED FINE												.15	.17	.06	.06	.45	.06	.58	.08
MED CRYST												.17	.17	.09	.08	.44	.13	.61	.10
MED COARSE												.09	.15	.01	.00	.40	.04	.52	.02
COARSE												.09	.15	.01	.00	.40	.04	.52	.02
FENESTRAE												.21	.08	.08	.08	.45	.18	.58	.09
VUGS												.15	.15	.14	.14	.50	.21	.65	.14
INTRACLASTS														.01	.01	.42	.11	.53	.02
MEGAFOSILS																.42	.10	.53	.02
LAMINATION																.51	.68	.42	
ZERRA																.42	.12	.62	.12
83																			.83

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.41	.32	.25	.16	.00	.00	.18	.20	.58	.00	.54	.70	.06	.08	.00	.00	.08	.14	.01	.00	.42	.10	.53	.02

Unit 3, Section G

WEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

	DK	MD	M	ML	LT	BF	HI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
CLIF	.42	.40	.40	.40	.44	.44	.28	.28	.23	.23	.23	.23	.03	.03	.03	.03	.05	.03	.03	.03
>2FT	.40	.40	.40	.40	.46	.46	.28	.28	.23	.23	.23	.23	.03	.03	.03	.03	.05	.03	.03	.03
>3F	.40	.40	.40	.40	.46	.46	.28	.28	.23	.23	.23	.23	.03	.03	.03	.03	.05	.03	.03	.03
>5FT	.40	.40	.40	.40	.46	.46	.28	.28	.23	.23	.23	.23	.03	.03	.03	.03	.05	.03	.03	.03
DARK							.46	.46	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38	.38
MED DK							.46	.46	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38	.38
MEDIUM							.46	.46	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38	.38
MED LT							.46	.46	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38	.38
LIGHT BY							.52	.52	.46	.46	.46	.46	.44	.44	.44	.44	.44	.44	.44	.44
BUFF							.52	.52	.46	.46	.46	.46	.44	.44	.44	.44	.44	.44	.44	.44
MICROCRYST													.28	.28	.28	.28	.30	.28	.28	.28
FINE													.28	.28	.28	.28	.30	.28	.28	.28
MED FINE													.20	.20	.20	.20	.22	.20	.20	.20
MED CRYST													.20	.20	.20	.20	.22	.20	.20	.20
MED COARSE													.20	.20	.20	.20	.22	.20	.20	.20
COARSE													.20	.20	.20	.20	.22	.20	.20	.20
FENESTRAE													.00	.00	.00	.00	.02	.00	.00	.00
VUGS													.00	.00	.00	.00	.02	.00	.00	.00
INTRACLASTS													.00	.00	.00	.00	.02	.00	.00	.00
MEGAFOSILS													.00	.00	.00	.00	.02	.00	.00	.00
LAMINATION													.00	.00	.00	.00	.02	.00	.00	.00
ZEBRA													.00	.00	.00	.00	.02	.00	.00	.00
23																	.02	.00	.00	.00

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.03	.02	.03	.03	.38	.38	.38	.38	.44	.44	.28	.28	.20	.20	.20	.20	.00	.00	.00	.00	.02	.00	.00	.00

Unit 3, Section G

STOS SECT

NO. OF SAMPLES: 179

9

COEFFICIENTS

MERGED: YES

DC	ND	M	ML	LT	BF	MI	PN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
461F=1.00=1.00	0.28	0.86	0.84	1.00	0.30	0.10	1.00	0.97	1.02	1.00	0.92	1.00	1.00	1.00	1.00	0.37	0.95	0.12	1.00
289F=1.00=1.00	0.83	0.97	0.87	1.00	0.68	0.55	0.65	0.31	1.00	1.00	0.84	0.34	0.96	1.00	0.72	0.65	0.76	1.00	
203F=1.00=1.00	0.87	0.96	0.17	1.00	0.70	0.61	0.74	0.36	1.00	1.00	0.84	0.43	1.00	1.00	0.80	0.70	0.81	1.00	
282F=1.00=1.00	0.87	1.00	0.77	1.00	0.93	0.77	1.00	0.70	1.00	1.00	0.77	0.64	1.00	1.00	0.90	1.00	0.93	1.00	
DARK								0.10	1.00	1.00	0.90	0.90	1.00	1.00	0.90	1.00	1.00	1.00	0.90
MED OK								0.10	1.00	1.00	0.90	0.90	1.00	1.00	0.90	1.00	1.00	1.00	0.90
MEDIUM								0.31	0.96	1.00	1.00	1.00	1.00	1.00	0.92	1.00	1.00	1.00	0.40
MED LT								0.72	0.63	1.00	1.00	1.00	0.72	0.87	1.00	1.00	0.58	1.00	0.59
LIGHT BY								0.21	0.05	0.71	0.46	1.00	1.00	0.67	0.97	1.00	0.57	0.80	0.17
SUFF								0.10	1.00	1.00	1.00	0.90	1.00	1.00	0.90	1.00	1.00	1.00	0.90
MICROCRYST													0.81	1.00	1.00	1.00	0.37	1.00	0.12
FINE													0.80	0.89	0.98	1.00	0.17	0.94	0.94
MED FINE													0.10	0.58	1.00	1.00	0.97	0.11	1.00
MED CRYST													0.10	0.07	1.00	1.00	0.88	0.52	1.00
MED COARSE													0.10	1.00	1.00	0.90	1.00	1.00	1.00
COARSE													0.10	1.00	1.00	0.90	1.00	1.00	1.00
FENESTRAE													0.98	1.00	1.00	0.77	1.00	0.90	0.87
VUGS													0.10	1.00	1.00	0.84	0.68	0.97	1.00
INTRACLASTS													0.10	1.00	1.00	0.97	1.00	1.00	1.00
MEGAPOSSILS																0.10	1.00	1.00	1.00
LAMINATION																	0.93	0.18	0.92
ZEOLITE																	0.93	1.00	0.94

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Unit 3, Section G (Merged)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	DS	HD	M	HL	LT	BF	HI	FN	WF	M	YC	CS	FE	VU	IN	FO	LA	ZE	23	24
COIF-8.00-8.00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
>2FT-8.00-8.00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
>3F-8.00-8.00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
>5F-8.00-8.00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
DARK	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MED DK	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MEDIUM	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MED LT	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
LIGHT BY	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
BUFF	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MICROCRYST	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
PINE	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MED FINE	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MED CRYST	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MED COARSE	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
COARSE	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
FENESTRAE	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
VUGS	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
INTRACLASTS	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
MEGAFOSSILS	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
LAMINATION	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
ZERRA	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

Unit 3, Section G (merged)

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

DK	4D	M	ML	LT	BF	MI	FN	MF	Y	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	
SWP	8.20	8.20	7.00	8.00	1.0010.00	1.00	1.0013.0014.0015.0016.0017.0018.0019.0020.00	1.0022.00	1.0024.00											
>2FT	8.20	8.20	8.00	8.00	2.0010.00	2.00	2.0013.0014.0015.0016.0017.0018.0019.0020.00	2.0022.00	2.0024.00											
>3F	8.20	8.20	8.00	8.00	3.0010.00	3.00	3.0013.0014.0015.0016.0017.0018.0019.0020.00	3.0022.00	3.0024.00											
>8FT	8.20	8.20	8.00	8.00	4.0010.00	4.00	4.0013.0014.0015.0016.0017.0018.0019.0020.00	4.0022.00	4.0024.00											
DARK						5.00	5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00 5.00													
MED DK						6.00	6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00 6.00													
MEDIUM						7.00	7.0013.0014.0015.0016.0017.0018.0019.0020.00	7.0022.00	7.0024.00											
MED LT						8.00	8.0013.0014.0015.0016.0017.0018.0019.0020.00	8.0022.00	8.0024.00											
LIGHT GY						9.00	9.0013.0014.0015.0016.0017.0018.0019.0020.00	9.0022.00	9.0024.00											
BUFF						10.0010.0010.0010.00	10.0010.0010.0010.00	10.0010.0010.0010.00	10.0010.0010.0010.00											
MICROCRYST							17.0018.0019.0020.0021.0022.0023.0024.00	17.0018.0019.0020.0021.0022.0023.0024.00	17.0018.0019.0020.0021.0022.0023.0024.00											
FINE							13.0013.0019.0020.0021.0022.0023.0024.00	13.0013.0019.0020.0021.0022.0023.0024.00	13.0013.0019.0020.0021.0022.0023.0024.00											
MED FINE							17.0014.0019.0020.0021.0022.0023.0024.00	17.0014.0019.0020.0021.0022.0023.0024.00	17.0014.0019.0020.0021.0022.0023.0024.00											
MED CRYST							15.0015.0015.00	15.0015.0015.00	15.0015.0015.00											
MED COARSE							14.0014.0014.00	14.0014.0014.00	14.0014.0014.00											
COARSE							17.0019.0020.0021.0022.0023.0024.00	17.0019.0020.0021.0022.0023.0024.00	17.0019.0020.0021.0022.0023.0024.00											
PENESTRAE							19.0020.0018.0022.0018.0024.00	19.0020.0018.0022.0018.0024.00	19.0020.0018.0022.0018.0024.00											
VUGS							20.0019.0019.0021.0022.0019.00	20.0019.0019.0021.0022.0019.00	20.0019.0019.0021.0022.0019.00											
INTRACLASTS																				
MEGAFOSILS																				
LAMINATION																				
.ZERRA																				
83																				

Unit 3, Section G (Merged)

#213-175 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	OK	40	H	ML	LT	BF	HI	FN	MF	H	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
<5FT	.32	.32	.57	.43	.80	.38	.70	.85	.46	.54	.41	.41	.45	.55	.41	.41	.64	.50	.64	.42
>2FT	.38	.35	.64	.84	.67	.38	.77	.98	.33	.36	.33	.33	.36	.35	.32	.32	.64	.36	.76	.33
>3FT	.28	.28	.60	.48	.68	.31	.73	.98	.30	.32	.28	.28	.29	.30	.25	.25	.59	.30	.71	.26
>5FT	.09	.09	.42	.20	.64	.10	.63	.84	.19	.24	.13	.13	.15	.20	.11	.10	.48	.21	.61	.11
DARK							.70	.84	.07	.14	.00	.00	.10	.11	.01	.00	.38	.05	.50	.00
MED DK							.70	.84	.07	.14	.00	.00	.10	.11	.01	.00	.38	.05	.50	.00
MEDIUM							.75	.84	.46	.53	.39	.39	.38	.47	.39	.38	.61	.43	.73	.38
MED LT							.75	.84	.28	.34	.20	.20	.26	.29	.21	.20	.48	.25	.58	.20
LIGHT BY							.94	1.00	.57	.57	.57	.87	.69	.60	.58	.58	.74	.58	.74	.58
BUFF							.66	.81	.08	.15	.00	.00	.11	.12	.01	.00	.32	.04	.47	.00
MICROCRYST													.57	.70	.55	.54	.74	.59	.74	.57
FINE													.84	.95	.84	.84	.90	.88	.84	.84
MED FINE													.15	.17	.06	.06	.45	.06	.58	.08
MED CRYST													.23	.20	.15	.14	.49	.15	.66	.16
MED COARSE													.09	.15	.01	.00	.40	.04	.52	.02
COARSE													.09	.15	.01	.00	.40	.04	.52	.02
PENESTRAE														.21	.08	.08	.45	.18	.58	.09
VUGS															.15	.14	.50	.21	.65	.16
INTRACLASTS																.01	.42	.11	.53	.02
MEGAFOSSILS																	.42	.10	.53	.02
LAMINATION																		.51	.68	.42
ZERRA																		.42	.42	.12
23																				.53

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.41	.22	.25	.10	.00	.00	.28	.20	.58	.00	.54	.84	.06	.14	.00	.00	.08	.14	.01	.00	.42	.10	.53	.02

Unit 3, Section G (Merged)

DE13-78 21 FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

	OK	40	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SUP	.40	.40	.40	.40	.44	.44	.28	.28	.23	.23	.23	.23	.23	.03	.03	.03	.05	.03	.03	.03
>2FT	.40	.40	.40	.40	.46	.46	.28	.28	.23	.23	.23	.23	.23	.03	.03	.03	.05	.03	.03	.03
>3FT	.40	.40	.40	.40	.46	.46	.28	.28	.23	.23	.23	.23	.23	.03	.03	.03	.05	.03	.03	.03
>5FT	.40	.40	.40	.40	.46	.46	.28	.28	.23	.23	.23	.23	.23	.03	.03	.03	.05	.03	.03	.03
DARK							.46	.46	.40	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38
MED DK							.46	.46	.40	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38
MEDIUM							.46	.46	.40	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38
MED LT							.46	.46	.40	.40	.40	.40	.40	.38	.38	.38	.38	.38	.38	.38
LIGHT GY							.52	.52	.48	.48	.45	.45	.45	.44	.44	.44	.44	.44	.44	.44
BUFF							.52	.52	.48	.48	.45	.45	.45	.44	.44	.44	.44	.44	.44	.44
MICROCRYST														.28	.28	.28	.30	.28	.28	.28
FINE														.28	.28	.28	.30	.28	.28	.28
MED FINE														.20	.20	.20	.22	.20	.20	.20
MED CRYST														.20	.20	.20	.22	.20	.20	.20
MED COARSE														.20	.20	.20	.22	.20	.20	.20
COARSE														.20	.20	.20	.22	.20	.20	.20
FENESTRAE														.00	.00	.00	.02	.00	.00	.00
VUGS														.00	.00	.00	.02	.00	.00	.00
INTRACLASTS														.00	.00	.00	.02	.00	.00	.00
MEGAFOSSILS																	.02	.00	.00	.00
LAMINATION																	.02	.02	.02	.02
ZERRA																		.02	.02	.02
23																		.00	.00	.00

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.03	.03	.03	.03	.38	.38	.38	.38	.44	.44	.28	.28	.20	.20	.20	.20	.00	.00	.00	.00	.02	.00	.00	.00

Unit 3, Section G (Limestone layer and above, only)

3105 SECT NO. OF SAMPLES 88

COEFFICIENTS MERGED? NO

OK	MD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
CALF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DEFT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DEFT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DEFT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED DK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEDIUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED LT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LIGHT BY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BUFF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MICROCRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED CRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FENESTRAE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VUGS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INTRACLASTS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEGAFOSSILS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAMINATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZEBRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Unit 3, Section G (limestone and above)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

OK	40	M	ML	LT	BF	MI	FN	MF	M	MC	C9	FE	VU	IN	FO	LA	ZE	23	24
SEIF-8.00-8.00	0.20	0.20	0.20	0.60	0.00	0.33	0.50	1.00	0.83	8.00-8.00	0.00	0.00	1.00-1.00	1.00-8.00	0.04	0.76	1.57	1.00	
SEFT-8.00-8.00	0.67	0.60	0.80	1.00	0.00	0.33	0.50	1.00	0.83	8.00-8.00	0.00	0.00	1.00-1.00	1.00-8.00	0.33	0.18	0.76	1.00	
SEF-8.00-8.00	1.00	0.60	0.75	1.00	0.00	0.33	0.50	1.00	0.83	8.00-8.00	0.00	0.00	1.00-1.00	1.00-8.00	0.52	0.18	0.86	1.00	
SEFT-8.00-8.00	1.00	1.00	0.50	0.00	0.00	0.33	0.50	1.00	0.83	8.00-8.00	0.00	0.00	1.00-1.00	1.00-8.00	0.75	0.10	0.83	1.00	
DARK																			
MED DK																			
MEDIUM																			
MED LT																			
LIGHT BY																			
BUFF																			
MICROCRYST																			
FINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
FENESTRAE																			
VUGS																			
INTRACLASTS																			
MEGAFOSFELS																			
LAMINATION																			
ZERRA																			
83																			

Unit 3, Section G, (limestone and above).

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

	DR	W	M	HL	LT	BF	HI	FN	HF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SLF 8.00 6.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00																				
28FT 8.00 6.00 7.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00																				
28FT 8.00 6.00 7.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00																				
28FT 8.00 6.00 7.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00																				
DARK																				
MED DK																				
MEDIUM																				
MED LT																				
LIGHT BY																				
BUFF																				
MICROCRYST																				
FINE																				
MED FINE																				
MED CRYST																				
MED COARSE																				
COARSE																				
PENESTRAE																				
VUGS																				
INTRACLASTS																				
MEGAFOSSILS																				
LAMINATION																				
ZEBRA																				
83																				

Unit 3, Section G (limestone and above)

WEIGHTS 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	DC	4D	M	HL	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SELF	.16	.16	.28	.25	.78	.16	.30	.88	.38	.45	.26	.26	.29	.55	.28	.27	.54	.44	.44	.29
>2FT	.61	.61	.76	.73	.70	.64	.63	.81	.49	.56	.49	.49	.48	.49	.45	.45	.69	.93	.78	.47
>3FT	.48	.48	.67	.61	.70	.48	.56	.78	.46	.46	.41	.41	.37	.44	.34	.33	.63	.45	.69	.36
>5FT	.12	.12	.30	.27	.67	.12	.32	.63	.32	.32	.20	.20	.18	.32	.15	.14	.48	.33	.51	.14
DARK							.17	.31	.21	.24	.00	.00	.06	.33	.03	.00	.14	.15	.15	.00
MED DK							.17	.31	.21	.24	.00	.00	.06	.33	.03	.00	.14	.15	.15	.00
MEDIUM							.17	.48	.39	.42	.18	.18	.24	.52	.21	.18	.36	.33	.33	.18
MED LT							.24	.31	.36	.39	.15	.15	.15	.45	.18	.15	.27	.30	.18	.15
LIGHT BY							.90	.79	.64	.67	.64	.64	.70	.67	.64	.64	.70	.64	.79	.64
BUFF							.21	.34	.26	.26	.02	.02	.02	.34	.04	.03	.21	.18	.15	.03
MICROCRYST													.18	.47	.13	.11	.49	.20	.45	.16
FINE													.53	.76	.53	.53	.67	.60	.56	.53
MED FINE													.18	.37	.13	.12	.48	.13	.50	.17
MED CRYST													.28	.42	.23	.22	.48	.30	.58	.27
MED COARSE													.07	.33	.02	.00	.37	.08	.38	.05
COARSE													.07	.33	.02	.00	.37	.08	.38	.05
PENESTRAE													.32	.07	.07	.06	.42	.25	.39	.08
VUGS													.28	.28	.28	.27	.56	.40	.65	.31
INTRACLASTS													.01	.01	.01	.01	.40	.20	.40	.08
MEGAFOSBILLS																	.40	.19	.39	.03
LAMINATION																	.87	.56	.40	
ZEBRA																	.87	.56	.40	
23																		.87	.56	.40

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.27	.48	.23	.14	.00	.00	.18	.15	.44	.02	.11	.52	.12	.22	.00	.00	.04	.27	.01	.00	.40	.19	.38	.02

Unit 3, Section G (Limestone and above)

WEIGHTS 21: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

OK	4D	M	ML	LT	BF	MI	FN	MF	Y	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
<3F	.64	.64	.64	.64	.64	.40	.40	.34	.34	.34	.34	.02	.02	.02	.02	.07	.02	.02	.02
>2FT	.62	.62	.62	.62	.62	.39	.39	.33	.33	.33	.33	.01	.01	.01	.01	.06	.01	.01	.01
>3F	.62	.62	.62	.62	.62	.39	.39	.33	.33	.33	.33	.01	.01	.01	.01	.06	.01	.01	.01
>2FT	.62	.62	.62	.62	.62	.39	.39	.33	.33	.33	.33	.01	.01	.01	.01	.06	.01	.01	.01
DARK						.67	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
MED OK						.67	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
MEDIUM						.67	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
MED LT						.67	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
LIGHT BY						.67	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
BUFF						.67	.67	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62
MICROCRYST												.37	.37	.37	.37	.42	.37	.37	.37
FINE												.32	.32	.32	.32	.36	.32	.32	.32
MED FINE												.32	.32	.32	.32	.36	.32	.32	.32
MED CRYST												.32	.32	.32	.32	.36	.32	.32	.32
MED COARSE												.32	.32	.32	.32	.36	.32	.32	.32
COARSE												.32	.32	.32	.32	.36	.32	.32	.32
FENESTRAE												.00	.00	.00	.00	.05	.00	.00	.00
VUGS												.00	.00	.00	.00	.05	.00	.00	.00
INTRACLASTS												.00	.00	.00	.00	.05	.00	.00	.00
MEGAFOSSILS																.05	.00	.00	.00
LAMINATION																	.05	.05	.05
ZEBRA																	.00	.00	.00
23																		.00	.00

8-50

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.02	.01	.01	.01	.62	.62	.62	.62	.62	.62	.62	.37	.32	.32	.32	.32	.00	.00	.00	.00	.05	.00	.00	.00

Unit 3, section G (limestone and above)

STOP SECT NO. OF SAMPLES: 88

COEFFICIENTS

MERGED: YES

OK	4D	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
<1F-1.00-1.00	.33	.50	.52	.50	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52	.52
>2FT-1.00-1.00	.86	.92	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
>3FT-1.00-1.00	.92	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
>5FT-1.00-1.00	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
DARK																			
MED DK																			
MED L																			
LIGHT GY																			
BUFF																			
MICROCRYST																			
PINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
FENESTRAE																			
VUGS																			
INTRACLASTS																			
MEGAFOSSILS																			
LAMINATION																			
ZERRA																			
23																			

Unit 3, Section G (limestone and above)

-ESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN) (MERGED)

OK	YD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SELF	8.00	8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>8FT	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
>3FT	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
>5FT	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
DARK																			
MED OK																			
MEDIUM																			
MED LT																			
LIGHT CY																			
BUFF																			
MICROCRYST																			
FINE																			
MED FINE																			
MED CRYST																			
MED COARSE																			
COARSE																			
FINESTRAS																			
VUGS																			
INTRACLASTS																			
MEGAFOSFELS																			
LAMINATION																			
ZERRA																			
23																			

Unit 3, Section G (limestone and above)
 #E13-478 11 POSITIVE AND MISMATCHES V.S. TOTAL MATCHES (merged)

	DC	43	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
S-1F	.16	.16	.37	.25	.78	.16	.30	.66	.38	.57	.26	.26	.29	.55	.28	.27	.54	.44	.43	.29
>2FT	.61	.61	.88	.73	.73	.64	.53	.93	.49	.56	.49	.49	.48	.49	.45	.45	.69	.53	.78	.47
>3F	.48	.48	.79	.61	.70	.48	.56	.89	.46	.51	.41	.41	.37	.44	.34	.33	.63	.45	.69	.36
>8FT	.12	.12	.48	.27	.67	.12	.33	.74	.32	.44	.20	.20	.18	.32	.15	.14	.48	.33	.51	.16
DARK							.17	.48	.21	.45	.09	.20	.06	.33	.03	.00	.18	.15	.15	.00
MED DK							.17	.48	.21	.45	.00	.00	.06	.33	.03	.00	.18	.15	.15	.00
MEDIUM							.24	.48	.55	.79	.33	.33	.33	.64	.36	.33	.45	.48	.36	.33
MED LT							.24	.48	.36	.61	.15	.15	.15	.45	.18	.15	.27	.30	.18	.15
LIGHT BY							.93	1.00	.67	.67	.67	.67	.73	.70	.67	.67	.73	.67	.79	.79
BUFF							.21	.52	.24	.45	.03	.03	.09	.36	.04	.03	.21	.18	.15	.03
MICROCRYST													.18	.47	.13	.11	.49	.20	.45	.16
FINE													.64	.87	.64	.64	.74	.71	.65	.64
MED FINE													.18	.37	.13	.12	.48	.13	.50	.17
MED CRYST													.40	.45	.35	.33	.59	.35	.70	.38
MED COARSE													.07	.33	.02	.00	.37	.08	.38	.05
COARSE													.07	.33	.02	.00	.37	.08	.38	.05
FENESTRAE														.32	.07	.06	.42	.25	.39	.08
VUGS															.28	.27	.56	.40	.45	.31
INTRACLASTS																.01	.40	.20	.40	.05
MEGAFOSSILS																	.40	.19	.39	.03
LAMINATION																		.67	.66	.40
XENOA																			.57	.23
23																				.39

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
 VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.27	.48	.23	.14	.00	.00	.33	.15	.67	.03	.11	.64	.12	.33	.00	.00	.06	.27	.01	.00	.40	.19	.23	.03

Unit 3, Section G (limestone and above)
WEIGHTS 21 FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR (merged)

	DC	WD	N	HL	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SOFT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SOFT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SOFT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SOFT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DARK	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MED DK	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MEDIUM	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MED LT	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
LIGHT CY	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
BLUFF	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MICROCRYST	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
PINE	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MED FINE	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MED CRYST	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MED COARSE	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
COARSE	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FENESTRAE	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
VUGS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
INTRACLASTS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
MEGAFOSILS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
LAMINATION	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ZEBRA	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

8-55

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.00	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01

EXIT J

Unit 3, Section K

NO. OF SAMPLES: 250

COEFFICIENTS MERGED: NO

OK	MD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED LT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LIGHT BY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BUFF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MICROCRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED CRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PENESTRAE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VUGS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INTRACLASTS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEGAFOSILS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAMINATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZERRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23																				
24																				

Unit 3, Section K

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	DK	40	M	ML	LT	BF	HI	FN	MF	M	YC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
SLIP-8.00-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2FT-8.00-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2-3F-8.00-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2FT-8.00-8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED DK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEDIUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED LT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LIGHT BY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BLUF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MICROCRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED CRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PENESTRAE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VUGS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INTRACLASTS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEGAPOSSILS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAMINATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZEBRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Unit 3, Section K

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

	OK	40	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
CLIF	5.00	5.00	7.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
28FT	5.00	5.00	7.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
28FT	5.00	5.00	7.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
28FT	5.00	5.00	7.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK																					
MED OK																					
MEDIUM																					
MED LT																					
LIGHT BY																					
BLUE																					
MICROCRYST																					
FINE																					
MED FINE																					
MED CRYST																					
MED COARSE																					
COARSE																					
PENETRAL																					
VUGS																					
INTRACLASTs																					
MEGAPOSSILs																					
LAMINATION																					
ZEIRA																					
23																					
24																					

Unit 3, Section K

HEIGHTS IN POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

OK	40	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	
SELF	.36	.36	.37	.38	.37	.26	.29	.30	.54	.59	.32	.28	.39	.82	.39	.38	.46	.81	.50	.28	.41
DEPT	.47	.47	.50	.49	.47	.72	.70	.64	.59	.54	.54	.49	.51	.46	.45	.64	.64	.69	.45	.49	
DEPT	.43	.43	.47	.45	.43	.69	.67	.62	.57	.52	.51	.45	.48	.42	.42	.61	.52	.67	.42	.45	
DEPT	.30	.30	.34	.32	.30	.54	.53	.51	.49	.38	.36	.33	.45	.30	.29	.51	.42	.54	.29	.34	
DARK						.13	.13	.29	.34	.04	.00	.04	.47	.01	.00	.20	.48	.29	.00	.05	
MED OK						.13	.13	.29	.34	.04	.00	.04	.47	.01	.00	.20	.48	.29	.00	.05	
MEDIUM						.14	.14	.34	.38	.09	.05	.06	.50	.02	.05	.22	.52	.31	.05	.10	
MED LT						.13	.13	.32	.37	.07	.03	.07	.49	.03	.03	.22	.50	.29	.03	.04	
LIGHT BY						.99	.98	.92	.92	.92	.92	.94	.94	.93	.93	.97	.93	.97	.93	.94	
BUFF						.13	.13	.29	.34	.04	.00	.04	.47	.01	.00	.20	.48	.29	.00	.05	
MICROCRYST												.14	.74	.18	.15	.27	.72	.29	.15	.14	
PINE												.16	.70	.14	.14	.24	.71	.29	.14	.17	
MED FINE												.31	.63	.28	.28	.47	.60	.55	.28	.35	
MED CRYST												.36	.57	.34	.34	.54	.54	.58	.34	.39	
MED COARSE												.07	.56	.05	.05	.26	.55	.30	.05	.10	
COARSE												.03	.54	.01	.01	.22	.53	.27	.01	.04	
FENESTRAE												.49	.49	.05	.04	.24	.80	.33	.04	.09	
VUSS													.46	.46	.45	.66	.51	.71	.45	.50	
INTRACLASTS															.01	.23	.47	.31	.01	.04	
MEGAFOSILS																.22	.46	.31	.00	.05	
LAMINATION																	.67	.39	.22	.24	
ZERRA																	.74	.44	.44	.51	
23																		.31	.31	.05	
24																					

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FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
.36	.46	.41	.29	.00	.00	.00	.02	.93	.00	.14	.14	.28	.33	.04	.00	.04	.45	.01	.00	.22	.46	.30	.00	.05

Unit 3, Section K

WEIGHTS 21 FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

OK	4D	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
SWP	.24	.04	.04	.04	.04	.30	.30	.22	.22	.22	.22	.00	.00	.00	.00	.00	.00	.01	.00	.00
2FT	.24	.04	.04	.04	.04	.30	.30	.22	.22	.22	.22	.00	.00	.00	.00	.00	.00	.01	.00	.00
23F	.24	.04	.04	.04	.04	.30	.30	.22	.22	.22	.22	.00	.00	.00	.00	.00	.00	.01	.00	.00
25FT	.24	.04	.04	.04	.04	.30	.30	.22	.22	.22	.22	.00	.00	.00	.00	.00	.00	.01	.00	.00
DARK						.31	.31	.24	.24	.24	.24	.04	.04	.04	.04	.04	.04	.04	.04	.04
MED DM						.31	.31	.24	.24	.24	.24	.04	.04	.04	.04	.04	.04	.04	.04	.04
MEDIUM						.31	.31	.24	.24	.24	.24	.04	.04	.04	.04	.04	.04	.04	.04	.04
MED LT						.31	.31	.24	.24	.24	.24	.04	.04	.04	.04	.04	.04	.04	.04	.04
LIGHT BY						.31	.31	.24	.24	.24	.24	.04	.04	.04	.04	.04	.04	.04	.04	.04
BUFF						.31	.31	.24	.24	.24	.24	.04	.04	.04	.04	.04	.04	.04	.04	.04
MICROCRYST												.30	.30	.30	.30	.30	.30	.30	.30	.30
FINE												.30	.30	.30	.30	.30	.30	.30	.30	.30
MED FINE												.23	.22	.22	.22	.22	.22	.22	.22	.22
MED CRYST												.23	.22	.22	.22	.22	.22	.22	.22	.22
MED COARSE												.23	.22	.22	.22	.22	.22	.22	.22	.22
COARSE												.23	.22	.22	.22	.22	.22	.22	.22	.22
FENESTRAE												.30	.30	.30	.30	.30	.30	.30	.30	.30
VUGS												.30	.30	.30	.30	.30	.30	.30	.30	.30
INTRAGLASTS												.30	.30	.30	.30	.30	.30	.30	.30	.30
MEGAPOSSILS												.30	.30	.30	.30	.30	.30	.30	.30	.30
LAMINATION												.30	.30	.30	.30	.30	.30	.30	.30	.30
ZEBRA												.30	.30	.30	.30	.30	.30	.30	.30	.30
23												.30	.30	.30	.30	.30	.30	.30	.30	.30
24												.30	.30	.30	.30	.30	.30	.30	.30	.30

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FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
.30	.00	.00	.00	.04	.04	.04	.04	.04	.04	.30	.30	.22	.22	.22	.22	.00	.00	.00	.00	.00	.00	.01	.00	.00

Unit 3, Section K.

NO. OF SAMPLES 250

SECT

MERGED? YES

DC	MD	M	ML	LT	BF	MI	FI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
SELF	1.00-1.00	.78	.24	.24	1.00	.22	.28	.28	.28	.28	.28	.28	.28	.28	.28	.28	.28	.28	.28	.28	.28
2FT	1.00-1.00	.98	.98	.04	1.00	.97	.92	.44	.13	.85	.85	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
3FT	1.00-1.00	.87	1.00	.10	1.00	.97	.91	.43	.33	.88	.84	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98
5FT	1.00-1.00	.98	1.00	.27	1.00	.98	.98	.47	.02	.98	.98	1.00	.98	.98	.98	.98	.98	.98	.98	.98	.98
DARK	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEDIUM	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED LT	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LIGHT BY	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BUFF	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MICROCRYST	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FINE	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED FINE	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED CRYST	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED COARSE	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
COARSE	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FINESTRAE	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VUGS	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INTRACLASTS	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEGAFOSFELS	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAMINATION	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZERRA	1.00-1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23																					
24																					

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Unit 3, Section K (merged)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

DK	4D	H	HL	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IV	FO	LA	ZE	23	24	25
SMF-8.00-8.00	.18	-.21	1.27	8.00	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
>2FT-8.00-8.00	-.65	-.67	1.27	8.00	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
>3F-8.00-8.00	-.76	1.00	1.27	8.00	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
>5FT-8.00-8.00	-.88	1.00	1.27	8.00	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
DARK																				
MED DK																				
MED LT																				
LIGHT BY																				
BUFF																				
MICROCRYST																				
PINE																				
MED FINE																				
MED CRYST																				
MED COARSE																				
COARSE																				
FENESTRAE																				
VUOS																				
INTRACLASTS																				
MEGAFOSILS																				
LAMINATION																				
ZERRA																				
23																				
24																				

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

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Unit 3, Section K (merged)

WEIGHTS 11 POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

DC	MD	M	ML	LT	BF	HI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
SMF	.36	.36	.36	.37	.36	.29	.33	.54	.85	.32	.32	.39	.82	.29	.38	.46	.81	.50	.28	.41
28PT	.47	.52	.49	.34	.47	.72	.83	.64	.70	.54	.54	.49	.51	.46	.45	.64	.54	.69	.45	.49
283F	.43	.49	.48	.34	.43	.69	.80	.62	.68	.52	.52	.45	.48	.42	.42	.61	.52	.47	.42	.45
28PT	.30	.30	.37	.32	.30	.54	.47	.51	.64	.38	.38	.33	.45	.30	.29	.51	.48	.54	.29	.34
DARK						.13	.27	.29	.62	.04	.04	.04	.47	.01	.00	.20	.48	.29	.00	.05
MED DK						.13	.27	.29	.62	.04	.04	.04	.47	.01	.00	.20	.48	.29	.00	.05
MEDIUM						.14	.27	.37	.70	.13	.13	.10	.53	.08	.07	.24	.55	.31	.07	.11
MED LT						.13	.27	.32	.65	.07	.07	.07	.49	.03	.03	.22	.50	.29	.03	.06
LIGHT BT						.99	.99	.92	.92	.92	.92	.94	.94	.93	.93	.97	.93	.97	.93	.94
BUFF						.13	.27	.29	.62	.04	.04	.04	.47	.01	.00	.20	.48	.29	.00	.05
MICROCRYST												.14	.74	.15	.15	.27	.72	.29	.15	.14
PINE												.27	.85	.28	.28	.31	.85	.34	.28	.28
MED FINE												.31	.63	.28	.28	.47	.60	.55	.28	.35
MED CRYST												.64	.66	.61	.61	.80	.63	.85	.61	.68
MED COARSE												.07	.54	.05	.05	.26	.55	.30	.05	.10
COARSE												.07	.54	.05	.05	.26	.55	.30	.05	.10
PENESTRAE													.49	.05	.04	.24	.80	.33	.04	.09
VUGS													.46	.46	.46	.66	.51	.71	.45	.80
INTRACLASTS													.01	.01	.01	.23	.47	.31	.01	.04
MEGAFOSFELS																.22	.46	.31	.00	.05
LAMINATION																	.67	.39	.22	.24
ZERRA																	.74	.54	.54	.51
23																		.31	.31	.05
24																				

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FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
.38	.46	.41	.29	.00	.00	.07	.02	.93	.00	.14	.28	.24	.61	.04	.04	.04	.45	.01	.00	.22	.46	.30	.00	.08

PERCENTAGE FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

8-65

PROACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

[illegible]

Unit 3, Section Y

Y	SECT	NO. OF SAMPLES	174																					
COEFFICIENTS				MERGED: NO																				
OK	MD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25				
<1F	1.00	-.74	-.28	-.84	-.97	1.00	1.00	-.94	-.95	1.00	-.95	1.00	-.53	1.00	-.84	1.00	-.84	1.00	-.43	1.00	-.70			
>2F	-.91	-.98	-.35	-.92	-.96	1.00	-.79	-.19	-.28	1.00	1.00	-.72	-.83	-.78	-.94	-.93	-.36	-.87	-.94	-.98				
>3F	-.90	-.98	-.45	-.91	-.95	1.00	-.83	-.22	-.32	1.00	1.00	-.74	-.81	-.77	-.96	-.92	-.29	-.93	-.93	-.98				
>5F	-.89	-.97	-.89	-.87	-.94	1.00	-.82	-.22	-.44	1.00	1.00	-.85	-.77	-.73	-.94	-.97	-.23	-.96	-.91	-.97				
DARK									-.94	1.00	1.00	-.88	-.94	1.00	-.20	1.00	-.88	1.00	1.00	-.75				
MED QX									-.94	1.00	1.00	-.89	-.89	1.00	-.92	1.00	-.90	-.76	1.00	-.86				
MEDIUM									-.94	1.00	1.00	-.97	-.97	1.00	-.92	1.00	-.84	-.71	1.00	-.83				
MED LT									-.94	1.00	1.00	-.98	-.98	1.00	-.92	1.00	-.87	-.95	1.00	-.86				
LIGHT QY									-.94	1.00	1.00	-.96	-.96	1.00	-.97	1.00	1.00	-.42	-.94	-.96				
BUFF									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
MICROCRYST									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
PINE									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
MED FINE									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
MED CRYST									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
MED COARSE									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
COARSE									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
PENESTRAE									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
VUGS									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
INTRACLASTS									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
MEGAFOSSILS									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
LAMINATION									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
ZERRA									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
23									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				
24									-.94	1.00	1.00	-.92	-.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00				

Unit 3, Section Y

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	DC	VD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
SMLE-1.00	.02	0.42	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48
>2FT 1.00	.00	.00	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27	.27
>3FT 1.00	.00	.00	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12
>5FT 1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
DARK																					
MED OK																					
MEDIUM																					
MED LT.																					
LIGHT BY																					
BUFF																					
MICROCRYST																					
FINE																					
MED FINE																					
MED CRYST																					
MED COARSE																					
COARSE																					
FENESTRAE																					
VUGS																					
INTRACLASTS																					
MEGAFOSFELS																					
LAMINATION																					
ZERRA																					
23																					
24																					

Unit 3, Section Y

LESS COMMON CHARACTERS BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN

DC	HD	M	ML	LT	BF	MI	FN	MF	M	YC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
CLIP	8.23	8.23	1.00	8.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DEFT	8.23	8.23	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00
DEFT	8.23	8.23	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00
DEFT	8.23	8.23	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00
DARK																				
MED OK																				
MED OK																				
MED LT																				
LIGHT BY																				
BUFF																				
MICROCRYST																				
PINE																				
MED FINE																				
MED CRYST																				
MED COARSE																				
COARSE																				
FINESTRAC																				
VUGS																				
INTRACLASTS																				
MEGAPOSSIBLE																				
LAMINATION																				
ZEARA																				
23																				
24																				

Unit 3, Section Y

RESULTS 11 POSITIVE AND 112 MATCHES V.S. TOTAL MATCHES

[illegible]

PRACTICE OF KNOWN CASES WHERE CHARACTER IS PRESENT.
 VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48

Unit 3, Section Y

44-38861-21 FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

8.-70

EXTRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

[illegible]

Unit 3, Section Y

NO. OF SAMPLES: 154

COEFFICIENTS

MERGED: YES

DC	NO	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
SELF	0.77	0.74	0.38	0.86	0.92	1.00	1.00	0.94	0.92	0.95	0.95	0.93	1.00	0.84	1.00	0.94	1.00	0.63	1.00	0.70
22FT	0.30	0.38	0.34	0.92	0.18	0.96	1.00	0.79	0.19	0.41	1.00	0.72	0.83	0.76	0.94	0.93	0.36	0.87	0.94	0.98
23FT	0.39	0.42	0.43	0.91	0.27	0.95	1.00	0.83	0.22	0.29	1.00	0.74	0.81	0.77	0.96	0.92	0.29	0.93	0.93	0.98
25FT	0.84	0.97	0.57	0.87	0.29	0.92	1.00	0.88	0.22	0.09	1.00	0.85	0.77	0.73	0.94	0.97	0.23	0.96	0.91	0.97
DARK																				
MED DK																				
MED OK																				
MED LT																				
LIGHT BY																				
BUFF																				
MICROCRYST																				
FINE																				
MED FINE																				
MED CRYST																				
MED COARSE																				
COARSE																				
PENESTRAE																				
VUSS																				
INTRACLASTS																				
MEGAFOSBILS																				
LAMINATION																				
ZEBRA																				
23																				
24																				

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Unit 3, Section Y (Merged)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	OK	40	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25
CLIF	.22	.27	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48	.48
DEFT	.29	.80	.04	.27	.63	.00	.00	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51	.51
DEFT	.29	.80	.08	.27	.63	.00	.00	.64	.64	.64	.64	.64	.64	.64	.64	.64	.64	.64	.64	.64	.64
DEFT	.22	.80	.08	.27	.63	.00	.00	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77	.77
DARK																					
MED DK																					
MEDJH																					
MED LT																					
LIGHT BY																					
BUFF																					
MICROCRYST																					
FINE																					
MED FINE																					
MED CRYST																					
MED COARSE																					
COARSE																					
FENESTRAE																					
VUGS																					
INTRACLASTS																					
MEGAFOSSILS																					
LAMINATION																					
ZEARA																					
23																					
24																					

Unit 3, Section Y, (merged)

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

	04	43	M	4L	LT	BF	MI	FN	MF	M	4C	CS	FE	VU	IN	FO	LA	ZE	23	24	25
CLIP 8.20 8.20 1.00 8.00 1.0010.0011.00 1.00 1.00 1.0015.0016.00 1.0018.0019.0020.0021.0022.0023.0024.0025.00																					
DEPT 8.20 8.20 1.00 8.00 9.0010.0011.0012.0013.00 2.0015.0016.0017.0018.0019.0020.0021.0022.0023.0024.0025.00																					
DEPT 8.20 8.20 1.00 8.00 9.0010.0011.0012.0013.00 3.0015.0016.0017.0018.0019.0020.0021.0022.0023.0024.0025.00																					
DEPT 8.20 8.20 1.00 8.00 9.0010.0011.0012.0013.00 4.0015.0016.0017.0018.0019.0020.0021.0022.0023.0024.0025.00																					
DARK																					
MED DM																					
MED DM																					
MED DM																					
MED LT																					
LIGHT BY																					
SUFF																					
MICROCRYST																					
FINE																					
MED FINE																					
MED CRYST																					
MED COARSE																					
COARSE																					
FENESTRAE																					
VUGS																					
INTRACLASTS																					
MEGAFOSBLS																					
LAMINATION																					
ZERRA																					
23																					
24																					

Unit 3, Section Y (Merged)

DESCRIPTORS: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

DC	4D	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	
COLE	.28	.24	.40	.28	.55	.24	.25	.41	.57	.82	.27	.27	.41	.30	.31	.26	.27	.47	.32	.24	.26
DEPT	.57	.88	.66	.66	.60	.58	.86	.65	.69	.60	.60	.74	.59	.60	.58	.61	.61	.67	.58	.62	
DEPT	.37	.84	.84	.61	.80	.49	.80	.60	.66	.52	.52	.68	.51	.53	.51	.53	.53	.61	.51	.54	
DEPT	.42	.74	.81	.81	.81	.39	.72	.52	.84	.41	.41	.53	.32	.40	.37	.41	.42	.42	.37	.40	
DARK						.11	.45	.43	.64	.13	.13	.35	.16	.19	.10	.13	.28	.19	.11	.12	
MED OK						.04	.42	.42	.64	.10	.10	.32	.14	.16	.09	.11	.26	.16	.08	.09	
MEDIUM						.51	.84	.77	.91	.53	.53	.61	.62	.57	.57	.54	.72	.59	.56	.54	
MED LT						.08	.42	.42	.64	.11	.11	.34	.14	.17	.09	.11	.28	.18	.09	.09	
LIGHT BY						.37	.73	.53	.64	.37	.37	.61	.36	.43	.35	.37	.41	.44	.34	.36	
BUFF						.02	.41	.37	.89	.04	.04	.31	.09	.12	.03	.03	.21	.14	.03	.04	
MICROCRYST												.20	.07	.06	.01	.04	.25	.14	.02	.04	
FINE												.41	.44	.42	.39	.38	.59	.43	.39	.38	
MED FINE												.52	.40	.36	.34	.37	.46	.45	.35	.38	
MED CRYST												.77	.61	.61	.60	.63	.63	.69	.60	.64	
MED COARSE												.23	.08	.09	.04	.06	.28	.17	.04	.07	
COARSE												.23	.08	.09	.04	.06	.28	.17	.04	.07	
FENESTRAE												.33	.32	.28	.28	.29	.49	.35	.29	.29	
VUGS												.15		.15	.08	.11	.28	.20	.07	.10	
INTRACLASTS															.10	.14	.31	.20	.10	.13	
MEGAPODOLS																.07	.23	.15	.03	.06	
LAMINATION																	.27	.17	.07	.08	
ZERRA																	.35	.24	.27		
23																		.14	.17		
24																				.04	

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FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
.24	.58	.60	.36	.09	.07	.56	.07	.33	.01	.00	.38	.34	.60	.02	.02	.27	.06	.09	.02	.05	.22	.14	.02	.04

Unit 3, Section Y (Merged)

11-11-68 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

8-75

ANALYSIS OF SAMPLES LACKING INFORMATION ON CHARACTER

FRACTION OF SAMPLES LACKING INFORMATION ON C																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	.00	.00	.00	.00	.17	.17	.17	.17	.20	.20	.12	.12	.11	.11	.11	.11	.00	.00	.00	.00	.00	.00	.00	.01	.00

8-76

Unit 4

Unit 4, Sections J and E

J+E SECT NO. OF SAMPLES 58

COEFFICIENTS																	MERGED: NO	
DK	WD	M	ML	LT	BF	MI	HF	M	MC	CS	VS	VU	Direct	LA	ZE	23	24	
SELF	.38	.86	1.00	1.00	.88	1.00	.67	.69	.77	.23	.69	1.00	.72	.55	1.00	.63	.71	
>2FT	.36	.30	1.00	1.00	1.00	1.00	.87	1.00	.80	.51	.28	1.00	.66	1.00	1.00	1.00	.76	
>2F	.36	.30	1.00	1.00	1.00	1.00	.87	1.00	.80	.51	.28	1.00	.66	1.00	1.00	1.00	.76	
>2FT	1.00	.84	1.00	1.00	1.00	1.00	1.00	1.00	.60	.19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
DARK							.22	.83	.70	.36	1.00	1.00	.26	.64	.79	.91	.65	
MED DK							.08	.98	1.00	.39	.05	1.00	.06	.86	1.00	.95	1.00	
MEDIUM							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED LT							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
LIGHT BY							1.00	1.00	1.00	.90	.80	1.00	1.00	1.00	1.00	1.00	1.00	
BUFF							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MICROCRYST							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
FINE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED FINE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED CRYST							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED COARSE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
COARSE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
bedded Limestone							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
VUGS							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
bedded Bedding							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MEGAFOSILS (Graptolite Fossils)							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
LAMINATION							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
ZERRA							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
83	> 5% wt. dolomite																1.00	

Unit 4, Sections J and E.

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

DK	QD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	VU	IN	FO	LA	ZE	23	24
CLIF	1.32	1.25	1.00	1.00	1.00	1.18	1.00	1.14	1.25	1.30	1.25	1.25	1.35	1.00	1.52	1.00	1.25	1.00
2FT	1.47	1.73	1.00	1.00	1.00	1.73	1.00	1.43	1.47	1.47	1.47	1.47	1.47	1.00	1.00	1.00	1.00	1.00
23F	1.47	1.73	1.00	1.00	1.00	1.73	1.00	1.43	1.47	1.47	1.47	1.47	1.47	1.00	1.00	1.00	1.00	1.00
2FT-1.0	1.32	1.25	1.00	1.00	1.00	1.18	1.00	1.14	1.25	1.30	1.25	1.25	1.35	1.00	1.52	1.00	1.25	1.00
DARK																		
MED DK																		
MED LUM																		
MED LT																		
LIGHT BY																		
2FT																		
MICROCRYST																		
FINE																		
MED FINE																		
MED CRYST																		
MED COARSE																		
COARSE																		
VUSS																		
MEGASPOSSIBLE																		
LAMINATION																		
ZENRA																		
83																		

Many "E" samples were punched as both Dark and Medium-Dark.

Also, a number of sample points were punched as Medium to Medium-Coarse.

83 25% wt. Lb.

Unit 4, Sections J and E.

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

	OK	ND	M	ML	LT	BF	MI	FN	MF	M	MC	CS	PE	VU	IN	FO	LA	ZE	23	24
SELF 1.0 1.0 1.0 7.00 8.00 9.0010.0011.0012.0013.00 1.0015.0016.0017.0018.0019.0020.0021.0022.0023.0024.00																				
22PT 2.0 2.0 2.0 7.00 8.00 9.0010.00 2.0012.0013.00 2.00 2.0016.00 2.00 2.0020.0021.00 2.00 2.0024.00																				
23PT 3.0 3.0 3.0 7.00 8.00 9.0010.00 3.0012.0013.00 3.00 3.0016.00 3.00 3.0020.0021.00 3.00 3.0024.00																				
25PT 4.0 4.0 4.0 7.00 8.00 9.0010.00 4.0012.0013.00 4.00 4.0016.00 4.00 4.0020.0021.00 4.00 4.0024.00																				
DARK																				
MED DK																				
MED LT																				
MED LT																				
LIGHT QY																				
BUFF																				
MICROCRYST																				
FINE																				
MED FINE																				
MED CRYST																				
MED COARSE																				
COARSE																				
FENESTRAE																				
VUGS																				
INTRACLASTS																				
MEGAFOSFELS																				
LAMINATION																				
ZERRA																				
23																				

Unit 4, Sections and E.

HEIGHTS 1: POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	DK	WD	H	ML	LT	BF	HI	FI	FN	WF	M	MC	CS	FE	VU	IN	FO	LA	ZE	E3	E4
SELF	.82	.85	.49	.49	.50	.50	.65	.48	.54	.54	.80	.69	.50	.65	.67	.77	.52	.49	.65	.78	.52
>2FT	.85	.85	.23	.23	.25	.22	.45	.30	.30	.30	.68	.36	.22	.43	.26	.09	.28	.23	.24	.37	.26
>3FT	.85	.85	.23	.23	.25	.22	.45	.30	.30	.30	.68	.36	.22	.43	.26	.09	.28	.23	.24	.37	.26
>5FT	.82	.83	.12	.12	.15	.12	.32	.20	.23	.23	.61	.29	.12	.37	.21	.09	.18	.12	.16	.32	.15
DARK							.69	.70	.69	.69	.99	.69	.69	.69	.92	.90	.70	.68	.94	.94	.71
MED OK							.55	.60	.64	.88	.88	.57	.54	.54	.60	.19	.57	.55	.53	.70	.55
MEDIUM							.27	.07	.10	.61	.30	.30	.30	.25	.21	.10	.04	.00	.16	.32	.03
MED LT							.27	.07	.10	.61	.30	.30	.30	.25	.21	.10	.04	.00	.16	.32	.03
LIGHT CY							.29	.10	.13	.61	.30	.30	.30	.28	.25	.09	.09	.03	.20	.36	.03
BUFF							.26	.07	.10	.61	.30	.30	.30	.26	.21	.09	.06	.00	.16	.32	.03
MICROCRYST														.26	.58	.09	.32	.25	.52	.70	.27
FINE														.33	.31	.23	.12	.06	.27	.43	.11
MED FINE														.36	.25	.26	.15	.11	.24	.40	.14
MED CRYST														.87	.64	.81	.61	.62	.51	.51	.63
MED COARSE														.55	.27	.16	.33	.30	.20	.36	.31
COARSE														.25	.21	.09	.06	.00	.16	.32	.03
PENESTRAE															.56	.09	.31	.25	.50	.68	.26
YUGS																.37	.21	.24	.40	.26	
INTRACLASTS																	.19	.09	.23	.54	.09
MEGAFOSSILS																		.06	.20	.32	.09
LAMINATION																			.16	.33	.03
ZERRA																			.40	.21	.38

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.82	.22	.22	.12	.49	.54	.02	.00	.03	.00	.24	.07	.10	.61	.30	.00	.25	.21	.09	.04	.00	.14	.22	.03

Unit 4, Sections J and E.

HEIGHTS 21 FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

	D4	D3	H	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SNIP	.04	.04	.04	.04	.03	.03	.03	.04	.04	.04	.04	.03	.03	.32	.54	.03	.04	.29	.34	.06
28FT	.03	.03	.03	.03	.01	.01	.01	.03	.03	.03	.03	.01	.01	.31	.53	.01	.03	.28	.32	.04
28FT	.03	.03	.03	.03	.01	.01	.01	.03	.03	.03	.03	.01	.01	.31	.53	.01	.03	.28	.32	.04
28FT	.03	.03	.03	.03	.01	.01	.01	.03	.03	.03	.03	.01	.01	.29	.53	.01	.03	.24	.31	.04
DARK							.01	.01	.01	.01	.01	.01	.01	.01	.54	.01	.03	.28	.31	.04
MED OK							.01	.01	.01	.01	.01	.01	.01	.01	.54	.01	.03	.28	.31	.04
MEDIUM							.01	.01	.01	.01	.01	.01	.01	.01	.54	.01	.03	.28	.31	.04
MED LY							.01	.01	.01	.01	.01	.01	.01	.01	.54	.01	.03	.28	.31	.04
LIGHT BY							.00	.01	.01	.01	.01	.03	.03	.03	.53	.03	.01	.26	.31	.03
BUFF							.00	.01	.01	.01	.01	.00	.00	.29	.53	.00	.01	.24	.31	.03
MICROCRYST												.00	.00	.29	.53	.00	.01	.26	.31	.03
FINE												.01	.01	.29	.54	.01	.03	.28	.31	.04
MED FINE												.01	.01	.29	.54	.01	.03	.28	.31	.04
MED CRYST												.01	.01	.29	.54	.01	.03	.28	.31	.04
MED COARSE												.01	.01	.29	.54	.01	.03	.28	.31	.04
COARSE												.00	.00	.29	.53	.00	.01	.24	.31	.03
FENESTRAE														.29	.53	.00	.01	.26	.31	.03
VUGS														.60						
INTRACLASTS														.29	.31	.34	.34	.56	.60	.53
MEGAFOSSILS														.53			.53	.56	.60	.53
LAMINATION														.01			.01	.26	.31	.03
ZERRA														.28			.28	.32	.34	.04
23														.31			.31	.29	.34	.06

8-81

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.03	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.01	.01	.01	.01	.00	.00	.29	.53	.00	.01	.26	.31	.03

Unit 4, Sections J and E

NO. OF SAMPLES: 68

COEFFICIENTS

MERGED: YES

J+E SECT

DC 43 N HL LT BF HI FN MF H MC CS FE VU IN FO LA GE 23 24

SEIF	0.08	0.88	1.00	1.00	0.88	0.00	0.87	0.88	0.77	0.24	0.63	0.63	0.72	0.55	1.00	0.82	1.00	0.68	0.71	0.88
SEPT	0.53	0.30	1.00	1.00	1.00	1.00	0.87	0.88	0.80	0.45	0.08	0.08	0.86	1.00	1.00	1.00	1.00	1.00	0.76	1.00
SEPT	0.53	0.30	1.00	1.00	1.00	1.00	0.87	0.88	0.80	0.45	0.08	0.08	0.86	1.00	1.00	1.00	1.00	1.00	0.76	1.00
SEPT	0.78	0.84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.64	0.16	0.16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK							0.45	0.32	0.78	0.25	0.46	0.46	0.48	0.57	0.81	0.91	1.00	0.66	0.33	1.00
MED DK							0.08	0.10	1.00	0.43	0.05	0.05	0.06	0.86	1.00	0.95	1.00	1.00	1.00	1.00
MEDIUM							1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED LT							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LIGHT BY							1.00	1.00	1.00	0.91	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BUFF.							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MICROCRYST							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PINE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED FINE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED CRYST							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED COARSE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
COARSE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FENESTRAE							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VUGS							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INTRACLASTS							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEGAFOSFELS							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAMINATION							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZEBRA							1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
83																				

Unit 4, Thin-sections and their locations, only - (from all 3 sections studied in detail)

JV 6		T.S.		NO. OF SAMPLES		29		V% Seismic		MERGED 91 VO		TERRIGENOUS sand		INTERNAL sediment		BITUMEN		PELLETS		PYRITIC		QUARTZ silt.		LIMESTONE	
COEFFICIENTS	OK	NO	M	ML	LT	BF	MI	FN	MF	M	MC	CS	RS	VU	IN	FO	LA	ZE	23	24	25	26	27	28	29
CLIF	.71	.32	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73	.73
2FT	.39	.88	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78
>3F	.49	.39	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78
>5F	.57	.39	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78
DARK	.67	.44	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78	.78
MED OK	.20	.54	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88
MEDIUM	.83	.85	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
MED LT	.83	.67	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71	.71
LIGHT BY	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
RUFF	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
MICROCRYST	.67	.75	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87	.87
FINE	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
MED FINE	.10	.25	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50
MED CRYST.	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
MED COARSE	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
COARSE	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
FENESTRAE	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
VUGS	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
INTRACLASTS	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
MEGAFOSILS	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
LAMINATION	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
ZEBRA	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
23	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
24	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
25	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
26	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
27	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
28	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10

Unit 4, Sections J and E. (Merged)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

DK	WD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
<MIF	1.47	1.21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>2FT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>3F	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>5FT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DARK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED DK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEDIUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED LT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LIGHT QY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BUFF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MICROCRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED FINE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED CRYST	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MED COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FENESTRAE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
VUGS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INTRACLASTS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
MEGAFOSSILS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAMINATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ZERRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
23																			

Unit 4, Sections J and E. (Merged)

USE COMMON CHARACTERS BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN

DK	MD	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
SHIF	1.00	1.00	7.00	8.00	9.00	10.00	11.00	12.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
>2FT	2.00	2.00	7.00	8.00	9.00	10.00	11.00	12.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
>3FT	3.00	3.00	7.00	8.00	9.00	10.00	11.00	12.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
>5FT	4.00	4.00	7.00	8.00	9.00	10.00	11.00	12.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
DARK									11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00
MED DK									11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00
MEDIUM									7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
MED LT									8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
LIGHT BY									9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
BUFF									10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
MICROCRYST									17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00
FINE									17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00
MED FINE									13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
MED CRYST									17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00
MED COARSE									17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00
COARSE									17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00
FENESTRAE									18.00	17.00	16.00	15.00	14.00	13.00	12.00	11.00	10.00	9.00	8.00
VUGS									19.00	18.00	17.00	16.00	15.00	14.00	13.00	12.00	11.00	10.00	9.00
INTRACLASTS									19.00	18.00	17.00	16.00	15.00	14.00	13.00	12.00	11.00	10.00	9.00
MEGAFOSSILS									21.00	20.00	19.00	18.00	17.00	16.00	15.00	14.00	13.00	12.00	11.00
LAMINATION									21.00	20.00	19.00	18.00	17.00	16.00	15.00	14.00	13.00	12.00	11.00
ZEBRA									21.00	20.00	19.00	18.00	17.00	16.00	15.00	14.00	13.00	12.00	11.00
23																			

Unit 4, Sections J and E. (Merged)

HEIGHTS 11 POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

OK	40	M	4L	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
51E 1.00	.83	.49	.49	.50	.50	.55	.65	.54	.85	.69	.69	.65	.67	.77	.52	.42	.65	.78	.52
>2FT	.97	.56	.23	.23	.25	.22	.45	.30	.71	.36	.36	.43	.26	.09	.23	.23	.24	.37	.26
>3F	.97	.56	.23	.23	.25	.22	.45	.30	.71	.36	.36	.43	.26	.09	.28	.23	.24	.37	.26
>5FT	.27	.53	.12	.12	.15	.12	.39	.45	.23	.67	.29	.37	.21	.09	.12	.12	.16	.32	.15
DARK						.97	.97	.97	1.00	1.00	.97	.97	.96	1.00	.97	.97	.96	.96	1.00
MED OK						.55	.60	.64	.94	.57	.57	.54	.60	.19	.57	.55	.53	.70	.55
MEDIUM						.27	.33	.10	.67	.30	.30	.25	.21	.10	.04	.00	.16	.32	.03
MED LT						.27	.33	.10	.67	.30	.30	.25	.21	.10	.04	.00	.16	.32	.03
LIGHT QY						.29	.35	.13	.67	.30	.30	.28	.25	.09	.09	.03	.20	.36	.03
BUFF						.24	.32	.10	.67	.30	.30	.25	.21	.09	.04	.00	.16	.32	.03
MICROCRYST											.26	.58	.09	.09	.32	.25	.52	.70	.27
FINE											.32	.67	.22	.38	.31	.60	.79	.33	
MED FINE											.14	.25	.24	.15	.11	.24	.40	.14	
MED CRYST											.93	.54	.87	.67	.68	.68	.53	.53	.69
MED COARSE											.55	.27	.16	.33	.30	.20	.36	.31	
COARSE											.55	.27	.16	.33	.30	.20	.36	.31	
FENESTRAE											.56	.09	.09	.31	.25	.80	.68	.26	
VUOS											.37	.37	.37	.21	.21	.21	.40	.26	
INTRACLASTS											.19	.19	.19	.19	.02	.23	.56	.09	
MEGAFOSILS											.06	.06	.06	.06	.06	.06	.20	.32	.09
LAMINATION											.16	.16	.16	.16	.16	.16	.33	.03	
ZERRA											.40	.40	.40	.40	.40	.40	.40	.21	
23											.38	.38	.38	.38	.38	.38	.38	.38	

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
.50	.22	.22	.12	.97	.54	.00	.00	.03	.00	.26	.32	.10	.67	.30	.30	.25	.21	.09	.06	.00	.16	.32	.03

Unit 4, Sections J and E (Merged)

4E13-7S 2: FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

	OK	NO	M	ML	LT	BF	MI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24
S1F	.04	.04	.04	.04	.03	.03	.03	.03	.04	.04	.04	.04	.03	.32	.54	.03	.04	.29	.34	.06
S2F	.03	.03	.03	.03	.01	.01	.01	.01	.03	.03	.03	.03	.01	.31	.53	.01	.03	.28	.32	.04
S3F	.03	.03	.03	.03	.01	.01	.01	.01	.03	.03	.03	.03	.01	.31	.53	.01	.03	.28	.32	.04
S5F	.03	.03	.03	.03	.01	.01	.01	.01	.03	.03	.03	.03	.01	.29	.53	.01	.03	.24	.31	.04
DARK					.01	.01	.01	.01	.01	.01	.01	.01	.01	.29	.54	.01	.03	.28	.31	.04
MED OK					.01	.01	.01	.01	.01	.01	.01	.01	.01	.29	.54	.01	.03	.28	.31	.04
MEDIUM					.01	.01	.01	.01	.01	.01	.01	.01	.01	.29	.54	.01	.03	.28	.31	.04
MED LT					.01	.01	.01	.01	.01	.01	.01	.01	.01	.29	.53	.01	.03	.26	.31	.03
LIGHT BY					.00	.00	.01	.01	.01	.01	.01	.01	.00	.29	.53	.02	.01	.24	.31	.03
BUFF					.00	.00	.01	.01	.01	.01	.01	.01	.00	.29	.53	.00	.01	.26	.31	.03
MICROCRYST													.00	.29	.53	.00	.01	.26	.31	.03
FINE													.01	.29	.54	.01	.03	.28	.31	.04
MED FINE													.01	.29	.54	.01	.03	.28	.31	.04
MED CRYST													.01	.29	.54	.01	.03	.28	.31	.04
MED COARSE													.01	.29	.54	.01	.03	.28	.31	.04
COARSE													.01	.29	.54	.01	.03	.28	.31	.04
FENESTRAE														.29	.53	.00	.01	.26	.31	.03
VUGS														.29	.60	.29	.31	.34	.34	.32
INTRACLASTS														.53		.53	.53	.54	.60	.53
MEGAFOSSILS																	.01	.26	.31	.03
LAMINATION																		.28	.32	.04
ZEBRA																		.31	.34	.34

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	.03	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00	.01	.01	.01	.01	.00	.29	.53	.00	.01	.26	.31	.03

Unit 4, Thin-sections and their locations, only - (from all 3 sections studied in detail)

JV #	T-8.	NO. OF SAMPLES	29	1/16 Section	MERGEOPI VO	OK	NO	M	ML	LT	BF	MI	FI	FN	VF	M	MC	CS	RS	VU	IV	FO	LA	ZE	23	25	27	28	29	30	
COEFFICIENTS																															
COIF	0.71	0.33	0.73	0.73	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
>2FT	0.59	0.88	0.78	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
>2.5F	0.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
>5FT	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
DARK	0.67	0.44	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED DK	0.20	0.56	0.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MEDIUM	0.83	0.85	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED LT	0.83	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
LIGHT OY	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
BUFF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MICROCRYST	0.67	0.75	0.87	0.62	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
FINE	1.00	0.33	0.71	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED FINE	1.00	0.25	0.50	0.65	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED CRYST.	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED COARSE	1.00	0.71	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
COARSE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
FENESTRAE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
VUGS	0.78	0.69	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
INTRACRYSTALS	1.00	0.33	0.50	0.73	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MEGAFORBILS	0.73	0.88	0.27	0.17	0.25	0.29	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	
MEGAFORBILS LAMINATION	1.00	0.88	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	0.67	0.69	
ZEBRA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
23	0.62	0.58	0.64	0.33	0.23	0.17	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	0.29	0.10	0.21	0.22	0.25	
24	0.20	0.53	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	
25	0.14	0.07	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	
26	0.47	0.34	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	
27	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	
28	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	

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Unit 4, Thin sections.

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	OK	NO	M	HL	LF	BF	HI	FN	HF	M	MC	CB	FE	VU	IN	'FO	LA	ZE	23	24	25	26	27	28	29	
SELF	..40	.08	1.33	1.33	8.00	8.00	.00	.00	1.40	.00	..50	8.00	1.33	1.33	.00	..33	..17	.03	..33	1.33	..60	.09	..33	1.33	1.33	..53
>2FT	1.33	..57	..33	1.00	8.00	8.00	1.33	..33	.00	1.33	8.00	1.33	1.33	..50	..20	..20	..33	1.00	1.33	..20	1.00	1.33	1.33	1.33	1.33	1.33
>3FT	1.33	1.33	1.00	1.00	8.00	8.00	1.33	..33	1.33	1.33	8.00	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	
>5FT	1.33	1.33	1.00	1.00	8.00	8.00	1.33	..33	1.33	1.33	8.00	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	
DARK	..33	..09	1.00	1.33	8.00	1.33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	
MED OK	.20	..27	.00	1.00	8.00	1.33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	
MEDIUM	..33	..33	.00	1.00	8.00	1.33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	..33	
MED LT	..33	1.33	1.00	..33	8.00	1.00	..33	..33	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	
LIGHT BY	..33	1.33	1.00	..33	8.00	1.00	..33	..33	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	
BUFF	..33	1.33	1.00	..33	8.00	1.00	..33	..33	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	
MICROCRYST	..33	1.33	1.00	..33	8.00	1.00	..33	..33	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	1.00	1.33	
FINE	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED FINE	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED CRYST	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MED COARSE	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
COARSE	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
FENESTRAE	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
VUGS	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
INTRACLASTS	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
MEGAPOSSIBLES	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
LAMINATION	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
ZIGZAG	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
23	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
24	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
25	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
26	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
27	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
28	..43	..67	..27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

Unit 4, Thin sections

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

	54	40	M	HL	LY	BP	MT	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27	28	29
CLIF	6.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00
DEFT	2.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00
DEFT	3.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00
DEFT	4.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00
DARK																									
MED OK																									
MEDIUM																									
MED LY																									
LIGHT BY																									
BUFF																									
MICROCRYST																									
FINE																									
MED FINE																									
MED CRYST																									
MED COARSE																									
COARSE																									
FENESTRAE																									
VUGS																									
INTRACLASTS																									
MEGAFOSILS																									
LAMINATION																									
ZONAL																									
23																									
24																									
25																									
26																									
27																									
28																									

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Unit 4, Thin sections.

HEIGHTS IN POSITIVE AND MIS-MATCHES V.S. TOTAL MATCHES

	OK	43	H	HL	LY	BF	HI	FI	MF	M	MC	CS	FE	VU	IN	FO	LA	2E	23	24	25	26	27	28	29
<1P	.81	.74	.86	.56	.82	.82	.72	.64	.56	.62	.52	.54	.56	.65	.60	.85	.56	.62	.77	.75	.81	.92	.95	.92	.74
>2P	.42	.63	.31	.35	.23	.23	.62	.58	.28	.28	.21	.24	.35	.36	.42	.71	.31	.24	.76	.39	.55	.52	.75	.92	.53
>3P	.38	.88	.23	.83	.12	.12	.50	.80	.20	.20	.18	.12	.27	.32	.30	.54	.13	.23	.68	.26	.50	.43	.74	.92	.38
>8P	.43	.32	.17	.17	.07	.07	.44	.44	.15	.21	.07	.11	.21	.29	.27	.56	.14	.14	.61	.19	.57	.46	.77	.85	.14
DARK							.69	.69	.50	.48	.42	.44	.54	.59	.52	.73	.43	.44	.81	.82	.59	.64	.81	.96	.57
MED DK							.56	.67	.48	.61	.44	.46	.48	.68	.64	.78	.48	.57	.71	.50	.87	.73	.86	.89	.53
MEDIUM							.44	.48	.15	.29	.11	.14	.24	.29	.36	.59	.17	.21	.64	.31	.61	.50	.82	.86	.38
MED LT							.44	.44	.19	.25	.11	.14	.21	.29	.36	.59	.17	.25	.57	.31	.65	.54	.82	.86	.34
LIGHT GT							.37	.41	.07	.18	.00	.04	.14	.25	.27	.56	.07	.14	.57	.19	.57	.46	.77	.86	.28
BUFF							.37	.41	.07	.18	.00	.04	.14	.25	.27	.56	.07	.14	.57	.19	.57	.46	.77	.86	.28
MICROCRYST													.41	.65	.48	.64	.37	.54	.73	.37	.71	.58	.90	.88	.41
FINE													.44	.62	.71	.84	.48	.58	.65	.58	.84	.63	.81	.92	.67
MED FINE													.19	.23	.33	.64	.15	.15	.65	.29	.57	.46	.81	.88	.37
MED CRYST													.29	.30	.38	.65	.25	.22	.67	.36	.64	.54	.82	.83	.66
MED COARSE													.11	.23	.29	.60	.07	.15	.58	.21	.57	.46	.76	.88	.30
COARSE													.14	.26	.29	.62	.11	.15	.59	.24	.59	.48	.77	.89	.32
FENESTRAE													.39	.45	.70	.70	.21	.29	.57	.35	.65	.62	.77	.86	.41
VUGS													.43	.43	.65	.65	.32	.22	.74	.46	.65	.56	.86	.89	.50
INTRACLASTS													.48	.48	.48	.48	.27	.36	.71	.25	.63	.35	.93	.90	.36
MEGAFOSFELS																	.56	.65	.85	.50	.74	.58	1.00	.92	.54
LAMINATION																		.81	.61	.83	.57	.46	.82	.86	.28
ZEBRA																			.74	.32	.55	.48	.81	.89	.43
23																			.64	.64	.86	.88	.82	.89	.68
24																					.65	.43	.81	.88	.31
25																					.70	.83	1.00	.65	
26																							.95	.88	.50
27																								1.00	.82
28																									.89

8-90

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
.52	.23	.12	.07	.43	.45	.10	.10	.00	.00	.37	.41	.07	.16	.00	.04	.14	.25	.27	.56	.07	.14	.87	.19	.87	.46	.77	.86	.28

Unit 4, Thin sections

RESEARCH 21 FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

OK	NO	M	ML	LT	BF	HI	FN	MF	M	MC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27	28	29
<15	.10	.07	.07	.07	.07	.14	.14	.14	.10	.14	.10	.07	.20	.31	.14	.07	.10	.10	.17	.28	.17	.28	.10	.07
>25T	.10	.10	.10	.10	.10	.17	.17	.17	.14	.17	.14	.10	.14	.34	.17	.10	.14	.14	.21	.31	.21	.31	.14	.10
>35F	.10	.10	.10	.10	.10	.17	.17	.14	.14	.14	.14	.10	.14	.31	.17	.10	.10	.14	.21	.31	.21	.34	.14	.10
>55T	.03	.00	.00	.00	.00	.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.23	.03
DARK						.10	.10	.10	.07	.10	.07	.03	.07	.28	.10	.03	.07	.07	.14	.24	.14	.28	.07	.03
MED OK						.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.03
MEDIUM						.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.03
MED LT						.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.03
LIGHT OY						.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.03
BUFF						.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.03
MICROCRYST												.07	.10	.28	.14	.07	.10	.10	.17	.28	.17	.28	.10	.07
PINE												.07	.10	.28	.14	.07	.10	.10	.17	.28	.17	.28	.10	.07
MED FINE												.07	.10	.28	.14	.07	.10	.17	.28	.17	.28	.10	.07	.07
MED CRYST												.03	.07	.28	.10	.03	.07	.07	.14	.24	.14	.24	.07	.03
MED COARSE												.07	.10	.28	.14	.07	.07	.10	.17	.28	.17	.28	.10	.07
COARSE												.03	.07	.28	.10	.03	.07	.07	.14	.24	.14	.24	.07	.03
FENESTRAE												.03	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.03
VUGS												.10	.03	.28	.10	.03	.07	.07	.10	.21	.14	.24	.07	.03
INTRACLASTS												.28	.24	.28	.14	.24	.24	.28	.31	.34	.31	.48	.28	.24
MEGAFOSILS												.07	.10	.28	.14	.07	.10	.10	.17	.28	.17	.31	.10	.07
LAMINATION												.03	.03	.10	.10	.03	.03	.10	.21	.10	.10	.24	.03	.03
ZEBRA												.07	.07	.14	.07	.14	.07	.14	.24	.14	.28	.07	.03	.03
23												.14	.24	.14	.24	.14	.24	.14	.24	.21	.21	.24	.07	.03
24												.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.24	.10	.10
25												.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.24	.24	.24
26												.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.24	.24	.24
27												.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.24	.24	.24
28												.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.24	.24	.24

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
.07	.10	.10	.00	.03	.00	.00	.00	.00	.00	.00	.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.03

8+91

157 1.8.1 NO. OF SAMPLES 29

157 1.5.1 NO. OF SAMPLES 29

MERGE? YES

carleton university computing centre

256937

Unit 4, Thin sections (Merged)

COEFFICIENTS BASED ON PRESENCE OF THE LESS COMMON CHARACTER

	DC	40	M	HL	LT	BF	HI	FN	HF	4	MC	CS	FE	VJ	IN	EO	LA	ZE	23	24	25	26	27	28	29
<2FT	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
>2FT	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
>3FT	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
>5FT	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
DARK	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MED CK	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MEDIUM	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MED LT	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
LIGHT BY	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
BUFF	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MICROCRYST	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
FINE	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MED FINE	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MED CRYST	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MED COARSE	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
COARSE	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
FENESTRAE	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
YUGS	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
INTRACLASTS	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
MEGAFOSFELS	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
LAMINATION	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
ZEBRA	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
23	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
24	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
25	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
26	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
27	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33
28	.57	.08	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33

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Unit 4, Thin sections (Merged)

LESS COMMON CHARACTERS (BASED ON SAMPLES WHERE BOTH CHARACTERS KNOWN)

	OK	40	M	ML	LT	BF	MI	FN	4F	M	MC	CS	FE	VO	IV	FD	LA	ZE	23	24	25	26	27	28	29
CLIF	1.00	6.00	7.00	8.00	9.00	10.00	11.00	1.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00
DRFT	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
DRFT	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
DRFT	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
DARK	11.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00	36.00
MED OK	11.00	6.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00
MEDIUM	7.00	7.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00
MED LT	8.00	8.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00
LIGHT OY	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
BUFF	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
MICROCRYST	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	40.00	41.00
FINE	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00	25.00	26.00	27.00	28.00	29.00	30.00	31.00	32.00	33.00	34.00	35.00	36.00	37.00	38.00	39.00	40.00	41.00
MED FINE	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
MED CRYST	17.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
MED COARSE	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
COARSE	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
FENESTRAE	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
VUGS	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
INTRACLASTS	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
MEGACRYSTALS	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
LAMINATION	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
ZEBRA	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
23	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
24	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
25	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
26	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
27	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
28	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00

Unit 4, Thin sections (Merged)

HEIGHTS IN POSITIVE AND MISMATCHES V.S. TOTAL MATCHES

	DC	40	H	HL	LT	BF	MI	FN	MF	M	YC	CS	FE	VU	IN	FO	LA	ZE	23	24	25	26	27	28	29
S&P	.93	.74	.82	.84	.82	.82	.72	.84	.54	.65	.52	.84	.56	.56	.80	.84	.56	.62	.77	.75	.81	.92	.95	.92	.74
>8PT	.81	.65	.42	.25	.23	.23	.62	.92	.26	.32	.21	.84	.38	.36	.42	.71	.31	.24	.76	.76	.58	.52	.75	.92	.50
>3P	.77	.88	.38	.23	.18	.12	.50	.83	.20	.28	.12	.12	.27	.32	.30	.58	.19	.23	.68	.26	.50	.43	.74	.92	.38
>8PT	.79	.82	.88	.17	.07	.07	.44	.78	.18	.29	.07	.11	.21	.29	.27	.56	.14	.14	.61	.19	.57	.46	.77	.84	.24
DARK							.88	.93	.81	.86	.78	.79	.83	.93	.82	.93	.79	.82	.93	.93	.77	.87	.88	.91	.83
MED DK							.56	.78	.48	.64	.44	.46	.48	.68	.64	.78	.48	.87	.71	.50	.87	.73	.86	.89	.55
MEDIUM							.52	.81	.26	.39	.22	.25	.31	.32	.45	.63	.28	.32	.64	.42	.70	.58	.84	.84	.45
MED LT							.44	.78	.19	.32	.11	.14	.21	.29	.34	.59	.17	.25	.57	.31	.65	.54	.82	.86	.34
LIGHT BY							.37	.74	.07	.25	.00	.04	.14	.25	.27	.56	.07	.14	.57	.19	.57	.46	.77	.84	.28
BUFF							.37	.74	.07	.25	.00	.04	.14	.25	.27	.56	.07	.14	.57	.19	.57	.46	.77	.84	.28
MICROCRYST													.41	.65	.48	.64	.37	.54	.73	.37	.71	.58	.90	.88	.41
FINE													.74	.96	.86	.88	.74	.92	.81	.75	.99	.92	.90	.96	.74
MED FINE													.19	.23	.33	.64	.15	.15	.65	.29	.57	.46	.81	.88	.37
MED CRYST													.36	.30	.43	.69	.32	.22	.74	.44	.64	.86	.86	.89	.54
MED COARSE													.11	.23	.29	.60	.07	.15	.58	.21	.57	.46	.76	.88	.30
COARSE													.14	.26	.23	.62	.11	.15	.52	.24	.52	.48	.77	.82	.32
FENESTRAE													.39	.45	.45	.70	.21	.29	.57	.35	.65	.62	.77	.86	.41
VUGS													.43	.43	.43	.68	.32	.22	.74	.46	.68	.56	.86	.89	.50
INTRACLASTS													.27	.36	.71	.25	.27	.36	.71	.25	.62	.35	.92	.92	.36
MEGAFOSSILS													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
LAMINATION													.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21	.21
ZEBRA													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
23													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
24													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
25													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
26													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
27													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86
28													.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86	.86

FRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
VARIABLES NUMBERED IN ORDER AS ABOVE.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
.52	.83	.12	.07	.79	.48	.81	.10	.00	.00	.37	.74	.07	.25	.00	.04	.14	.25	.27	.56	.07	.14	.57	.19	.57	.46	.77	.86	.28

Unit 4, Thin sections (Merged)

WEIGHTS AS FRACTION OF SAMPLES LACKING INFORMATION ON THE PAIR

OK	HD	H	HL	LY	BF	HI	FN	HF	H	MC	CB	FE	VU	IN	FO	LA	ZE	23	24	25	26	27	28	29
CLIF	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
SEPT	.10	.10	.10	.10	.10	.17	.17	.17	.14	.17	.14	.10	.14	.34	.34	.17	.10	.14	.21	.31	.21	.31	.14	.10
SEPT	.10	.10	.10	.10	.10	.17	.17	.17	.14	.14	.14	.10	.14	.31	.31	.17	.10	.14	.21	.31	.21	.34	.14	.10
SEPT	.10	.10	.10	.10	.10	.17	.17	.17	.14	.14	.14	.10	.14	.31	.31	.17	.10	.14	.21	.31	.21	.34	.14	.10
DARK	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MED DK	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MEDIUM	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MED LY	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
LIGHT BT	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
BUFF	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MICROCRYST	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
PINE	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MED PINE	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MED CRYST	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MED COARSE	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
COARSE	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
FENESTRAE	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
VUGS	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
INTRACLASTS	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
MEGASPOSSIBLE	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
LAGINATION	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
ZERRA	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
23	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
24	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
25	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
26	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
27	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07
28	.07	.07	.07	.07	.07	.14	.14	.14	.14	.14	.14	.10	.07	.10	.31	.14	.07	.10	.17	.28	.17	.28	.10	.07

FRACTION OF SAMPLES LACKING INFORMATION ON CHARACTER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
.07	.10	.10	.00	.00	.00	.00	.00	.00	.00	.07	.07	.07	.03	.07	.03	.00	.03	.24	.07	.00	.03	.03	.10	.21	.10	.24	.03	.00

EXIT

carleton university computing centre

256937

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APPENDIX III

DIAMOND DRILL HOLE LOGGING EXAMPLE

DIAMOND DRILL HOLE NO. 5 - Top 85 feet -

9-2

Legend: See Figure 3-13

APPENDIX IV

Bed Thickness Distributions

(Thickness of enclosing bed recorded for sample points at 2 foot intervals along graphic logs. All bedding planes sufficiently distinct to have been drawn all the way across the graphic log, even if discontinuously, were counted.)

Unit 2, Section P

PLD# FRYE BEDD

PERCENT

FREQUENCY

MIDPOINT

12.37

24.00

.500

9.28

18.00

1.500

10.31

20.00

1.500

12.37

24.00

2.000

10.31

20.00

2.500

13.48

26.00

3.000

6.19

12.00

3.500

5.67

11.00

4.000

2.66

4.00

4.500

3.61

7.00

5.000

2.58

5.00

6.500

1.55

3.00

6.000

3.61

7.00

6.500

.00

.00

7.000

.00

.00

7.500

2.06

4.00

8.000

.00

.00

8.500

.00

.00

9.000

.00

.00

9.500

.00

.00

10.000

2.58

5.00

10.500

MEAN

3.013

STANDARD DEVIATION

2.263

MEDIAN

2.512

Percent Frequency Distribution of
Bed Thicknesses-
Section P, Unit 2, Top 400 Feet.

Unit 2, Section V

V30T. SECT. 8500

MIDPOINT	FREQUENCY	PERCENT
.500	1.00	2.08
1.000	.00	.00
1.500	3.00	6.23
2.000	.00	.00
2.500	.00	.00
3.000	.00	.00
3.500	.00	.00
4.000	2.00	4.17
4.500	9.00	18.75
5.000	5.00	10.42
5.500	5.00	10.42
6.000	9.00	18.75
6.500	3.00	6.23
7.000	.00	.00
7.500	.00	.00
8.000	.00	.00
8.500	.00	.00
9.000	.00	.00
9.500	5.00	10.42
10.000	.00	.00
10.500	.00	.00
11.000	.00	.00
11.500	6.00	12.50

MEAN 6.167 STANDARD DEVIATION 2.768 MEDIAN 5.575

Note: Some bedding planes may have been obscured by severe fracturing and alteration.

Unit 3, Section V

VTOS SECT BEDD

MIDPOINT	FREQUENCY	PERCENT	MEAN	STANDARD DEVIATION	MEDIAN
.500	45.00	37.82	1.731	1.811	1.026
1.000	24.00	20.17			
1.500	17.00	14.29			
2.000	12.00	10.00			
2.500	1.00	.83			
3.000	4.00	3.36			
3.500	.00	.00			
4.000	.00	.00			
4.500	2.00	1.68			
5.000	2.00	1.68			
5.500	.00	.00			
6.000	9.00	7.56			
6.500	.00	.00			
7.000	.00	.00			
7.500	3.00	2.52			
8.000	.00	.00			

Unit 3, Section P (below 450 feet from bottom of unit)

ST03 450 BEDD

MIDPOINT	FREQUENCY	PERCENT
.500	30.00	34.09
1.000	25.00	28.41
1.500	8.00	9.09
2.000	8.00	9.09
2.500	1.00	1.14
3.000	.00	.00
3.500	4.00	4.55
4.000	2.00	2.27
4.500	4.00	4.55
5.000	.00	.00
5.500	6.00	6.82

MEAN 1.631 STANDARD DEVIATION 1.501 MEDIAN 1.015

Unit 3, Sect. K
(Bottom part of section omitted due to keypunch
error shown at bottom of page.)

MIDPOINT	FREQUENCY	PERCENT
0.500	34.00	14.47
1.000	54.00	22.98
1.500	14.00	5.96
2.000	21.00	8.94
2.500	9.00	3.83
3.000	6.00	2.55
3.500	13.00	5.53
4.000	6.00	2.55
4.500	3.00	1.28
5.000	4.00	1.70
5.500	2.00	.85
6.000	6.00	2.55
6.500	.00	.00
7.000	.00	.00
7.500	.00	.00
8.000	12.00	5.11
8.500	5.00	2.13
9.000	17.00	7.23
9.500	.00	.00
10.000	10.00	4.26
10.500	5.00	2.13
11.000	.00	.00
11.500	.00	.00
12.000	.00	.00
12.500	.00	.00
13.000	.00	.00
13.500	.00	.00
14.000	14.00	5.96

MEAN 4.104

STANDARD DEVIATION 4.034

MEDIAN 2.060

FORTRAN RUN-TIME ERROR IN 'INPUT' CALLED AT LCC X'00836'.

21.11.13.1.0.31.21.4.2.5.3.1.1.3.5.1.2.4.4.2.4.5.1.0.5.1.2.5.1.3.1.0.0

ILLEGAL NUMERIC INPUT CHARACTER. FIELD TERMINATED.

Unit 4, Section J

J SECT 8E00

MIDPOINT	FREQUENCY	PERCENT	MEAN	STANDARD DEVIATION	MEDIAN
.500	21.00	37.50	1.071	.684	.958
1.000	21.00	37.50			
1.500	8.00	14.29			
2.000	1.00	1.79			
2.500	1.00	1.79			
3.000	4.00	7.14			

SECRET

Note: incipient and discontinuous or poorly visible bedding planes are counted here.

Unit 4, Section E (lower part: mainly limestone).

EBOT SECT BEDD

MIDPOINT	FREQUENCY	PERCENT
1.200	7.00	35.00
1.300	7.00	35.00
1.500	3.00	15.00
2.200	3.00	15.00

MEAN 1.050 STANDARD DEVIATION .522 MEDIAN .982

10-11

APPENDIX V

Computer Programs and Data Forms

TABLE 1

Program for 1) Converting Millimetre Measurements
to Grouped Phi-unit Form, and/or

2) Computing **Mean**, Median and Standard
Deviation for Grouped Data by the Product-
Moment Method.

PROGRAM FOR (A) ALLOTTING MILLIMETRE MEASUREMENTS TO PHI
INTERVALS, (B) COMPUTING MEAN, MEDIAN AND STANDARD DEVIATION
FOR GROUPED DATA, BY THE PRODUCT-MOMENT METHOD

A. H. TAYLOR

JUNE 1973

DIMENSION F(40), C(50), PROD(40), PROD2(40), PCENT(40)
COMMON PHIMID(40), PHI, I, J, NPHI
CALL EQFSET(3055)

IPAGE=0
60 READ 310, 101, 102, 103
SPEC NO, COMPONENT MEASURED, TYPE OF MEASUREMENT

310 FORMAT(3A4)

INPUT K

K IS ZERO IF USING PART A OF PROGRAM, OTHERWISE ANOTHER NO.

IF(K.NE.0) GO TO 300

PART A: PHI GROUPS

INPUT N, PHI, NPHI ^(turns)

N IS NO. OF MM. COUNTS, PHI IS LOWEST PHI SIZE (LARGEST SIZE)

NPHI IS HIGHEST PHI SIZE (SMALLEST SIZE)

INPUT C(1), I=1, N

C(1) ARE THE MM. COUNTS, IN ORDER OF DECREASING SIZE OF MM INTERVAL.

THESE MUST START WITH A MM INTERVAL BOUNDARY ABOVE ALL COUNTS

AN EMPTY

I=2

J=1

5 IF(PHI.LT.2.375) GO TO 8

IF(PHI.EQ.2.375) GO TO 9

IF(PHI.EQ.2.625) GO TO 10

IF(PHI.EQ.2.875) GO TO 11

IF(PHI.EQ.3.125) GO TO 12

IF(PHI.EQ.3.375) GO TO 13

IF(PHI.EQ.3.625) GO TO 14

IF(PHI.EQ.3.875) GO TO 15

IF(PHI.EQ.4.125) GO TO 16

IF(PHI.EQ.4.375) GO TO 17

IF(PHI.EQ.4.625) GO TO 18

GO TO 40

300 INPUT NPHI

NPHI IS NO. OF INTERVALS PRESENT

INPUT PHIMID(J), F(J), J=1, NPHI

43. C PHIMIC(J) ARE MIDPOINTS OF INTERVALS, F(J) ARE CORRESPONDING

44. C FREQUENCIES.

45. C GO TO 501

46. 8 F(J)=C(I)+.5*C(I+1))+(.5*C(I-1))

47. CALL COUNT1(650)

48. C GO TO 5

49. 9 F(J)=C(I)+.5*C(I-1))+(.8*C(I+1))

50. CALL COUNT1(650)

51. 10 F(J)=C(I)+.2*C(I-1))+(.6*C(I+1))

52. CALL COUNT1(650)

53. 11 F(J)=C(I)+.4*C(I-1))+C(I+1)

54. CALL COUNT1(650)

55. 12 F(J)=C(I)+C(I+1)

56. CALL COUNT1(650)

57. 13 F(J)=C(I)+.7*C(I+1)

58. CALL COUNT1(650)

59. 14 F(J)=C(I)+.3*C(I-1))+(.1*C(I+1))

60. CALL COUNT1(650)

61. 15 F(J)=(.9*C(I-1))+(.25*C(I))

62. CALL COUNT2(650)

63. 16 F(J)=(.2*C(I))+(.75*C(I-1))

64. CALL COUNT3(650)

65. 17 F(J)=(.8*C(I))+(.1*C(I+1))

66. CALL COUNT2(650)

67. 18 F(J)=.7*C(I)

68. CALL COUNT3(650)

69. F(J)=(.2*C(I))+(.4*C(I+1))

70. CALL COUNT2(650)

71. F(J)=.7*C(I)

72. CALL COUNT2(650)

73. F(J)=(.13*C(I-1))+(.29*C(I))

74. CALL COUNT3(650)

75. F(J)=.55*C(I)

76. CALL COUNT3(650)

77. F(J)=.30*C(I)

78. CALL COUNT2(650)

79. F(J)=.06*C(I-1))+(.19*C(I))

80. CALL COUNT3(650)

81. F(J)=.21*C(I)

82. CALL COUNT3(650)

83. F(J)=.17*C(I)

84. CALL COUNT3(650)

85. F(J)=.15*C(I)

86. CALL COUNT3(450)

87. F(J)=.13*C(I)

88. CALL COUNT3(350)

89. F(J)=.10*C(I)

90. PHIMID(J)=PHI

91. 50 NPHI=J

92. C

93. C

94. C

95. C

96. C

97. C

98. C

99. C

100. C

101. C

102. C

103. C

104. C

105. C

106. C

107. C

108. C

109. C

110. C

111. C

112. C

113. C

114. C

115. C

116. C

117. C

118. C

119. C

120. C

121. C

122. C

123. C

124. C

125. C

126. C

127. C

128. C

PART B1 STATISTICS

--PHI MEAN

301 SFREQ=0.

SPROD=0.

DO 2 J=1,NPHI

SFREQ=SFREQ+F(J)

PRCD(J)=PHIMID(J)*F(J)

SPROD=SPROD+PROD(J)

2 CONTINUE

PHIMN=SPROD/SFREQ

DO 45 J=1,NPHI

PCENT(J)=F(J)/SFREQ*100.

45 CONTINUE

--STANDARD DEVIATION

SPROD2=0.

DO 3 J=1,NPHI

PRCD2(J)=((PHIMN-PHIMID(J))**2)*F(J)

SPROD2=SPROD2+PRCD2(J)

3 CONTINUE

SIGMA=SQRT(SPROD2/SFREQ)

--PHI MEDIAN

FIFTY=SFREQ/2.

J=0

SFIFTY=0.

4 J=J+1

SFIFTY=SFIFTY+F(J)

IF(SFIFTY.LT.FIFTY)GO TO *

DIF=SFIFTY-FIFTY

PHIMED=PHIMID(J)+.125-(.250*DIF/F(J))

```

129.      C      PRINT STATEMENTS AND OUTPUT FORMATS
130.      C
131.      C
132.      C      NSUM,
133.      C      IPAGE=IPAGE+1
134.      C      PRINT 312,101,102,103,IPAGE
135.      C      IF(K.NE.0)GO TO 70
136.      C      PRINT 200, PHIMID(J),F(J),PCENT(J), J=12,NPHI
137.      C      PRINT 210, PHIMN,SIGMA,PHIMED
138.      C      GO TO 60
139.      C      70 PRINT 220, PHIMID(J),F(J),PCENT(J), J=1,NPHI
140.      C      PRINT 230, PHIMN,SIGMA,PHIMEC
141.      C      GO TO 60
142.      C      2BX,2HN= ,I,5,34X
143.      C      312 FORMAT(1M1,T8,312X,A4,10X,4HPAGE,1A,/)
144.      C      200 FORMAT(T20,12HPHI MIDPOINT,T40,9HFREQUENCY,T60,7HPERCENT//T2,F6.
145.      C      13,T43,F6.2,T61,F6.2)
146.      C      210 FORMAT(//T10,8HPHI MEAN,5X,F6.3,T39,22HPHI STANDARD DEVIATION,5X,F
147.      C      16,3,T82,10HPHI MEDIAN,5X,F6.3)
148.      C      220 FORMAT(T2,8HPHIOPPOINT,T40,9HFREQUENCY,T60,7HPERCENT//T2,F6.3,T43
149.      C      12,F6.2,T61,F6.2)
150.      C      230 FORMAT(//T18,4HMEAN,4X,F6.3,T43,18HSTANDARD DEVIATION,4X,F6.3,T86,
151.      C      16HMEDIAN,4X,F6.3)
152.      C      305 CALL EXIT
153.      C      END

```

NSUM = 0
 DO 65, I=1, N
 NSUM = NSUM + C(I)
 AS CONTINUE

```
1.  C
2.  C
3.  SUBROUTINE COUNT(I*)
4.  COMMON PHIMID(I*O),PHI,I,J,HPHI
5.  PHIMID(I)=PHI
6.  PHIMID(I)=250
7.  IF (PHI.GT.HPHI) RETURN
8.  I=I+2
9.  J=J+1
10. RETURN
11. END
```



```
1. SUBROUTINE COUNT2(+)
2. COMMON PHIMID(40),PHI,ISJ,HPHI
3. PHIMID(J)=PHI
4. PHI=PHI+280
5. IF(PHI.GT.HPHI)RETURN
6. I=I+1
7. J=J+1
8. RETURN
9. END
10.
```

```
1. C
2. SUBROUTINE COUNT3(*)
3. COMMON PHIC(150),PHI,JA,HPHI
4. PHICID(J)=PHI
5. PHI=PHI+.250
6. IF(PHI.GT.HPHI)RETURN
7. J=J+1
8. RETURN
9. END
```

Data Card Formats for Phi-grouping and
Statistics Program

On card # 1 put

- specimen number or other identifier in spaces 1,2,3 and 4, only.
- component measured, or other identifier in spaces 5,6,7 and 8, only.
- type or kind of measurement in spaces 9,10,11 and 12, only.

On card #2 put

- the numeral for zero, if using the phi-grouping part of the program.
- any non-zero integer, if not using phi-grouping.

On card # 3

- if using phi-grouping, put, in order as listed,
 - a) the number of millimetre intervals to be processed in this set, including one or two zeros at the large-size end as explained below.
 - b) The phi value of the largest millimetre size (using table).
 - c) the phi value of the smallest millimetre size (using table).

The above numerals must be separated by commas.

- if not using phi-grouping, put the number of intervals present in the distribution to be processed anywhere on the card.

On card # 4

-if using phi-grouping, put, in order of decreasing measurement size, the millimetre counts, separated by commas. These must always begin with a count value for a millimetre boundary "interval" which contains zero counts. Thus, either one or two zeros will always be added at the head of the list of numbers;

-if not using phi-grouping, put the midpoint of the first interval of the distribution, then the frequency for that interval. Repeat this for all midpoints and corresponding frequencies, in order, separating all numerals by commas.

Repeat cards # 1 through 4 as above for the next data set.

TABLE 2

TABLE 3

Specimen No. _____		DESCRIPTION CHART (For lab study of specimen characteristics) A. H. Taylor, Feb 1972	Descriptive Name: _____	
Colour	{ WS { _____ { FS { _____ { _____		Specimen's size and shape: _____	

Materials Used. Pol Surf. _____		Peris _____	T. S. _____	
Photos _____		X-Ray Diff _____	Other _____	

PICTURE DESCRIPTIONS

Hand Specimen.

Microscopic Examination Summary.

Spec. No. _____

(3)

PARTICLE COMPOSITION

Particle	%	Size		Shape	Other Phys. Char.	Distribution
		Range	Mean			
Detritus						
"Micrite"						
"Spar"						
Intraclasts						
Ooids						
Pellets						
Alloch. Fossils						
Most Abund. Fossils						

→ See Paleontological Data Sheet 9 ←

Notes and Summary.

Spec No. _____

FABRIC

Item	Comments
Homogeneity	
Porosity	
Packing	
Preferred Orientations	
Evidence of Binding	
Evidence of Replacement	
Ev. of Strain Recrystallization	
Ev. of Other Recrystallization (Kink bands, microspines, pseudomictic, boundary relationships)	
Ev. of Diagenetic Carbonates of Uncertain Origin	
Ev. of Precipitation in Voids (Collapsed micrite envelopes, etc.)	
Ev. of Leaching	
Ev. of Inversion	
Ev. of: Boring Micrite coating	

Notes and Summary.

Spec No. _____

(5)

PALEONTOLOGICAL DATA

Fossil	Fragmentation and Wear	Distribution and Orientation	Size		
			Range	Max	Min
Unident.					
Stromatolites					
Algae					
Trilob.					
Ostrac.					
Crin.					
Gastrop.					
Brachiopods					
Bryozoa					
Corals					
Amph. Stromatolites					
Forams					

Notes and Summary.

Spec No. _____

STRUCTURES

	Type of Structure	Dimensions & Description
Primary	Cross Bedding	
	Ripple Marks	
	Lamination	
Penecontemporaneous	Ev. of Burrowing	
	Dessic. Features	
	Slumps and Sim. Penecont. Def.	
Secondary	Ev. of Compaction	
	Stylolites	
	Fractures	
	"Sloty" Cleavage	
	Microfolds (Secondary)	

INTERPRETATIONS

Depositional Environment: _____

Diagenesis (& Paragenesis): _____

TABLE 4

Program for Computing Matching Coefficient Matrices.

(Note that the dimensioning must be changed in this program to fit the size and shape of the data set, in order not to waste a considerable amount of computer space.)

1. C PROGRAM FOR CALCULATING MATCHING COEFFICIENTS FOR SETS OF DISCRETE-
 2. C STATE VARIABLES. A.M.TAYLOR JULY-AUGUST, 1973

4. C EXPLANATION:

5. C POS RECORDS NUMBER OF PRESENT/PRESENT MATCHES.
 6. C RMIS RECORDS NUMBER OF PRESENT/ABSENT MATCHES (MISMATCHES).
 7. C RMIS RECORDS NUMBER OF ABSENT/ABSENT MATCHES.
 8. C RMIS RECORDS NUMBER OF ABSENT/ABSENT MATCHES.

9. C THE MATCHING COEFFICIENT USED IS POS+RMIS DIVIDED BY POS+RMIS

10. C A SECOND COEFFICIENT IS COMPUTED ANALOGOUSLY, BASED ONLY ON THE
 11. C SAMPLES IN WHICH THE LESS COMMON OF THE TWO CHARACTERS IS
 12. C PRESENT

13. C TWO WEIGHTING MATRICES ARE ALSO COMPUTED
 14. C THE FIRST (P) COMPARES NUMBER OF MATCHES USED WITH TOTAL VALID
 15. C MATCHES (POS+RMIS)/(POS+RMIS+RNEG).
 16. C THE SECOND (UNCERT) COMPARES NUMBER OF SAMPLES LACKING INFORMATIO
 17. C N ON ONE OR BOTH VARIABLES WITH TOTAL SAMPLES IN SET.

18. C DIMENSION VA(27,200),VB(200),C(27,27),P(27,27),UNCERT(27,27),D(27,
 19. C 127)/E(27,27)

20. C CALL EOFSET (5005)

21. C 1 READ 5,101,102,N,NN,MERGE

22. C IDENTIFIERS, NO. VARIABLES, NO. SAMPLES, DATA COMBINING INDICATOR

23. C 10 IF DARK MEANS MEDIUM=DARK OR DARK AND ANALOGOUSLY FOR MED, LT,

24. C FINE, MED & COARSE --ANY OTHER INTEGER IF CATEGORIES NOT TO BE

25. C COMBINED)

26. C 5 FORMAT(2A,3G,0)

27. C MG=5

28. C DO 9, K=1,NN

29. C READ 160, VA(J,K),J=1,N

30. C 150 FORMAT(30G,0)

31. C 9 CONTINUE

32. C 11 DO 80,I=1,N

33. C DO 10, K=1,NN

34. C VB(K)=VA(I,K)

35. C 10 CONTINUE

36. C DO 80, J=1,N

37. C POS=0.

42.

```

43. RMIS=0.
44. RNEG=0.
45. KA=0
46. KB=0
47. DO 30, K=1,NN
48. IF(VAL(J,K).EQ.0.100 TO 30
49. IF(VB(K).EQ.0.100 TO 30
50. SUM=VAL(J,K)+VB(K)
51. IF(SUM.EQ.2.100 TO 14
52. IF(SUM.EQ.2.100 TO 15
53. POS=POS+1.
54. GO TO 30
55. 14 RNEG=RNEG+1.
56. GO TO 30
57. 15 RMIS=RMIS+1.
58. IF(VAL(K).EQ.1.100 TO 14
59. KA=KA+1
60. GO TO 30
61. 16 KB=KB+1
62. 30 CONTINUE
63. IFAC1=POS+RMIS
64. IF(IFAC1.EQ.0.100 TO 18
65. FAC1=IFAC1
66. C(I,J)=(POS+RMIS)/FAC1
67. IF(ICA*GT.KB100 TO 17
68. G=KA
69. E(I,J)=1
70. GO TO 21
71. 17 G=KB
72. E(I,J)=J
73. 21 IFAC3=POS+G
74. IF(IFAC3.EQ.0.100 TO 22
75. D(I,J)=(POS-G)/IFAC3
76. GO TO 21
77. 22 O(I,J)=8.
78. 31 FAC2=FAC1+RNEG
79. P(I,J)=FAC1/FAC2
80. UNCERT(I,J)=1.=(FAC2/NN)
81. GO TO 80
82. 18 P(I,J)=0.
83. C(I,J)=9.
84. O(I,J)=9.
85. P(I,J)=0.

```



```

86.      UNCERT(I,J)=1.-(RNE3/NN)
87.      80 CONTINUE
88.      MM=N-4
89.      IE(LM3-QI-QJGO TO 81
90.      MERGED=3HYES
91.      00 TO 82
92.      81 MERGED=2HNO
93.      82 PRINT 180, I01,I02,NN,MERGED
94.      PRINT 200, N=22,I, I=23,N),((MM,(C(I,J), J=5,N)), I=1,4)
95.      LL=N-10
96.      PRINT 201,(LL,(C(I,J), J=11,N)), I=5,10
97.      KK=N-16
98.      PRINT 202,(KK,(C(I,J), J=17,N)), I=11,16
99.      PRINT 203, (5*I-14,N-1,(C(I,J), J=1+1,N)), I=17,22
100.     PRINT 204, (I,(5*I-14,N-1,(C(I,J), J=1+1,N)), I=23,N=1
101.     PRINT 207
102.     PRINT 200, N=22,(I, I=23,N),((MM,(D(I,J), J=5,N)), I=1,4)
103.     PRINT 201,(LL,(D(I,J), J=11,N)), I=5,10
104.     PRINT 202,(KK,(D(I,J), J=17,N)), I=11,16
105.     PRINT 203, (5*I-14,N-1,(D(I,J), J=1+1,N)), I=17,22
106.     PRINT 204, (I,(5*I-14,N-1,(D(I,J), J=1+1,N)), I=23,N=1
107.     PRINT 208
108.     PRINT 200, N=22,(I, I=23,N),((MM,(E(I,J), J=5,N)), I=1,4)
109.     PRINT 201,(LL,(E(I,J), J=11,N)), I=5,10
110.     PRINT 202,(KK,(E(I,J), J=17,N)), I=11,16
111.     PRINT 203, (5*I-14,N-1,(E(I,J), J=1+1,N)), I=17,22
112.     PRINT 204, (I,(5*I-14,N-1,(E(I,J), J=1+1,N)), I=23,N=1
113.     PRINT 205
114.     PRINT 200, N=22,(I, I=23,N),((MM,(P(I,J), J=5,N)), I=1,4)
115.     PRINT 201,(LL,(P(I,J), J=11,N)), I=5,10
116.     PRINT 202,(KK,(P(I,J), J=17,N)), I=11,16
117.     PRINT 203, (5*I-14,N-1,(P(I,J), J=1+1,N)), I=17,22
118.     PRINT 204, (I,(5*I-14,N-1,(P(I,J), J=1+1,N)), I=23,N=1
119.     PRINT 400, N=(J,J=1,N)/N/(P(I,J),J=1,N)
120.     PRINT 206
121.     PRINT 200, N=22,(I, I=23,N),((MM,(UNCERT(I,J), J=5,N)), I=1,4)
122.     PRINT 201,(LL,(UNCERT(I,J), J=11,N)), I=5,10
123.     PRINT 202,(KK,(UNCERT(I,J), J=17,N)), I=11,16
124.     PRINT 203, (5*I-14,N-1,(UNCERT(I,J), J=1+1,N)), I=17,22
125.     PRINT 204, (I,(5*I-14,N-1,(UNCERT(I,J), J=1+1,N)), I=23,N=1
126.     PRINT 401, N=(J,J=1,N)/N/(UNCERT(I,J), J=1,N)
127.     IF(MERGE-QT-0)GO TO 1
128.     DD 8, K=1,NN

```

```

129. IF(VA(5,K).EQ.2.100 TO 7
130. VA(5,K)=VA(6,K)
131. 7 IF(VA(7,K).EQ.2.100 TO 6
132. VAL(7,K)=VA(8,K)
133. 6 IF(VA(9,K).EQ.2.100 TO 4
134. VA(9,K)=VA(10,K)
135. 4 IF(VA(12,K).EQ.2.100 TO 3
136. VA(12,K)=VA(11,K)
137. 3 IF(VA(14,K).EQ.2.100 TO 12
138. VAL(14,K)=VA(13,K)
139. 12 IF(VA(16,K).EQ.2.100 TO 8
140. VA(16,K)=VA(15,K)
141. 8 CONTINUE
142. MERGE=2
143. MG=0
144. 80 TO 11
145. 150 FORMAT(1H,10X,4,5X,4,15X,15HNO. OF SAMPLES:,5X,15,10X,12HCOEF
146. 1FICIENTS,16X,8HMERGED:,2X,4)
147. 200 FORMAT(//,18,2HDK,3X,2HMD,4X,1HM,3X,2HML,3X,2HLT,3X,2HBF,3X,2HMI,3X
148. 1,2HFN,3X,2HMF,4X,1HM,3X,2HMC,3X,2HCS,3X,2HFE,3X,2HVV,3X,2HIN,3X,2H
149. 1FO,3X,2HLA,3X,2HZE,N(1X,13,1X)/,1X,4HK=1F,T6,NF5.2/1X,4H>2FT,T6,NF
150. 15.2/1X,4H>3E,T6,NF5.2/1X,4H>5FI,T6,NF5.2)
151. 201 FORMAT(1X,4HDARK,T36,NF5.2/1X,6HMED DK,T36,NF5.2/1X,6HMEIDIUM,T36,N
152. 1F5.2/1X,6HMED LT,T36,NF5.2/1X,8HLIGHT 3Y,T36,NF5.2/1X,4HBUFF,T36,N
153. 1F5.2)
154. 202 FORMAT(1X,10HMICROCRYST,T66,NF5.2/1X,4HFINE,T66,NF5.2/1X,8HMED FI
155. 1NE,T66,NF5.2/1X,9HVED CRYST,T66,NF5.2/1X,10HVED COARSE,T66,NF5.2/1
156. 1X,6HCOARSE,T66,NF5.2)
157. 203 FORMAT(1X,9HFENESTRAE,TN,NF5.2/1X,4HVJGS,TN,NF5.2/1X,11HINTRACLAST
158. 1S,TN,NF5.2/1X,11HMEGAFOSSILS,TN,NF5.2/1X,10HLAMINATION,TN,NF5.2/1X
159. 1,5HZEBSA,TN,NF5.2)
160. 204 FORMAT(1X,17,TN,NF5.2)
161. 205 FORMAT(1H,10X,53HHEIGHTS 1: POSITIVE AND MISMATCHES V.S. TOTAL MA
162. 1TCHES)
163. 206 FORMAT(1H,10X,62HHEIGHTS 2: FRACTION OF SAMPLES LACKING INFORMATI
164. 1ON ON THE PAIR)
165. 207 FORMAT(1H,10X,59HCOEFFICIENTS BASED ON PRESENCE OF THE LESS COMMO
166. 1N CHARACTER)
167. 208 FORMAT(1H,10X,69HLESS COMMON CHARACTERS (BASED ON SAMPLES WHERE B
168. 1OTH CHARACTERS KNOWN))
169. 400 FORMAT(//,2X,51HFRACTION OF KNOWN CASES WHERE CHARACTER IS PRESENT.
170. 1/2X,37H VARIABLES NUMBERED IN ORDER AS ABOVE,//T12,N(1X,13)/,T12,NF
171. 14.2)

```

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172. 401 FORMAT(//2X,52HFRACTION OF SAMPLES LACKING INFORMATION ON CHARACTE
173. 1R//T12,N(1X,131//T12,NF4.2)
174. 500 CALL EXIT
175. END

Raw Data Coding Form For Matching Coefficients

[illegible]

2 or 2

[illegible]

TABLE 6

Program for Computing Volume Percentage Composition
from Point Counts.

PROGRAM FOR COMPUTING VOLUME PERCENTAGE COMPOSITION FROM

POINT COUNTS

A. H. TAYLOR

FEBRUARY 1973

DIMENSION A(10), B(10), C8UM(10), C(10,6), PTOT(10), P(10)

CALL EOFSET (458)

1 SUMT=0

2 READ 10, N, M, I01, I02

3 N: NUMBER OF TRAVERSES, M: NUMBER OF CONSTITUENTS

4 I01 & I02: SPECIMEN NO. AND MIN OR PART COUNTED

5 PRINT 25, I01, I02

6 DO 4 J=1, N

7 SUM=0

8 READ 20, (A(J), J=1, M)

9 READ 20, (B(J), J=1, M)

10 A(J): LIST OF INITIAL READINGS, B(J): LIST OF FINAL READINGS

11 DO 5 J=1, M

12 C(J, I)=B(J)-A(J)

13 SUM=SUM+C(J, I)

14 5 CONTINUE

15 FAC=100.0/SUM

16 PSUM=0

17 DO 6 J=1, M

18 P(J)=C(J, I)*FAC

19 6 PSUM=PSUM+P(J)

20 INPUT TA, TB

21 TOTAL COUNT READINGS: TA=INITIAL READINGS, TB=FINAL READINGS

22 T=TB-TA

23 IF (T.EQ.0.0) GO TO 70

24 ERR=100.0*(T-SUM)/T

25 GO TO 60

26 7J ERR=-999.9

27 6C SUMT=SUMT+SUM

28 PRINT 30, I, SUM, PSUM, (P(J), J=1, M)

29 PRINT 40, T, ERR

30 4 CONTINUE

31 IF (N.EQ.1) GO TO 1

32 FAC=100.0/SUMT

33 PSTOT=0

34 DO 7 J=1, M

35 C8UM(J)=0

42.

```

43.      DO 3 I=1,N
44.          8 CSDM(I)=CSUM(I)+C(I)*I
45.          PTOT(I)=CSUM(I)*FAC
46.          PSTOT=PSTOT+PTOT(I)
47.      7 CONTINUE
48.          PRINT 50, PSTOT, (PTOT(I), I=1, N)
49.          GO TO 1
50.      10 FORMAT(IX,2I2,2A4)
51.      20 FORMAT(1G,0)
52.      25 FORMAT(1H1,T10,A4,2X,A4)
53.      30 FORMAT(//12,//T10,21F50.4//T10,15H$UM OF COUNTS EQUALS ,F6.1//T10,16H$UM OF PER
54.          1CENTS ,F6.1//T10,37HCONSTITUENT PERCENTS IN ORDER COUNTED,T52,10F6
55.          1,1)
56.      40 FORMAT(//T10,11HTOTAL COUNT,T52,5X//1HPERCENT DIFF BETH COUNTER TOTAL
57.          11 COUNT AND SUM OF COUNTS (MACHINE ERROR),F6.1)
58.      50 FORMAT(//22HALL TRAVERSES COMBINED//T10,15H$UM OF PERCENTS,2X,F6.1
59.          1//T10,37HCONSTITUENT PERCENTS IN ORDER COUNTED,T52,10F6.1)
60.      45 CALL EXIT
61.      END

```


Data Card Formats for Percentage Composition Program

Each set of data is coded as follows:

on card # 1-

- number of traverses, in spaces 2 and 3, right-justified
- number of constituents, " " 4 and 5, " "
- specimen number, in spaces 6, 7, 8, 9, only.

(Abbreviate to four spaces. Use any symbols or letters desired.)

- abbreviation showing what is counted, in spaces 10, 11, 12, 13, only.

on card # 2-

- the initial count numbers for each component, in order counted, starting anywhere on the card and leaving at least one blank space between any two numbers.

on card # 3-

- the final count numbers for the same traverse or set of traverses as on card 2, arranged in the same way as for card 2.

on card #4-

- the initial and then the final numbers from the "total count" register of the point counter, separated by a comma and placed anywhere on the card.

on subsequent cards, repeat cards 2, 3 and 4 for each other traverse or set of traverses done on the same specimen and using the same components.

for the next new data set from a different specimen or using different components, start at card 1.

FIGURE 3-5: SECTION H

Theses
M.Sc.
1977
T39
V.3

Thickness
in feet
↓

Dark grey dolostone with zebra, bitumin
and fossils

UNIT 4

UNIT 3

80 Feet of light grey-weathering,
light grey dolostone measured here
without logging. Some beds with
abundant quartz sand.

NOTE: Graphic log for Unit 3
constructed from measurements
and brief notes (somewhat
generalized).

900

860

| 1 OF 1 |

820

780

2 of 1

740

700

660

3 OF 1

620

580

540

| 4 OF |

540

500

C

5 OF 1

Large covered interval
measured with "pogo
stick". Accuracy
believed comparable
to that in exposed
section due to consistent
dips.

Contact location estimated
on basis of topography and
lithology ($\pm 15'$?).

UNIT 3

UNIT 2

0

C

L.-F.; internal sediment.

Mottled, "marbled" texture with some
recognizable brachiopod pieces
Pseudobreccia with a few possible
brachiopod fragments.

NOTE: Unit 2 portion of
log constructed from
detailed, bed-by-bed
field notes.

UNIT 2

NOTE: Unit 2 portion of log constructed from detailed, bed-by-bed field notes.

6 OF

FIGURE 3-9: SECTION K

These
M.S.C.
1977
T39
V.3

Thickness
in feet
↓
(Distance above
base of Unit 3
is approximate.
Footages have
been changed
somewhat on
Figure 2-5 to
correspond to
best stratigraphic
correlation.)

Crystal size
MIC FN MED CSE
Colour (FRESH SURF.)
DK MED LT BUFF

BESA RIVER FORMATION

1340

C

Tentaculites tests abundant
and well preserved in thin,
argillaceous layer in rubble

UNIT 4

Bedding: 450°; 35° N.E.
(average of 10 readings with
low variance).

Numerous separated crinoid
columnals.

Rubby weathering and dense,
with possible algal lamination.

Thamnopora with zebra.

A few crinoid columnals
visible in outcrop.

Thamnopora near base.

A few small, semi-ramosa
stromatopores here.

1300

C

A few Thamnopora skeletons
with stromatopores and
minor zebra. (Note zebra
above and below this horizon.)

Sand-sized, fragmental framework
visible in outcrop in some fossil-rich
layers, above.

1 OF 1

UNIT 4

UNIT 3

160 feet estimated stratigraphic
separation between outcrops,

UNIT 4

UNIT 3

160 feet estimated stratigraphic separation between outcrops, based on measurements on covered slopes and on maps, plus estimated average bedding attitude. (Probably a minimum.)

920

L-F

Stylolitic bedding plane.

Pellet-like, micrite intraclasts.

Horn coral.

A few, thin brachiopod or
pelecypod shells, plus
internal sediment.

L-F.

880

Slightly generalized.

4 OF

840

5 OF 1

L-F

800

Bioturbate.

Rippled surface and
intraclasts 40 ft. laterally.

Bioturbate at many levels.

Bioturbation.

760

Gradational contact.

Dolomitic sandstone.

Intraclasts.

6 OF 1

Faulted and drag-folded zone here, partly covered, involves 50 to 100 feet of stratigraphic section, according to estimate based on field relationships.

Lithologies are mainly thin and medium beds, some very sandy; also a few massive beds (badly fractured and sheared).

Locally cross-laminated.

7 OF 1

This lowest segment of
Section K contains
light-coloured dolomite.
Most beds are fine or
microcrystalline but
some of the thickest
beds coarsen upward
or are wholly medium
to medium-fine
crystalline.

8 of 8

Thesis
M.Sc.
1977
T39
V.3

1 OF

FIGURE 3-10 : SECTION J

FIGURE 3-10 : SECTION J

ic

Crystal
size

Colour
(Fresh surface)

MIC
FN
MED.
CSE

BK.
DK.
MED.
LT.
BUFF

BESA RIVER FORMATION
UNIT 4

2 of 1

Pyritic gossan with marcasite pseudomorphs
approx. 20 feet laterally to west.

This section is limestone 15 to 25 feet
southeast of line of section.

- Fine crystalline pyrite pellets.
- Fossils: stromatolites, etc.
- Fossils: stromatolites and stromatolites
- Lenses and pockets of fine pyrite
- Pyritic and argillaceous fossils
- Dolomitic shale

Pyritic gossium with marcasite pseudomorphs approx 20 feet laterally to west

This section is Limestone 15 to 25 feet southeast of line of section

Fossils

Fossils (poorly preserved)

Fossils (poorly pres.)

Shaly and very pyritic

Shale and argillaceous dolostone with a middle quartzite layer.

Dolomitic sandstone to sandy dolostone with pyrite nodules.

LATERAL OFFSET APPROX. 600 FT.

UNIT 4
UNIT 3

- Dolostone.
- Limy shale
- Limestone with trilobite fragments
- Limy shale.
- Pyrite flecks
- ~ 7% quartz grains
- Fossil fragments
- Argillaceous limestone.
- Black shale
- Scattered fine pyrite aggregates

M/C
FN
MED
CSE
BX
DA
MFR
LT
LULF

Sandy, light grey dolostone exposed to -260 feet: cover below that.

FIGURE 3-11: SECTION E

These
M. SC.
1977
T39
V.3

FIGURE 3-13

Symbols used in stratigraphic sections.

Note: Basic lithology is always dolostone except where otherwise stated in side note.

- *Sandy dolostone. Relative abundance of quartz sand indicated by density of dots*
- *Sandy dolostone with cross-bedding*
- *Laminated dolostone*
- *Shale (with side note)*
- *Fissile dolostone*
- *Lumpy-bedded dolostone*
- *Vuggy dolostone*
- *Dolostone with pockets, streaks or masses of white dolomite (or occasionally of quartz)*
- *Dolostone with small flecks of white dolomite filling fenestrae*
- *Dolostone with abundant fractures*
- *Dolostone with breccia pockets or locally brecciated (essentially bedded and intact)*
- *Dolostone, chaotically brecciated (bedding unrecognizable or recognizable within breccia blocks)*
- *Dolostone with "zebra" structure*
- *Dolostone with "semi-zebra" structure (white dolomite along an even lamination, grading to zebra pattern)*
- *Dolostone with "layered zebra"*
- *Dolostone with casts of large brachiopods and gastropods as well as internal sediment.*
- *Bioturbate dolostone*
- *Dolostone with veins of white dolomite (or quartz) filling fractures*
- *Covered interval*
- *Dark gray dolostone with stick corals and bulbous stromatoporiids*

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END

29 | 1 | 2 | 8 | 1 |

FIN