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Wayne David Ewert

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NAME OF SUPERVISOR/NOM DU DIRECTEUR DE THÈSE

Dr. G.B. Skippen

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**LA THÈSE A ÉTÉ
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METAMORPHISM OF SILICEOUS CARBONATE
ROCKS IN THE GRENVILLE PROVINCE
OF SOUTHEASTERN ONTARIO

by

WAYNE DAVID EWERT, B.SC. (HONS.)

A thesis submitted to the Faculty of
Graduate Studies in partial fulfilment
of the requirements for the degree of

Doctor of Philosophy

Carleton University

Ottawa, Ontario

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The undersigned hereby recommend to the Faculty
of Graduate Studies acceptance of this thesis, submitted by
Wayne David Ewert, B.Sc. (Hons.), in partial fulfilment of the
requirements for the degree of Doctor of Philosophy.

..... Skiffen
Supervisor

..... H. Moore
Chairman of Department

..... Walter E. Peck
External Examiner

Carleton University
Ottawa, Ontario
March 4, 1977

ABSTRACT

Siliceous carbonate rocks of the Grenville Supergroup within the Carleton Place, Perth, Westport and East-Titchborne map areas have undergone metamorphism ranging in grade from middle greenschist facies to granulite facies. Coexisting mineral assemblages within these siliceous carbonate rocks have been established and used to outline areas of varying metamorphic grade. Five isoreaction-grads based on isobarically univariant reactions (a divariant isoreaction-grad) and one isoreaction-grad based on an isobarically invariant mineral assemblage (a univariant isoreaction-grad) have been mapped. The univariant isoreaction-grad intersects the plane of a map at a point in pressure-temperature space that is independent of fluid composition. The univariant isoreaction-grad involves the phases, tremolite-diopside-calcite-dolomite-quartz, and its trace across the map is interpreted as an isotherm. The divariant isoreaction-grads are dependent on changes in temperature, pressure, and fluid composition.

The disposition of these isoreaction-grads in areas adjacent to plutonic igneous rocks displays a spatial relationship that indicates a changing metamorphic gradient towards the plutonic masses. The position of the univariant isoreaction-grad shows that, around at least some of the plutonic masses, the variation in metamorphic gradients is partly related to temperature increases whereas the disposition of the divariant isoreaction-grads indicates that the changes in grade are

related to variations in X_{CO_2} . Extensive areas of low-grade rocks that display primary sedimentary features are present and have not undergone metamorphism of a grade higher than that presently observed. Siliceous carbonate rocks within the east-Tichborne, west-Westport map-areas have undergone high-grade regional metamorphism and isoreaction-grads in these areas display no spatial relationship to specific plutonic bodies.

T - X_{CO_2} equilibrium curves and invariant points upon which the isoreaction-grads were established have been computed at 5 kilobars, the pressure indicated for the southern portion of the thesis area by sphalerite geobarometry. Relative phase relations suggest a pressure of 3 kilobars for northern portions of the area.

The calcite-dolomite geothermometer has been corrected for pressure effects and used to infer temperatures within the thesis area. Indicated temperatures range from less than 350°C for the low-grade regions to over 670°C in the high-grade forsterite zone of the Tichborne map-area. In general, the temperature measurements from the higher-grade zones appear to more accurately reflect original equilibrium temperatures.

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INTRODUCTION

The response of siliceous carbonate rocks to changes in pressure, temperature and fluid composition which occur during progressive metamorphism can be defined in terms of a number of specific reactions. Many of these reactions have been studied experimentally, e.g., Greenwood (1967), Metz and Winkler (1969), Gordon and Greenwood (1970), Metz (1970), and Skippen (1971), and used to construct comprehensive experimental models for the metamorphism of siliceous carbonate rocks, e.g., Metz and Trommsdorff (1968), Skippen (1971, 1974), Slaughter, Kerrick and Wall (1975), and Winkler (1975).

Although these models illustrate the importance of both CO_2 and H_2O as constituents of the fluid phase, it was not until Carmichael (1970) mapped intersecting isograds in the field that the importance of varying fluid composition on the interpretation of isograds was clearly established. More recent field studies of metamorphosed siliceous carbonate rocks, e.g., Trommsdorff (1972), Hutcheon and Moore (1972), Puhon and Hoffer (1973), Hoy (1976), and Allen (1976), have further demonstrated the influence of varying fluid composition and have shown that isogradic patterns in siliceous carbonate rocks must often be interpreted in terms of both fluid composition and thermal gradients.

The regional isogradic patterns which have been established in siliceous carbonate rocks within the present study area clearly show the divariant nature of most isograds and further display the necessity of considering both fluid composition and thermal gradients when interpreting the metamorphic history of an area. To help overcome the ambiguities presented by the divariance of such isograds, an attempt was made to map an additional isograd based solely on univariant mineral assemblages. The intersection of the trace of these univariant mineral assemblages with the plane of the map defines a point in P-T space that is independent of fluid composition. Thus, such an isograd is directly related to pressure and temperature in the classical sense of Tilley (1924). To the extent that additional elements such as Fe, Mn, Al, etc., are present in the minerals, the isograd will expand into a band rather than a line on the map surface. It was found, that at the scale of mapping reported in this project, the isograd may be reasonably treated as a line.

The isothermal character of the univariant isograd enables it to be interpreted directly from the experimental models. Interpretation of the divariant isograds is somewhat more complicated. However, with independent data on the pressures and temperatures of metamorphism and assuming relatively pure mineral components, reasonable estimates of fluid compositions can be obtained and the metamorphic grade interpreted.

Pressures of metamorphism for the thesis area can be determined from the assemblage sphalerite-pyrite-pyrrhotite. Solvus data for this assemblage are provided by Scott (1973) who indicated that below 600°C and five kilobars the FeS content of sphalerite coexisting with pyrite and pyrrhotite is independent of temperature and dependent only upon pressure. Electron microprobe analysis of the FeS content of sphalerites from localities within and surrounding the thesis area has enabled a reasonable metamorphic pressure to be determined.

The temperatures of metamorphism can be determined from coexisting calcite-dolomite. The amount of MgCO_3 in solid solution in calcite is dependent mainly on temperature, although some slight pressure dependence can be demonstrated. The influence of pressure has been calculated from data given by Goldsmith and Newton (1969) and all previous solvus data corrected to a common isobaric state. Electron microprobe analysis of the MgCO_3 content of calcites coexisting with dolomite from the thesis area has been used to determine temperatures from the pressure-corrected solvus data.

CHAPTER 1 THE GRENVILLE SUPERGROUP

1.1 Introduction

The term Grenville was introduced into the geological literature by Logan (1863) when he used the term "Grenville band", to describe a marble-rich metasedimentary sequence in the vicinity of Grenville Village, Argenteuil County, Quebec. Previously, Logan and others had considered the Precambrian metamorphic rocks of the area as belonging to a single entity, the "Laurentian System". With the realization that the "Laurentian System" consisted of an upper marble-bearing sedimentary series, the "Grenville band" and a lower gneissic sequence, "The Ottawa" or "Fundamental Gneiss", the usefulness of the term "Laurentian" was questioned. An international committee headed by F.P. Adams examined the Laurentian question and recommended that the term Laurentian be restricted to orthogneisses intrusive into the "Grenville Series" (Adams, 1907). The "Grenville Series" was thus firmly established and gradually took over much of the usage previously given to the term Laurentian. Adams and Barlow (1910); Wright (1923); Wilson (1925, 1933); Osborne (1931, 1936a, 1936b); Brown (1936); and Buddington (1939), among others, recognized "Grenville Series" rocks in areas removed from the type section and started the process which has gradually extended the "Grenville Series" into southwestern Quebec, southeastern Ontario, and the Adirondack area of the northeastern United States.

With the increasing awareness of the structural and tectonic divisions of the Canadian Shield, the "Grenville Series" became part of a larger entity, the Grenville Province (Wilson, 1918, 1925; Stockwell, 1961). The Grenville Province became the object of investigation by numerous workers trying to depict the structural, metamorphic and spatial relationships of all rock units influenced by the Grenville Orogeny (Gill, 1948, Wilson 1949). Osborne (1956), Hewitt (1956), Engel (1956), Engel and Engel (1953a) and Wynne-Edwards (1972) provide detailed accounts of these early investigations. In general, these investigations were concerned with problems such as the nature of the "Grenville Front" (Quirke and Collins (1930), Deland (1956), Phemister (1960, 1961), Grant (1964), Brown (1967), Henderson (1967), Krogh and Davis (1969), Davis et al. (1970)), the relationship of rocks in the Grenville Province to those in other tectonic provinces (Quirke and Collins (1930), Stockwell (1961, 1963a, 1963b, 1964), Snelling (1962), Wynne-Edwards (1964), Dalziel et al. (1969)), and the nature of anorthositic and related intrusive bodies within the Grenville Province (Buddington (1939, 1948), Satterly (1942), Thompson (1943), Harding (1946), Wynne-Edwards (1961, 1967a, 1972), Philpotts (1966), Emslie (1970), Martignole and Schryver (1971) and Kehlenbeck (1971)). The most enduring problem of the Grenville Province, however, has been the extent and stratigraphic significance of the type "Grenville Series". The term "Grenville Group" (Engel, 1956) and subsequently Grenville Supergroup (Moore and Thompson, 1972)

have replaced the original "Grenville Series" as more detailed stratigraphy has become known. Presently the term Grenville Supergroup, as defined by Moore and Thompson (1972), is used as a "rock stratigraphic term to describe metamorphosed sedimentary and volcanic rocks, probably deposited between 1300 m.y. and 1000 m.y. ago, exposed in eastern Ontario and western Quebec". The extent of the lithologies characteristic of the Grenville Supergroup is shown by Wynne-Edwards (1964) to be encompassed by a circle of 135 miles radius centered on Ottawa.

1.2 Grenville Basement

Logan (1863) stated that the "Grenville Series" was younger than the "Fundamental Gneiss" underlying it - i.e., a suggested basement/cover relationship. Further evidence in support of this possible relationship has recently been provided by Appleyard (1973). Adams and Barlow (1910) stated that the "Grenville Series" was invaded by the underlying "Ottawa Gneiss" which could not form a basement for it. Miller and Knight (1914) concluded that the "Grenville Series" conformably overlies Keewatin volcanic rocks. Lumbers (1967) has shown that the volcanic rocks in the Bancroft area are in fact part of the Grenville Supergroup (i.e., the Hermon Group) and not Keewatin. As late as 1956, the "Grenville Group" was thought by Hewitt (1956) not to have a basement. Subsequent studies by Wynne-Edwards (1964, 1969, 1972), Krogh and Davis (1967a),

Osborne and Morin (1962), Stöckwell (1964), Dalziel et al. (1969), and Appleyard (1973) have revealed extensive areas of basement rock although the basement/cover relationship has been obscured by the Grenville progeny. It has also been shown that the Grenville Supergroup is intruded by plutonic rocks in some areas, for example the Elzevir pluton (Moore and Thompson, 1972). Such intrusive relationships have similarly been demonstrated between plutonic rocks and Grenville Supergroup rocks within the thesis area (Wynne-Edwards, 1967a). No areas of suggested basement/cover relationships are known or postulated within or near the thesis area.

1.3 Hastings Series

The possibility of younger Precambrian material overlying the Grenville Supergroup is as intriguing as the basement problem. Vennor and Selwyn, in the Geological Survey of Canada Reports of Progress 1877 to 1878, noted that in Hastings County, Ontario, the "Grenville Series" was conformably overlain by the "Hastings Series" which was assigned a "Huronian age". Adams and Barlow (1910) stated that rocks of the "Grenville Series" graded into the "Hastings Series" which they believed was a less altered phase of the Grenville. Miller and Knight (1914) described a conglomerate containing pebbles of older intrusive rocks; the conglomerate was therefore thought to be younger than most of the rocks that were intrusive into the "Grenville Series". Wilson (1940) similarly believed the "Grenville Series" to be overlain by conglomerate-bearing "Hastings" material. Meen (1942) and Ambrose and Burns (1956) reported several conglomerate horizons and experienced

difficulty in deciding which of the several marked the "Grenville"-
 "Hastings" contact. For example, Meen (1942) shows a conglomerate
 outcropping near Flinton as belonging to the "Hastings Series" but
 does not include a conglomerate outcropping near Kaladar. More
 recently these conglomerates have been assigned to the Grenville
 Supergroup (Moore and Thompson, 1972). Moore and Thompson (1972)
 have successfully traced Flinton Group material over a strike length
 of 110 km, and state that "The sequence overlies plutonic, volcanic,
 carbonate and clastic sedimentary rocks with angular unconformity, and
 comprises the youngest Precambrian layered rocks known in eastern
 Ontario". They suggest that the term Flinton Group be used in pre-
 ference to "Hastings Group", where correlation with the Flinton Group
 is possible as the term "Hastings Group" has been used in the past to
 include rocks below the unconformity.

1.4 Metamorphism of the Grenville Supergroup

The Grenville Supergroup, occupying the "Central Metasedimentary
 belt" of Wynne-Edwards (1972), has been shown to consist of several
 distinct tectonic and metamorphic segments as shown in Figure 1.1
 (Hewitt, 1956; Lumbers, 1964, 1967; Moore, 1967; Wynne Edwards, 1967b,
 1972). These segments have been described as follows:

Figure 1.1 - Distribution of tectonic and metamorphic
divisions within the Grenville Supergroup
of Southeastern Ontario (after Hewitt, 1956).

a) Hastings-Haliburton-Madawaska Highlands

The Hastings-Haliburton and Madawaska Highlands occupy the northwestern part of the "Central Metasedimentary belt". They comprise domes of layered granitic gneisses and their metasedimentary envelopes (Hewitt, 1965). The area has been referred to as the "Glamorgan-Cardiff dome segment" by Wynne-Edwards (1972). The gneissic terrain contains rocks of upper amphibolite and granulite metamorphic facies (Hewitt, 1956; Wynne-Edwards, 1972). Adams and Barlow (1910) suggested that the high-grade metamorphism in this area was due principally to the large percentage of granitic material thought to intrude the region. A contrary position is held by Hewitt (1956) who believes that the granitic material is not a direct cause of the high-grade metamorphism but rather a result of it. He postulates that the metamorphic gneisses are products of "deep-zone regional metamorphism".

b) Hastings Basin

The Hastings Basin lies centrally between the Hastings-Haliburton Highlands to the northwest and the Frontenac Axis to the southeast from which it is separated by the Kaladar-Dalhousie Trough. The basin is described by Moore (1967) as containing the only metavolcanics, metaconglomerates and greenschist facies metamorphism known to exist in the Grenville Province. The metavolcanics were placed by

Lumbers (1967) into a lower Grenville unit, the Hermon Group, which is in turn overlain by the Mayo Group, which contains lithologies more typical of the type Grenville locality described by Logan. The grade of metamorphism in the Hastings Basin was first established by Lumbers (1964) who identified greenschist facies rocks on the basis of the assemblage albite-epidote in metavolcanic rocks. Sethuraman and Moore (1973) mapped chlorite, biotite, blue-green hornblende, green hornblende and diopside zones in the metavolcanic rocks; this work indicated an eastward increase in grade from greenschist to amphibolite facies, with the lowest grade located in an area between Madoc and Bancroft (Figure 1.2).

The Kaladar-Dalhousie Trough, intermediate between the Hastings Basin and the Frontenac Axis contains a series of northeast trending folds within which are found the Flinton, Kaladar, Clare River and Ompah conglomerates of the "Hastings-type" sediments (Hewitt, 1956; Smith, 1969; Moore and Thompson, 1972). The metamorphic grade increases from greenschist facies in the Madoc area to amphibolite facies as the Frontenac axis is approached (Lumbers, 1967; Wynne-Edwards, 1967; Hounslow and Moore, 1967; Sethuraman and Moore, 1973; Moore and Thompson, 1972). Successive zones of chloritoid-biotite, staurolite-kyanite, sillimanite-muscovite and sillimanite-potassium feldspar are encountered. This area of intermediate grade is shown in Figure 1.1.

The style of metamorphism within the Kaladar-Dalhousie Trough

Figure 1.2 - Isograds in the Frontenac Axis
(after Wynne-Edwards, 1967)

is mainly that associated with intermediate-pressure regional metamorphism (Moore and Thompson, 1972). Lumbers (1967) states that "in both time and space the least intense metamorphism is related closely to orogenesis and to plutons of the biotite diorite series, and the most intense metamorphism is related closely to plutons of the quartz monzonite group". This style is similar to that noted by Wynne-Edwards (1969) in the Kempt Lake-Mont Laurier area. He states that "close to the larger masses the metamorphic rocks attained granulite facies during the Grenville orogeny; away from them they reached only amphibolite facies". He suggests that the isograds may reflect hydrous and anhydrous conditions more than temperature variation. Carmichael (1970) in the Whetstone Lake area also concludes that the intersection of isograds in the area is attributable to changes in the H_2O/CO_2 ratio near the Whetstone Lake granite pluton. The importance of plutonic activity, especially that activity of the quartz monzonite group thought to be late syntectonic, is summed up by Engel and Engel (1953a): "the widespread chemical alterations and dynamothermal metamorphism of the Grenville series largely are related, however, to the emplacement of granites which postdate both anorthosite and gabbro".

While these studies suggest a spatial relationship between specific plutonic intrusions and varying metamorphic grade the true genetic relationship of the metamorphism and the plutons is not clear. The problem exists as to whether the plutons are a primary influence on metamorphism or whether they were emplaced prior to metamorphism and subsequently

acted to modify regional metamorphic pressure, fluid composition, and thermal gradients. Wynne-Edwards (1967a) in the Westport area states that the plutons are syntectonic to late syntectonic in origin while Moore and Thompson (1972) have shown that the Elzevir pluton, at least, predates both the first phase of deformation and the subsequent metamorphism. Clearly several different models must be examined when considering the genetic relationship between existing plutonic massifs and present metamorphic patterns.

1.5 Relationship of the Hastings Basin Area to the Northern Part of the Thesis Area

Both the low-grade metamorphic zone of the Hastings Lowland (although closed at Highway 41) and the intermediate-grade metamorphic zone of the Kaladar-Dalhousie Trough are elongated towards Lanark and Arnprior, i.e., the northern part of the thesis area. Liberty and Reinhardt (1963) indicated that amphibolites, migmatites, and tremolite marbles were present in this region but no detailed information on the metamorphic petrology was available. A preliminary investigation suggests that the low to intermediate-grade metamorphic zones of the Hastings Basin might also exist in the Lanark-Arnprior area and that a more detailed study of the metamorphic petrology would be worthwhile.

1.6 Frontenac Axis - Adirondack Lowlands

The Frontenac Axis is defined by Wynne-Edwards (1967b) as "that part of the Grenville Province lying between the St. Lawrence River and the Clare River syncline". The region was originally mapped by Wilson (1930) and Harding (1947) but was subsequently remapped and investigated by Wynne-Edwards (1956b, 1967a).

Metamorphism within the Frontenac Axis is depicted by Wynne-Edwards (1967a, 1967b) as being consistently high-grade, either hornblende granulite or pyroxene granulite facies. The Westport area was divided by Wynne-Edwards (1967a) into two metamorphic zones. The eastern region, characterized by cordierite-garnet or cordierite-sillimanite assemblages, was assigned by Wynne-Edwards to the upper amphibolite facies. In contrast, the western metamorphic zone displays granulite facies metamorphism and is characterized by the lack of cordierite and the presence of coexisting potassium feldspar and hypersthene. The area north of Westport, including the Westport plutonic complex, is thought by Wynne-Edwards to represent a transition zone where granulite facies metamorphism has been overprinted by metamorphic zones of the Frontenac Axis as outlined by Wynne-Edwards (1976b). Currie and Ermanovics (1971) investigated the Loughborough Lake region (southwest corner of the Westport map-area). They report the area as being underlain by rocks of sedimentary origin displaying amphibolite to granulite-grade metamorphism. They have compared the observed mineral assemblages with experimental data, and concluded that the peak metamorphic temperature close to the Crow Lake pluton was in the range of 640°C to

755°C. They estimated a total pressure of 4.8 to 6.5 kilobars from the assemblages. Currie (1971), using the reaction $3 \text{ cordierite} = 2 \text{ garnet} + \text{sillimanite} + 5 \text{ quartz}$ as a geological thermometer, obtained peak metamorphic temperatures of 600°C to 750°C around the same pluton. He estimated a pressure of between 5.7 and 6.7 kilobars. Some of the garnet-cordierite assemblages used by Currie (1971) had previously been investigated and reported by Reinhardt (1968) and Wynne-Edwards and Hay (1962).

South of the Frontenac Axis the Grenville Supergroup enters the Adirondack lowlands. The metamorphic grade is reported by Wynne-Edwards (1967b) as decreasing to amphibolite facies around Canton, New York. Engel and Engel (1958, 1960) report amphibolite facies metamorphism in the Emeryville area. They estimate a temperature of about 500°C at Emeryville, New York, which increases to about 600°C 35 miles northeast at Colton, New York. Depths of burial around 5 to 7 miles were thought reasonable by Engel and Engel (1958) for this area. Engel and Engel (1960) report similar temperatures and pressures for this area and further justify the case for the decreasing metamorphic grade away from the Frontenac Axis.

1.7 Relationship of Frontenac Axis to the Southern Part of the Thesis Area

The Westport-Tichborne area was chosen as the southern third

of the thesis area. The reportedly high-grade metamorphism in this southern area contrasted with the suspected lower-grade in the northern Lanark-Arnprior area and offered a chance to study the regional metamorphism of carbonate rocks over a wide range of metamorphic grade. The existence of numerous plutons in the Westport area also provided an opportunity to study the influence of large plutonic masses on the metamorphism of carbonate rocks.

The occurrence of the assemblage sphalerite-pyrite-pyrrhotite in the Tichborne area provided a means for measuring the pressure at which rocks of the region had been equilibrated (Scott, 1973). The pressure from sphalerite geobarometry could also be compared with that estimated by Currie and Ermanovics (1971) and Currie (1971) from cordierite-garnet assemblages. The calcite-dolomite solvus was also available for measurement of the temperature of equilibration at various localities within the area. It was of particular interest to be able to compare the temperatures of metamorphism determined by the calcite-dolomite geothermometer with those determined by Currie and Ermanovics (1971) and Currie (1971) using the cordierite-garnet geothermometer.

1.8 Summary

The Lanark-Arnprior map-area, the northern section of the thesis area, is shown from the early work of Liberty and Reinhardt (1963) as

containing abundant low-grade tremolite-bearing marble. This low-grade zone would appear to be a possible repetition of the low to intermediate grade zones established in the Hastings Basin. Clearly establishing the low-grade nature of this northern region of the thesis area would greatly increase the amount of low-grade metamorphism known within the Grenville.

The Westport and Tichborne map-areas, comprising the southern portion of the thesis area, in contrast to the low-grade nature of the northern section, contain high-grade rocks of the Frontenac Axis, as observed by Wynne-Edwards (1965, 1967a, 1967b), Engel and Engel (1958, 1967) and others along the flanks of the axis in the Hastings Basin and Northern New York State regions. It is suggested that a decreasing metamorphic gradient, continuous with the low-grade rocks of the northern section of the thesis area, is occurring away from the Frontenac Axis in the southern portion of the study area.

CHAPTER 2 FIELD WORK

2.1 Location

The thesis area comprises a region including metamorphosed siliceous carbonate rocks defined by the National Topographic map sheets of Carleton Place, Perth, Westport and Tichborne (east half). The area is outlined in Figure 2.1. It extends from latitude $45^{\circ}15'$ to $44^{\circ}30'$ and from longitude $76^{\circ}00'$ to $76^{\circ}30'$. The southern third of the area extends slightly further west to longitude $76^{\circ}45'$ in order to include the east Tichborne sheet.

2.2 Previous Work

Regional geological maps have been published by the Geological Survey of Canada and include: Carleton Place map-area (Liberty et al., 1963), Perth map-area (Dugas, 1950, 1961), Westport map-area (Wilson, 1930; Wynne-Edwards, 1967) and Tichborne map-area (Harding, 1947; Wynne-Edwards, 1965).

Several M.Sc. and Ph.D. theses have been concerned with siliceous carbonate rocks in the region (Wynne-Edwards, 1959; Laakso, 1960; Brown, 1961) and related rocks (McGlynn, 1949; Maingot, 1955; Wynne-Edwards, 1956; Hay, 1962; and Jen, 1967). Currie and Ermanovics (1971) have mapped granitic rocks in the Loughborough Lake region. Wynne-Edwards and Hay (1963) and Reinhardt (1968) described garnet-cordierite gneiss in the Opinicon Lake area. Currie (1971) used garnet-cordierite assemblages to estimate temperature-pressure conditions around Crow Lake Pluton.

Figure 2.1 - Location map of thesis area (outlined in solid line)

2.3 Field Methods and Data Collection

Previous geological mapping of the area was used to delineate regions of carbonate outcrop. An attempt was made to establish field data stations at approximately half-mile intervals, although much of the region underlain by carbonate rocks is covered by extensive low-land terrain characterized by sporadic outcrops. To ensure systematic and complete data collection, a computer data collection system was established. A field data card, shown in Figure 2.2, was completed at each field station, allowing the systematic collection of data for both outcrop and specimens. The specimen description included a tentative recognition of the mineral parageneses at each station. The identification of minerals was subsequently confirmed by X-ray and petrographic studies in the laboratory. All field stations and rocks samples were referenced by their Universal Transverse Mercator Grid co-ordinates. Detail can be established to within 200 feet using this reference system which is ideally suited to a regional survey.

Mischief, a Fortran IV program, was developed to retrieve any desired data from the 650 stations established during the field program. In addition, it can establish localities that conform to any specified variables (e.g. photo taken, color, textural characteristics, etc.). While this system was designed more or less specifically for the present study, it should be possible to insert at least part of this scheme into a more generalized data collection system.

CHAPTER 3 PETROLOGY AND MINERALOGY OF THE SILICEOUS CARBONATE ROCKS

3.1 Lithology of Carbonate Rocks

Marble lithologies within the thesis area have enough distinguishing features to allow the region to be divided into three distinct lithologic zones:

- a) Northern siliceous zone
- b) Central zone
- c) Southern potassic zone

Lithologic detail within each of the zones is as follows:

a) Northern Siliceous Zone

The northern siliceous zone, comprising the Carleton Place and northern Perth map-areas, is characterized by thick sequences of relatively pure calcite and calcite-dolomite marble with intimately interlayered primary siliceous layers. These thin (.1 to 2.0 cm) bands of quartzite are microcrystalline in places and may represent original chert layers (plate 1B, C, F). Such interlayered quartz has reacted in many instances with enclosing dolomitic horizons to produce the layers of tremolite that are so characteristic of the northern zone (plate 1A). In areas of severe deformation, the relatively

rigid siliceous layers have become broken and dispersed by flowage within the marble (plate 1B, F). Interlayered non-carbonate meta-sedimentary or metavolcanic units are rare to absent in marble sequences.

The characteristic variety of marble in this zone is a relatively pure, fine-banded, grey calcite or calcite-dolomite marble (plate 1E). It may contain up to 20% silicate minerals usually restricted to well-defined compositional layers. The well-banded outcrops of the marble, generally characteristic of Grenville marbles, is usually the result of variation in the graphite content of the various layers, although variation in the calc-silicate mineralogy, reflecting original differences in the magnesium, aluminum, silicon or potassium content may also define banding.

Textural variation is minimal within this zone, although grain size and degree of recrystallization may vary significantly across an outcrop. A representative outcrop is medium to fine-grained, well-recrystallized and finely banded. The grain size generally reflects the degree of recrystallization which appears to be quite uniform. Areas of extremely coarse-grained pegmatitic textured carbonate can occur randomly, although they are more prevalent in the southern part. Relatively little colour variation occurs, one notable exception being the development of blue calcite marble in the Tatlock Quarry area.

b) Central Zone

The central mixed zone encompasses the bulk of the Perth map-area and represents a gradational change in the carbonate rocks to more diverse and mixed carbonate and non-carbonate, metasedimentary and meta-igneous lithologies. Interlayered non-carbonate horizons become increasingly diverse in composition and more abundant southward. Much of the interlayered material has become highly disrupted and is now present as trains of subrounded to angular inclusions. The amount and size of these inclusions increase markedly into the Southern Potassic Zone. In general, three types of interlayered material and inclusions can be distinguished: i) rusty paragneiss, ii) amphibolite (metadiorite?), and iii) quartzite.

The rusty paragneiss is present both as inclusions and as thin highly-contorted layers often broken and dispersed by flowage in the marble (plate 1D). Pyrite is abundant, producing the rusty colour typical of the weathered surface. The rusty paragneiss is interpreted by Wynne-Edwards (1967a) as representing original silty or sandy beds within the limestone.

Amphibolite and quartzite compose 35-40% of the total inclusions. They have been interpreted by Wynne-Edwards (1967a) as sedimentary material which has become broken and dispersed by flowage during late-stage deformation.

A fourth type of inclusion, white granite pegmatite, is noted mainly in the Southern Potassic Zone.

The variety of carbonate most prevalent is a banded white to tan coloured calcite-dolomite or dolomite marble. Dolomite marble makes up to 30% of the total carbonate and may form thick massive tan to cream coloured horizons up to 30 feet thick.

Silicate minerals amount to 20% of a given carbonate unit and are mainly disseminated, although layering defined by silicate content is not uncommon. Typically, the marble in this zone has a "dirty, silty" appearance due mainly to the disseminated nature of the silicate and calc-silicate minerals.

Textural variation within the carbonate of this zone is considerable. Although well-recrystallized medium-grained calcite-dolomite marble dominates, up to one third of the outcrops are fine or coarse-grained, poorly recrystallized and often very friable. Irregular pegmatitic carbonate patches are common and are found randomly throughout.

c) Southern Potassic Zone

The Westport and East Tichborne map-areas make up this southern zone. Gradational from the central zone, the Southern

Potassic Zone displays a systematic increase in the percentage of interlayered non-carbonate layers and inclusions. In addition, a marked increase in the amount of potassium feldspar occurs, due mainly to the large percentage (up to 20%) of white granite pegmatite inclusions. These inclusions range in size from massive outcrops that are tens of square feet in size to disseminated clasts only fractions of inches in diameter. Individual clasts of quartz and potassium feldspar are present, presumably derived from weathering of this pegmatite material. It is clear from trains of isolated inclusions that many areas represent original blocks broken and dispersed within the marble during metamorphism. The exact relationship of this pegmatitic material to the carbonate is not yet certain, nor is it clear whether or not more than one generation of pegmatite is present (Wynne-Edwards, 1967a).

In addition to the appearance of the white granite pegmatite inclusions in this zone the percentage of inclusions and interlayered material is greater than in the Central Zone, locally composing 40-50% of the total outcrop.

In contrast to the northern and central zones, the carbonate of the southern zone is dolomitic. Although massive white calcite marble is present, tan coloured dolomite marble is dominant in the West Westport and East Tichborne map-areas. The dolomite marble occurs as well-recrystallized, medium to coarse-grained material that

is rather uniform in appearance. Textural variation is pronounced within calcite or calcite-dolomite marbles which vary from fine-grained, poorly recrystallized and friable to massive, well-banded and sometimes coarse-grained as the surrounding dolomite. Colour variation is also more diverse within the calcitic marbles. Dolomite marble is invariably tan to cream in colour, whereas calcite marble may be white, orange, pink or blue. This colour variation is thought to be either the result of ionic substitutions such as Sr, Mn, Li or Co or of varying amounts of finely disseminated minerals such as graphite or hematite.

3.2 Mineralogy of Carbonate Rocks

The coexisting minerals which form the stable assemblages within the relatively pure siliceous carbonate rocks of the thesis area can be represented within the system $\text{CaO} - \text{MgO} - \text{SiO}_2 - \text{KAlO}_2 - \text{CO}_2 - \text{H}_2\text{O}$. Minerals formed within this system and found in the area include calcite, dolomite, quartz, tremolite, diopside, forsterite, talc, serpentine, phlogopite, and potassium feldspar. Common accessory minerals are apatite, chlorite, sphene, spinel, plagioclase, scapolite and chondrodite. Many of these minerals are sensitive to small amounts of chemical impurity and may exhibit considerable local variation in their colour. In general, however, the mineralogy is distinctive and can be characterized as follows:

Calcite-Dolomite:

Calcite and dolomite form the basic framework of the carbonate rocks. In the field dolomite can be physically distinguished from calcite by its buff to tan colour, its greater hardness and its positive weathering. (Chemically it can be distinguished by its slight reaction to dilute HCl). In thin section calcite and dolomite have been distinguished by staining after the method of Warne (1962).

Calcite and dolomite vary in texture from cloudy, poorly-recrystallized material in low-grade rocks (plate 3A, C, E) to clean, well-recrystallized mosaic carbonate material in higher grade rocks (plate 2A). Both these carbonates are typically well-twinned and may be good indicators of post-metamorphic deformation (Plate 2E, F) where twin lamellae are bent. Rhombs of dolomite are present only at low metamorphic grades (plate 2B, C, D) and become recrystallized to anhedral in intermediate and high-grade sections. Characteristically, both calcite and dolomite recrystallize easily and generally form equigranular mosaic textures at even moderate grades of metamorphism (plate 3D).

Quartz:

Quartz is present both as recrystallized cherty layers and as individual rounded to subangular clastic grains and aggregates.

Thick cherty layers varying in thicknesses from fractions of inches to several feet are characteristic of the Carleton Place map-area (plate 1F). Such layers decrease in abundance southward where quartz is typically present as individual clastic grains. In low-grade regions quartz maintains its original clastic outline and frequently displays overgrowths (Plate 3F). Such clastic grains typically consist of fine-grained polygonal or radiating quartz aggregates (plate 3B, C, D). Large polygonal grains are characteristic of higher grade sections. Calc-silicate minerals such as tremolite or diopside may be poikiloblastic with inclusions of quartz.

Tremolite:

Tremolite shows a great variation in its form, habit and colour. It varies from its characteristic white colour to green, brown or blue shades. Tremolite crystals which are usually in fibrous radiating aggregates, may be stubby or blocky in many instances. In combination with quartz, tremolite is present in the form of positive-weathering orange grains similar in appearance to humite group minerals. In such cases the quartz-tremolite intergrowths can be distinguished from the humite group minerals by the vitreous lustre and hard, brittle nature of the quartz-tremolite mixture. Despite its variation in colour and habit, tremolite in hand specimen can usually be distinguished from wollastonite and scapolite by its cleavage and cross section, its fibrous habit and its resistance to weathering.

In thin section tremolite varies from radiating fibrous bundles (plate 4B, D) to stubby or blocky crystals with amphibole cross-section (plate 4A). Tremolite crystals are often poikiloblastic, generally containing inclusions of quartz. Talc is an extensive alteration product and nearly all tremolite displays some retrograde talc (plate 4C). Tremolite is most often mistaken for diopside but can be distinguished by cleavage, birefringence and extinction angle. Tremolite has been distinguished from ~~wollastonite~~ by the three cleavage directions of wollastonite.

Diopside:

(Diopside is seen in the field as stubby crystals up to 1½ cm. long. The mineral is usually dark green but may on occasion be pale green to blue. When present, diopside is often in great abundance, comprising 30 to 40% of some horizons. When highly weathered, diopside may be difficult to distinguish from serpentine, although crystal habit and cleavage usually serve to identify it.

In thin section diopside generally forms large poikiloblastic crystals. It may be occasionally altered to tremolite (plate 5C) but in most instances is altered to serpentine (Plate 5E) or serpentine-chlorite mixtures. Diopside is readily identified by its high relief, cross section and large (40°) extinction angle.

Forsterite:

Forsterite, although difficult to find in anunaltered state, is present as small, rounded, positive-weathering orange crystals. Alteration of forsterite to serpentine is characteristic and the presence of serpentine serves to distinguish forsterite from similar appearing humite group minerals.

Forsterite (plate 5E) is present mainly as remnant cores within serpentine pseudomorphs (plate 5F). Serpentine pseudomorphs of forsterite are rounded and irregular in outline (plate 5F) in contrast to the form of serpentine pseudomorphs after diopside (plate 5E). Forsterite is most likely to be confused with either chondrodite, which is pleochroic and often twinned, or diopside which displays cleavage, has lower birefringence and relief and displays pyroxene crystal outlines.

Talc and Serpentine:

Primary talc or serpentine have not been identified in the thesis area. Both, however, are abundant as pseudomorphs after tremolite and forsterite or diopside. Talc is most often finely crystalline and may be confused with sericite. It can be distinguished from sericite in thin sections where it retains its pseudomorphic habit after tremolite, but in other ambiguous sections it must be

distinguished by X-ray or microprobe analysis. Serpentine occurs as rounded, irregular pseudomorphs after forsterite (plate 5F) or as stubby crystals pseudomorphing diopside (plate 5E). It often occurs in mixtures with Mg-chlorite which can be distinguished from the serpentine by its blue interference colour.

Phlogopite:

Phlogopite is the dominant mica in carbonate rocks of the thesis area. It is invariably found as well-formed hexagonal crystals, often several inches in diameter. It is generally pale brown but may take on a characteristic violet hue. Due to the increasing potassium feldspar content of the marbles southward in the thesis area, phlogopite is most abundant in the Westport and Tichborne map-areas. In thin-section phlogopite is distinguished from muscovite and biotite by its pale yellow pleochroism and its small optic angle.

Potassium Feldspar:

Potassium feldspar, along with plagioclase, is present throughout the entire thesis area but is typical of only the southern portion. In hand specimen, potassium feldspar is difficult to distinguish from the plagioclase feldspars but is generally less altered than plagioclase feldspar, which invariably is altered to sericite or scapolite. Ideally the feldspars should be X-rayed or studied in thin section to determine their composition.

Potassium feldspar in thin section is usually quite fresh in appearance but may be altered to sericite-chlorite mixtures. In lower grade rocks, it may display overgrowths. In low-grade dolomitic rocks it is often found reacting with dolomite to form phlogopite (plate 4E, F).

Accessory Minerals:

Accessory minerals such as sphene, spinel (hercynite), apatite, tourmaline, scapolite and humite may be locally abundant. Humite group minerals were X-rayed and identified as norbergite and chondrodite.

3.3 Coexisting Mineral Assemblages

The mineralogical changes that are observed in progressively metamorphosed rocks are the result of a series of reactions by which rocks tend towards a state of chemical equilibrium. In rocks which have attained or closely approached a state of chemical equilibrium, it is possible to use the laws governing such equilibria to interpret the petrological significance of the mineralogical changes that have been mapped as isograds (for example, Thompson 1955). This approach, however, requires that some criteria be established for deciding when a state of chemical equilibrium has been obtained. Where possible, the criteria of textural equilibrium as outlined by Winkler (1975) have been used for this purpose in the present study. Thus, minerals which are in contact with no evidence of reaction between them are assumed to be

in equilibrium. In the case of mineral assemblages observed in the field, equilibrium was assumed if minerals were present in close proximity within a hand specimen. By necessity the acceptance of textural relationships as a practical means of establishing chemical equilibrium requires the problem of kinetic barriers to the onset of a reaction, and possibilities of chemical complexities such as compositional zoning of minerals, to be ignored.

CHAPTER 4 TEXTURAL ANALYSIS OF CARBONATE ROCKS

In the present study, five major carbonate textures were recognized. All sections studied petrographically were also studied texturally and an attempt made to place them into the appropriate subdivision within one of the five major categories. Such data are given in Appendix C for both the regional and detailed areas. The five major textural types and their subdivisions are:

1) Unrecrystallized Sedimentary: (Plates 3A, C, E)

This textural type is found only in rocks of the lowest metamorphic grade. Carbonate grains display vague crystal outlines, are cloudy in appearance, and are generally untwinned. Quartz, if present, may retain a rounded clastic outline and may also retain the quartz overgrowths characteristic of sedimentary rocks (see plate 3F). Feldspars may also retain sedimentary overgrowths. Unrecrystallized dolomite or calcite rhombs, often zoned, are characteristic of this textural type (see plates 2B, C, D).

3) Recrystallized Mosaic: (Plate 2A)

Carbonates displaying this texture are characterized by a granoblastic polygonal or "mosaic" texture. Twinning is well-developed, often creating "rainbow" arrays. This texture is subdivided as follows:

- 2a) Undifferentiated
- 2b) Slight elongation and serration of grain boundaries
- 2c) Minor foliation due mainly to micaceous material
- 2d) Minor lineation due mainly to tremolite
- 2e) Silicates dominate the framework and are typically ididioblastic
- 2f) Minor strain indicated by slight elongation and suturing of grain boundaries.

3) Recrystallized Deformation Texture: (Plates 2E, F)

Material displaying deformation textures can be characterized as follows:

- 3a) Fibrous growth
- 3b) Marked elongation, suturing, etc.
- 3c) Rotated poikiloblastic crystals.
- 3d) Deformed foliation (typically bent mica plates)
- 3e) Strain shadows
- 3f) Distorted twinning

4) Reaction Texture: (Plates 4C, D, E, F)

Carbonate and calc-silicate minerals display a "frozen-in" reaction texture. The matrix may be one of the other textural types. Reaction rims are common around silicates. Retrograde textures are

also included within this group and pseudomorphs may be present.

5) Hydrothermal Texture: (Plates 5A, B, D)

5a) Carbonate framework consists of "islands" of recrystallized, well-tinned material in a "sea" of cloudy, ill-defined material. Embayment of recrystallized "islands" is common due to solution phenomena. Zones of what appears to be an accumulation of a carbonaceous residue material can occur. Such zones are thought to be the remains of large scale carbonate solution. Extensive retrograde alteration is characteristic.

5b) Similar textural type to 5a but cloudy areas display some tendency to recrystallization. Twinning in the cloudy areas is irregularly disposed. This texture may resemble an unrecrystallized sedimentary texture and care must be taken to distinguish the two.

PLATE 1

- 1A: Reaction rim of tremolite (Trem) surrounding a large quartz inclusion. Dolomite marble host. Perth map-area.
- 1B: Contorted quartz (Qtz) horizons within a calcitic (Cc) marble. Carleton Place map-area.
- 1C: Differential weathering of thinly interlayered quartzite (Qtz) and carbonate horizons. Siliceous layers form prominent positive weathering layers. Carleton Place map-area.
- 1D: Thick carbonate horizons containing interlayered pelitic material which has become broken and dispersed by flowage in the marble. Westport map-area.
- 1E: Calcitic (Cc) marble displaying the fine, dark graphitic layering so characteristic of Grenville marbles. Carleton Place map-area.
- 1F: Calcitic (Cc) and dolomitic (Dol) marble containing highly contorted interlayered siliceous (Qtz) material. Where the siliceous (Qtz) horizons are in contact with dolomite, they have reacted to form tremolite (Trem). Carleton Place map-area.

PLATE 1

PLATE 2

- 2A: Calcite (Cc) displaying a well recrystallized mosaic texture. Twinning within calcite (Cc) grains is well developed while retrograde alteration is usually at a minimum in such a texture. Crossed nicols. U.T.M. co-ordinates 882849.
- 2B: Zoned rhombohedra of calcite (stained dark) and dolomite are outlined within a recrystallized dolomitic (Dol) host. Rhombs persist across present grain boundaries but become quite vague in well recrystallized areas. Plane polarized. U.T.M. co-ordinates 118368.
- 2C: Zoned calcite (Cc) rhombs (stained dark) persisting across poorly recrystallized dolomite (Dol). Grains become difficult to detect where the recrystallization is more advanced (left side of photo). Plane polarized. U.T.M. co-ordinates 118368.
- 2D: Zoned dolomitic (Dol) and calcitic (Cc) rhombs present within unreacted quartz-dolomite grade material. Staining of the calcite (Cc) reveals the intricate zoning. Plane polarized. U.T.M. co-ordinates 940376.
- 2E: Large calcite (Cc) grain displays distorted twins. Strain shadows also present. Such features are interpreted as representing post-metamorphic deformation. Crossed nicols. U.T.M. co-ordinates 927591.
- 2F: Deformed calcite (Cc) grains displaying strain features such as distorted twinning, serrated edges and elongation of grain boundaries. Plane polarized. U.T.M. co-ordinates 927591.

PLATE 2

PLATE 3

- 3A: Unrecrystallized sedimentary texture. Calcite (Cc) grains display irregular boundaries and most often are very cloudy. Twinning is absent. Note rounded clasts of polygonal quartz (Qtz) in upper right hand edge of photo. Crossed nicols. U.T.M. co-ordinates 089574.
- 3B: Rounded clast of polygonal quartz (Qtz) coexisting with dolomite (Dol). The unrecrystallized sedimentary texture of the calcite-dolomite framework confirms the low-grade nature of this assemblage. Crossed nicols. U.T.M. co-ordinates 089574.
- 3C: Unrecrystallized sedimentary texture with several rounded clasts of polygonal quartz (Qtz). Note rhomb of dolomite at left central margin of photo. Crossed nicols. U.T.M. co-ordinates 072571.
- 3D: Irregular area of radiating quartz (Qtz) within a well recrystallized mosaic framework. Crossed nicols. U.T.M. co-ordinates 859688.
- 3E: Coexisting potassium feldspar (Kspar)-dolomite (Dol). The dolomite (Dol) framework displays an extremely minimal degree of recrystallization. Crossed nicols. U.T.M. co-ordinates 073558.
- 3F: Coexisting quartz (Qtz)-dolomite (Dol). The presence of overgrowths (pen and ink outlining overgrowths) on some of the quartz (Qtz) grains attests to the lack of substantial recrystallization. Crossed nicols.

PLATE 3

PLATE 4

- 4A: Cross section of large tremolite (Trem) grain. Typical amphibole outline is indicated. Contrast with radiating fibres of tremolite (Trem) in plate 4B and D. Plane polarized. U.T.M. co-ordinates 071291.
- 4B: Radiating bundles of tremolite (Trem) fibres showing the characteristic habit of tremolite. Plane polarized. U.T.M. co-ordinates 885025.
- 4C: Wedge of tremolite (Trem) surrounded by calcite (Cc) growing into mosaic framework of dolomite (Dol). Tremolite (Trem) shows alteration to talc along its margins. Crossed nicols. U.T.M. co-ordinates 891853.
- 4D: Fibrous tremolite (Trem) growing along and into dolomite (Dol) grains. Calcite (Cc) is intermixed with tremolite. Crossed nicols. U.T.M. co-ordinates 885025.
- 4E: Reaction of potassium feldspar (Kspar) - dolomite (Dol) to produce phlogopite (Phlog)-calcite (dark areas). Thin blades of phlogopite (Phlog) are growing into the potassium feldspar (Kspar) grains at right angles to the grain boundaries. Crossed nicols. U.T.M. co-ordinates 111319.
- 4F: Magnified view of phlogopite (Phlog) growing at right angles to the potassium feldspar (Kspar) grain boundary. Crossed nicols. U.T.M. co-ordinates 111319.

PLATE 4

PLATE 5

- 5A: Hydrothermal texture. Recrystallized "islands" of calcite (Cc) in a "sea" of cloudy, ill-defined carbonate material. Recrystallized calcite (Cc) grains are characteristically well twinned in contrast to the lack of structure in the surrounding carbonate. Plane polarized. U.T.M. co-ordinates 095567.
- 5B: Hydrothermal texture showing solution effects along the margins of the recrystallized calcite (Cc) grains (right center). Note the remains of a recrystallized grain still vaguely visible at the bottom center of the photo. Plane polarized. U.T.M. co-ordinates 095567.
- 5C: Diopside (Diop) grained surrounded by tremolite (Trem). Plane polarized. U.T.M. co-ordinates 783469.
- 5D: Hydrothermal texture showing signs of partial recrystallization. The dark area surrounding the lighter twinned calcite (Cc) grains is in optical continuity, the first sign of recrystallization. Crossed nicols. U.T.M. co-ordinates 087360.
- 5E: Serpentine (Serp) pseudomorph after diopside (Diop). Serpentine (Serp) displays a characteristic pyroxene outline. Crossed nicols. U.T.M. co-ordinates 821377.
- 5F: Forsterite (Fo) remnants in a serpentine (Serp) pseudomorph. In contrast to the serpentine after diopside, the pseudomorphs of serpentine (Serp) after forsterite (Fo) are rounded to irregular in outline characteristically lacking a crystal outline. Plane polarized. U.T.M. co-ordinates 764359.

PLATE 5

CHAPTER 5 - GEOBAROMETRY BASED ON THE ASSEMBLAGE: PYRITE-PYRRHOTITE-
SPHALERITE

The maximum pressure reached during metamorphism can be estimated from coexisting sphalerite-pyrrhotite-pyrite. It has been demonstrated by Boorman (1967), Scott and Barnes (1971), and Scott (1973) that the FeS content of sphalerite decreases with increasing pressure. Scott (1973) located the solvus isobars experimentally at several pressures and showed that the composition of sphalerite is essentially independent of temperature below 600°C and 5 kilobars. Early attempts at calibrating the pressure effect were made by Boorman (1967), Boorman, Sutherland and Chernyshev (1971), and Scott and Barnes (1971). Using the thermodynamic data of Toulmin and Barton (1964), and Barton and Toulmin (1966), Scott and Barnes (1971) calculated the solvus isobars to 6 kilobars after having determined them to 1 kilobar experimentally. Scott (1973) experimentally determined the solvus isobars to greater than 6 kilobars, substantially improving the earlier calculations. The experimental solvus isobars of Scott (1973) are shown in Figure 5.1 as functions of temperature and sphalerite composition. If the temperature of metamorphism can be reasonably estimated to be under 600°C the measured composition of sphalerite should yield pressures accurate to within $\pm .5$ kilobars. Above 600°C or 5 kilobars an accurate temperature of equilibration is required. DeWitt and Essene (1974) maintain that Scott's 1973 data need to be corrected by a factor of $-.7$ mole per cent FeS or $-.8$ kilobars in order to take account of

Figure 5.1 - Sphalerite - pyrite - pyrrhotite solvus:
The mole % of FeS in sphalerite below
5 kilobars and 600° C is essentially
independent of temperature, (after
Scott, 1973).

small systematic errors in Scott's microprobe correction factors using Rucklidge's EMPADR program. This correction, they state, "brings Scott's (1973) experimental geobarometer into better correspondence with Scott and Barnes' (1971) tests of natural sphalerites".

The sphalerite composition from four localities within or close to the thesis area were used to estimate regional pressures during metamorphism. Compositional data on the sphalerites were derived by electron microprobe analysis, conducted by Paul Mainwaring, on the Carleton University "Microscan 5" electron probe. Material was obtained from the following localities:

- a) Thirty Island Lake: located within the Tichborne map-area at U.T.M. co-ordinates 731357.
- b) Lynx Canada Mine: located just west of Mountain Grove, Ontario. The mine is situated within the Tichborne map area at U.T.M. co-ordinates 530550.
- c) New Calumet Mine: located north of the thesis area, approximately 60 miles northwest of Ottawa, along the Ottawa River.

Data for the Balmat-Edwards mining district, northern New York state were obtained from Scott and Barnes (1971) and DeWitt and Essene (1974).

The pressure determined at Thirty Island Lake is perhaps the most applicable to the thesis area since it actually lies within the Tichborne map-area. An average sphalerite composition, taken from Table 5.1, of $14.8 \pm .72$ mole % FeS indicates a pressure of 4.75 kilobars ($\pm .5$ kilobars). This value compares well with the pressure of 4.8 to 6.5 kilobars estimated for the area by Currie and Ermanovics (1971).

Two specimens from the Lynx Canada mine yielded average sphalerite compositions of $14.2 \pm .32$ and $14.6 \pm .31$ mole % FeS (Table 5.1) corresponding to pressures of $5.2 \pm .5$ and $4.75 \pm .5$ kilobars respectively. DeWitt and Essene (1974) estimate a pressure of $3.9 \pm .5$ kilobars for this deposit using their corrected data of Scott (1973).

The New Calumet mine gave an average sphalerite composition of $13.4 \pm .68$ mole % FeS. This corresponds to a pressure of 5.5 to 6.0 $\pm .5$ kilobars.

A pressure of $5.5 \pm .5$ kilobars was determined for the Balmat-Edwards district by recalculating the data of Scott and Barnes (1971) using the solvus of Scott (1973). A somewhat lower pressure of 4.7 ± 1.0 kilobars is given by DeWitt and Essene (1974) for this area.

The pressure during metamorphism of material from areas north, south and west of the thesis area is consistently in the range 4.5 to

5.5 $\pm$.5 kilobars. This corresponds well with the pressure of 4.75 $\pm$.5 kilobars suggested from within the thesis area at the Thirty Island Lake locality. A pressure of 5 kilobars has therefore been taken as representative of the pressure present during metamorphism within the thesis area. This pressure would be reduced to around 4 kilobars if the -.8 kilobar correction of DeWitt and Essene (1974) is considered valid.

It has been assumed in using this method to estimate the pressure present during metamorphism that:

- (1) The coexisting sulphide minerals reached equilibrium;
- (2) Retrograde reequilibration was absent to very minor;
- (3) Sulphide, carbonate, and silicate mineral assemblages reached equilibration under the same conditions.

Table 5.1 - Sphalerite Analysis

<u>Location</u>	<u>Section N°</u>	<u>Weight % FeS</u>	<u>Mole % FeS</u>	<u>Estimated Temperature (°C)</u>
Thirty Island Lake	30 IS-4	8.68	15.1	545 - 470
	30 IS-4	8.81	15.3	" "
	30 IS-4	8.94	15.6	" "
	30 IS-4	8.02	14.0	" "
	30 IS-4	<u>8.08</u>	<u>14.1</u>	" "
	Average	<u>8.51</u>	<u>14.8</u>	*s. dev. ± .72
Lynx Canada	Lyx-3A	8.10	14.1	530 - 550
	Lyx-3A	8.01	14.0	" "
	Lyx-3A	<u>8.35</u>	<u>14.6</u>	" "
	Average	<u>8.15</u>	<u>14.2</u>	*s. dev. ± .32
	Lyx-3B	8.58	14.6	530 - 550
	Lyx-3B	8.44	14.3	" "
	Lyx-3B	8.44	14.4	" "
	Lyx-3B	8.62	14.7	" "
	Lyx-3B	<u>8.94</u>	<u>15.1</u>	" "
	Average	<u>8.60</u>	<u>14.62</u>	*s. dev. ± .31
	N° 16	7.43	12.7	-
	N° 16	8.09	13.9	-
New Calumet	N° 16	7.75	13.2	-
	N° 16	7.87	13.5	-
	N° 16	8.56	14.7	-
	N° 16	7.41	12.8	-
	N° 16	7.20	12.3	-
	N° 16	7.68	13.2	-
	N° 16	7.94	13.6	-
	N° 16	<u>7.87</u>	<u>13.6</u>	-
	Average	<u>7.78</u>	<u>13.4</u>	*s. dev. ± .68

* Standard deviation calculated according to the formula

$$s = \left(\frac{\sum x_n^2 - k\bar{x}^2}{k-1} \right)^{1/2}$$

CHAPTER 6 CALCITE-DOLOMITE SOLVUS GEOTHERMOMETER

6.1 Introduction

It was recognized by Chave (1952) that the skeletal carbonate of many marine organisms is a magnesium-rich calcite. He was able to clearly demonstrate that calcite could accommodate substantial amounts of magnesium in solid solution, by presenting data relating chemical analyses and X-ray diffraction studies. A curve was published giving the weight per cent MgCO_3 and the "d" value of the strongest X-ray reflection (Chave, 1952).

Factors affecting the magnesian content of calcite over a wide range of geologically important conditions were subsequently investigated by Graf and Goldsmith (1955, 1958), Goldsmith, Graf, and Joensuu (1955), Harker and Tuttle (1955), and Goldsmith and Heard (1961). It became obvious as a result of these studies that the magnesium content of calcite in equilibrium with dolomite was dependent upon temperature and relatively independent of pressure. This being the case, the rather limited solid solution of magnesium in calcite represents a natural thermometer in rocks where calcite and dolomite coexist. That this calcite-dolomite solvus geothermometer can be useful is suggested by the numerous apparently successful field studies conducted by workers such as Goldsmith, Graf, and Joensuu (1955), Sheppard (1966), Carpenter (1967), Höy (1976), Wong (1971), Hutcheon and Moore (1972) and DeWitt and Essene (1974).

The present study is a further attempt to apply this thermometer to a field area where varying metamorphic grade has been established on the basis of mineral assemblages. An attempt has been made to utilize computer methods in order to correct all data for pressure effects, expanding upon the data presented by Goldsmith and Newton (1969). Much of the data presented by previous investigators have been reduced in this study to a standard pressure of one bar and a uniform solvus established. Moderately good agreement among most of the previously published data is indicated.

6.2 Solvus Thermometry: Techniques and Problems.

The equilibration temperature of calcite coexisting with dolomite can be determined from the solvus if the mole percentage MgCO_3 in calcite is known (Figure 6.1). Accuracy of the estimated temperature is primarily a function of:

- i) Accuracy of the experimentally measured solvus data;
- ii) Accuracy with which the MgCO_3 content of the calcite has been determined;
- iii) Amount of pressure influence;
- iv) Degree to which the equilibrium composition has been retained during cooling of the natural assemblage.

6.3 Solvus Data

Graf and Goldsmith (1955) presented solvus data for the

Figure 6.1 - Solubility of MgCO_3 in calcite
as a function of temperature
(after Goldsmith & Newton, 1969).

interval 500° to 800°C and 0.1 to 1.4 kilobars; Harker and Tuttle (1955) for the interval 500° to 900°C and 1.4 to 3.1 kilobars; Goldsmith and Heard (1961) for the interval 700°C to 1,200°C and 2 to 8.5 kilobars; and Goldsmith and Newton (1961) for the interval 400° to 800°C and 1 to 25 kilobars.

The techniques used in solvus determinations are similar for most investigations and are well-described by Goldsmith, Graf and Joensuu (1955). In general, they are subject to one or more of the following influences (Graf and Goldsmith, 1958):

- a) The accuracy of the X-ray spacing measurements;
- b) The accuracy of the analytical method, whether spectrochemical or chemical, used in determining the magnesium content of the calcites;
- c) The assumption that complete equilibrium had been reached so that all MgCO_3 is tied up in solid solution within the calcite, none being present in small quantities of dolomite.

Goldsmith and Newton (1969) state that their solvus data are in good accord with those published earlier by Harker and Tuttle (1955) and Graf and Goldsmith (1958). This agreement of the various experimental data argues well for the accuracy of the presently available calcite-dolomite solvus data. While the solvus data are in reasonable agreement, a precise comparison is not possible without taking into consideration the wide variation in pressure conditions

under which the data were established. An attempt is therefore made in this section to reduce all of the data available to a common pressure in order to obtain the best possible fit to all of the experimental data.

6.4. Pressure Effects

The effect of pressure upon the solubility of MgCO_3 in calcite has for the most part been considered negligible. Goldsmith and Heard (1961) reported from unpublished data that the solubility of MgCO_3 in CaCO_3 was increased by approximately 1% MgCO_3 per 5 kilobars total pressure up to 15 kilobars. Goldsmith and Newton (1969) considered the problem in more detail. They measured solubility increases due to pressure at several temperatures suggesting that in the range 500° to 800°C the increase in MgCO_3 solubility was about .12 mole per cent per kilobar. In addition they calculated the pressure effect, using regular solution theory, obtaining results in good accord with their experimental findings. They conclude that "the regular solution theory provides a nearly quantitative estimate of the pressure effect on the solvus".

The following expression given by Goldsmith and Newton (1961) can be used to calculate the change in mole fraction MgCO_3 with pressure:

$$(1) \quad dX_{\text{Mc}}/dP = V_{\text{Cc}} + V_{\text{Mc}} - V_{\text{d}}/(2X_{\text{Mc}}-1) + RT/X_{\text{Mc}}(1-X_{\text{Mc}}) - Q$$

where;

X_{Mc} = the mole fraction of MgCO_3 in calcite

P = pressure (bars)

V_{cc} = partial molal volume of CaCO_3 in calcite

V_{mc} = partial molal volume of MgCO_3 in calcite

V_d = molar volume of dolomite

R = gas constant

T = temperature ($^{\circ}\text{K}$)

Ω = interchange energy

The partial molal volume of CaCO_3 (V_{cc}) is given by the equation:

$$(2) \quad V_{cc} = 36.92 - .00088 X_{mc} - .0002 X_{mc}^2$$

which was obtained by applying a polynomial fit to the data of Goldsmith and Newton (1969) (their figure 10). Similarly the partial molal volume of MgCO_3 (V_{mc}), given by the equation

$$(3) \quad V_{mc} = 26.43 + .07 X_{mc} - .0009 X_{mc}^2$$

was obtained from Goldsmith and Newton (1969). The molar volume of dolomite (V_d) was taken as $V_d = 32.14 \text{ cm}^3$, the value given by Goldsmith, Graf and Heard (1961) for ordered dolomite.

The interchange energy (Ω) as shown by Goldsmith and Newton (1969) is a function derived from regular solution theory by Guggenheim (1952). Goldsmith and Newton (1969) give the following expression for the interchange energy:

$$(4) \quad \Omega = -\Delta H + T \Delta S - RT \ln \left[\frac{(X_{mc} - (1 - X_{mc}))}{(2X_{mc}^2 - 2X_{mc} - 1)} \right]$$

The values of $\Delta H_{298} = 3150 \text{ cal/mole}$ and $\Delta S_{298} = .81 \text{ cal/}^{\circ}\text{C mole}$ were taken from Robie (1957), where H and S are an enthalpy and entropy calculated as $H(\text{magnesite}) + H(\text{calcite}) - H(\text{dolomite})$.

It needs to be stated that the change in solubility of MgCO_3 with pressure given by equation (1) is very sensitive to the relative values of $V_{cc} + V_{mc}$ and V_d . As the value of $V_{cc} + V_{mc}$ approaches that of V_d , the numerator of equation (1) approaches zero and the equation cannot be calculated. As an example, the equation reported by Gordon and Greenwood (1970) for the partial molal volume of MgCO_3 in calcite (V_{mc}) causes the sum of $V_{cc} + V_{mc}$ to approach sufficiently close to the value of V_d so as to create almost no change in solubility with pressure.

The integration of equation (1) has been accomplished graphically by computer (see Appendix A for computer program). The equation was integrated over temperature and pressure intervals necessary to reduce the previous solvus data to a standard pressure state of one bar. Table 6.1 and Table 6.2 show the various solvus data corrected to pressures of 1 bar and 5 kilobars respectively. (Sphalerite geobarometry suggests that a pressure of 5 kilobars is applicable to the field area under investigation).

The corrected data from Tables 6.1 and 6.2 were used to produce the composite isobaric solvus curves shown in Figure 6.2 and Figure 6.3 for 1 bar and 5 kilobars respectively. A 4th degree polynomial equation was computer fitted to these solvus data giving equations 5 and 6 at 1 bar and 5 kilobars respectively. Solution of these equations allows a direct calculation of temperature from the measured MgCO_3 in calcite.

Table 6.1 - Solvus data reduced to 1 kilobar pressure

Temperature (centigrade degrees)	Experimental mole % MgCO_3	Experimental pressure (k bar)	Mole % MgCO_3 at 1 bar	Source
400	2.5	2.0	2.40	1
	3.3	9.0	2.80	1
450	3.4	2.0	3.27	1
	3.2	2.0	3.08	1
	4.7	9.0	4.00	1
	4.5	10.0	3.78	1
500	4.6	1.9	4.49	1
	4.6	2.0	4.49	1
	5.5	1.4	5.32	3
	5.5	1.4	5.32	3
	5.5	12.0	4.49	1
540	6.5	13.5	5.15	1
550	5.5	1.9	5.30	1
575	6.6	3.0	6.28	1
	7.7	14.0	6.21	1
	7.9	15.0	6.09	1
	7.0	7.0	6.12	2
584	5.9	0.7	5.82	2
600	6.9	1.9	6.70	1
	7.0	2.1	6.72	3
	8.0	2.1	7.70	3
	8.5	2.1	8.20	3
605	7.7	0.036	7.70	2
650	9.0	0.067	9.99	2
	9.5	0.586	9.41	2
	9.0	1.9	8.70	1
	9.1	1.9	8.80	1
	9.4	4.0	8.78	1
	9.5	5.0	8.70	1
	9.8	6.0	8.80	1
	10.0	7.0	8.80	1
	9.8	7.0	8.70	1
	9.9	8.0	8.61	1
	10.0	9.0	8.50	1
	10.0	10.0	8.40	1
	10.4	12.0	8.40	1
	10.7	14.0	8.40	1
	10.9	16.0	8.28	1
	10.2	17.0	7.42	1
	10.1	17.8	7.42	1
	11.0	18.5	7.75	1
668	10.0	2.0	9.65	4
685	10.0	2.0	9.66	4
697	11.3	0.689	11.15	2
700	11.0	2.1	10.60	3
	13.7	21.0	9.10	1
704	11.5	1.448	11.15	2
720	11.5	1.9	11.09	1

Table 6.1 (cont'd.)

Temperature (centigrade degrees)	Experimental mole % MgCO_3	Experimental pressure (k bar)	Mole % MgCO_3 at 1 bar	Source
734	14.4	0.248	14.33	2
762	15.6	0.689	15.40	2
780	14.6	1.7	14.10	1
	15.4	1.7	14.80	1
	15.5	1.7	15.00	1
	15.9	4.0	14.70	1
	16.0	4.0	14.78	1
	15.8	4.0	14.60	1
	16.5	5.5	14.81	1
	16.2	6.0	14.47	1
	16.5	9.0	13.90	1
	17.2	12.0	13.70	1
	17.7	15.0	13.22	1
	18.0	19.0	12.60	1
	18.8	24.0	11.99	1
788	17.1	0.689	16.89	2
796	17.5	0.689	16.70	2
800	16.0	2.1	15.32	3
	17.5	2.1	16.72	3
	17.5	2.1	16.72	3
831	21.3	1.4	20.50	5
841	21.6	1.4	20.70	5
850	17.6	2.0	16.89	1
855	20.0	3.0	18.80	4
863	21.1	1.4	20.30	5
873	20.0	3.0	18.74	4
888	20.0	4.0	18.48	4*
900	24.7	15.0	18.10	1
	24.0	3.1	22.60	3
925	26.9	12.0	20.40	1
975	30.0	5.0	25.40	4
985	30.0	5.0	25.80	4*
1060	40.0	8.0	-	4*
1074	40.0	8.5	-	4*
1038	42.5	6.0	-	4
1054	42.5	8.0	-	4
1069	42.5	8.5	-	4
1085	42.5	8.5	-	4*

* Source

- 1 Goldsmith and Newton, 1969
- 2 Graf and Goldsmith, 1958
- 3 Harker and Tuttle, 1955
- 4 Goldsmith and Heard, 1961
- 4* Goldsmith and Heard, 1961 calcite only
- 5 Graf and Goldsmith 1955, calcite only

Table 6.2 - Solvus data reduced to 5 kilobars pressure

Temperature (centigrade degrees)	Experimental mole % MgCO_3	Experimental pressure (k bar)	Mole % MgCO_3 at 5 k bars	Source
400	2.5	2.0	2.68	1
	3.3	9.0	3.05	1
450	3.4	2.0	3.60	1
	3.2	2.0	3.30	1
	4.7	9.0	4.33	1
	4.5	10.0	4.10	1
500	4.6	1.9	4.91	1
	4.6	2.0	4.91	1
	5.5	1.4	5.90	3
	5.5	1.4	5.90	3
	5.5	12.0	4.82	1
540	6.5	13.5	5.50	1
550	5.5	1.9	5.85	1
575	6.6	3.0	6.83	1
	7.7	14.0	6.50	1
	7.9	15.0	6.50	1
	7.0	7.0	6.75	2
584	5.9	0.7	6.40	2
600	6.9	1.9	7.30	1
	7.0	2.1	7.40	3
	8.0	2.1	8.50	3
	8.5	2.1	9.00	3
605	7.7	0.036	8.48	2
650	9.0	0.067	10.00	2
	9.5	0.586	10.37	2
	9.0	1.9	9.59	1
	9.1	1.9	9.60	1
	9.4	4.0	9.63	1
	9.5	5.0	9.50	1
	9.8	6.0	9.64	1
	10.0	7.0	9.64	1
	9.8	7.0	9.42	1
	9.9	8.0	9.34	1
	10.0	9.0	9.35	1
	10.0	10.0	9.10	1
	10.4	12.0	9.10	1
	10.7	14.0	9.10	1
	10.9	16.0	8.92	1
	10.2	17.0	8.30	1
	10.1	17.8	8.10	1
	11.0	18.5	8.50	1
668	10.0	2.0	10.53	4
685	10.0	2.0	10.51	4
697	11.3	0.689	12.34	2
700	11.0	2.1	11.65	3
	13.7	21.0	10.18	1
704	11.5	1.448	12.34	2
720	11.5	1.9	12.25	1

Table 6.2 (cont'd.)

Temperature (centigrade degrees)	Experimental mole % MgCO_3	Experimental pressure (k bar)	Mole % MgCO_3 at 5 k bars	Source*
734	14.4	0.248	15.91	2
762	15.6	0.689	17.15	2
780	16.4	0.689	18.20	2
	14.6	1.7	15.70	1
	15.4	1.7	16.60	1
	15.5	1.7	16.70	1
	15.9	4.0	16.30	1
	16.0	4.0	16.40	1
	15.8	4.0	16.28	1
	16.5	5.5	16.40	1
	16.2	6.0	15.85	1
	16.5	9.0	15.22	1
	17.2	12.0	14.95	1
	17.7	15.0	14.40	1
	18.0	19.0	13.50	1
	18.8	24.0	12.95	1
788	17.1	0.689	18.90	2
796	17.5	0.689	19.28	2
800	16.0	2.1	17.05	3
	17.5	2.1	18.72	3
	17.5	2.1	18.72	3
831	21.3	1.4	22.15	50
841	21.6	1.4	22.52	5
850	17.6	2.0	18.80	1
855	20.0	3.0	20.75	4
863	21.1	1.4	21.75	5
873	20.0	3.0	20.78	4
888	20.0	4.0	20.30	4*
900	24.7	15.0	18.95	1
	24.0	3.1	24.25	3
925	26.9	12.0	22.35	1
975	30.0	5.0	29.60	4
985	30.0	5.0	29.60	4*
1060	40.0	8.0	-	4*
1074	40.0	8.5	-	4*
1038	42.5	6.0	-	4
1054	42.5	8.0	-	4
1069	42.5	8.5	-	4
1085	42.5	8.5	-	4*

*Source

- 1 Goldsmith and Newton, 1969
- 2 Graf and Goldsmith, 1958
- 3 Harker and Tuttle, 1955
- 4 Goldsmith and Heard, 1961
- 4* Goldsmith and Heard 1961 calcite only
- 5 Graf and Goldsmith 1955, calcite only

$$(5) \text{ Temp} = 477.63 + 88.77x - 6.08x^2 + .22x^3 - .0032x^4 \text{ (1 bar)}$$

$$(6) \text{ Temp} = 474.96 + 82.24x - 5.11x^2 + .17x^3 - .0022x^4 \text{ (5 kb.)}$$

6.5 Determination of MgCO_3 Content of Calcite

The most common method of determining the MgCO_3 content of calcite has been to measure selected cell parameters by X-ray diffraction (Harker and Tuttle (1955) report precision to within 1% by this method while Goldsmith and Newton (1969) claim an accuracy of $\pm .2$ mole percent). This technique however assumes that all MgCO_3 is tied up in solid solution and does not therefore account for exsolved dolomite. Exsolution of dolomite is a common occurrence in metamorphic carbonates and is reported as extensive by Goldsmith, Graf and Joensuu (1955), and Hutcheon and Moore (1973) among others. Carbonates in the present study, almost without exception displayed some degree of dolomite exsolution. While attempts at reheating carbonates to affect a rehomogenization of exsolved dolomite have met with some success, (Wong, 1971), 'statistical rehomogenization' by electron microprobe methods appears to be more favourable. For this reason the Cambridge Instrument microscan-5 electron probe at Carleton University was used to produce analyses of the MgCO_3 content of calcite. Individual calcite grains, including exsolved dolomite were scanned for 10 second intervals using a slightly defocused beam (2x - 3x focused beam diameter). A large number (10 to 15) of these 10 second scans were conducted on each grain with up to 10 grains

analyzed in each section.

A defocused electron beam minimizes several of the basic problems associated with carbonate analysis.

i) Under normal operating conditions (greater than 12 kv. electron voltage) carbonate material tends to decompose very rapidly. By using a slightly defocused beam the intensity at a given point is somewhat reduced and decomposition minimized.

ii) The attempt at 'rehomogenization' of the calcite by including areas of exsolved dolomite is greatly enhanced by a defocused beam. Areas of exsolved dolomite tend to be very small, seldom exceeding the diameter of a normal beam. While it is considered possible for a focused beam to be centered entirely upon an area of exsolved dolomite at any given moment this possibility is greatly reduced by using a larger beam diameter.

The main argument against using a defocused beam is that control over the exact position of the beam is reduced. The fact that carbonate material will fluoresce when excited by an electron beam (producing a faint pinkish spot) allows continuous monitoring of the beam size and position. As protection against the possibility that the area of activation exceeds the area of fluorescence, analyses were conducted so that at all times the beam was never closer than 2 beam diameters to the edge of the grain.

6.6 Presence of FeCO_3 and MnCO_3

The presence of FeCO_3 and MnCO_3 in solid solution can affect

the solvus temperature. It has been estimated by Sheppard and Schwarcz (1970) that 1 mole per cent FeCO_3 will increase the indicated temperature by 8°C . As a preliminary indication of the presence of Fe^{++} all specimens were stained with a solution of HCl, Alizarin Red-S, and Potassium Ferricyanide. This test indicated that all probe specimens were virtually Fe^{++} free. In addition the presence of Fe^{++} and Mn^{++} was checked by probe analysis of a number of grains from each section. Less than 1 mole per cent Fe^{++} and only trace amounts of Mn^{++} were encountered in all analyses.

6.7 Temperature Determinations

Calcites coexisting with dolomite were analyzed from a number of field stations representing a wide variation in metamorphic grade. Complete analyses from these stations are given in Appendix B. The determination of temperatures at these stations was based on the analysis giving the highest MgCO_3 content. The maximum amount of magnesium possible in calcite is established by the highest temperature reached during metamorphism. While numerous factors, as outlined below, can reduce this maximum value, none except increasing temperature can increase it. For this reason the maximum MgCO_3 content determined for a sample is used to estimate the temperature. Table 6.3 is summary of the maximum analysis from each sample and the corresponding temperature.

Table 6.3 Maximum MgCO_3 Content of Calcite and Temperature Determinations

<u>Sample No.</u>	<u>Max. Mole % MgCO_3</u>	<u>Temperature ($^{\circ}\text{C}$)*</u>
921037-1	3.4	428
920035-2	3.0	407
895033-1	2.7	390
885025-1	3.2	418
028004-3	4.1	463
028004-3	4.4	478
868808-2	3.8	449
891807-1	4.4	478
906788-1	6.8	573
061674-1	1.2	293
834662-3	5.3	517
860653-1	4.3	473
857634-1	1.6	321
948621-1	0.7	258
089574-1	0.9	295
902568-3	2.5	378
095567-1	1.5	314
104563-3	0.8	264
981563-2	2.2	359
931382-2	5.0	505
931382-1	6.8	573
940376-3	1.0	279
943369-3	0.5	241
764359-1	7.7	602
697352-2	5.3	516
722344-1	10.4	670
119320-1	5.2	513
111319-1	1.2	293
887293-1	4.6	487

* Pressure = 5.0 kilobars

6.8 Factors Affecting the Accuracy of Temperature Determinations

The magnesium content of calcite established at the peak of metamorphism is subject to many subsequent processes which tend to reduce the original amount of magnesium. It is important therefore to determine if post-metamorphic processes may have seriously affected the magnesium content of the calcite. In general the following factors may affect the composition of magnesian calcite:

- i) The degree to which equilibrium was originally approached;
- ii) The rate of cooling following peak metamorphic conditions;
- iii) The degree of weathering to which the sample has been subjected;
- iv) The response of the sample to complex and highly variable phenomena such as local variations in impurity content and grain size at time of reaction, etc.

CHAPTER 7 COMPARISON OF EXPERIMENTAL MODELS WITH FIELD OBSERVATIONS

7.1 Introduction

Experimental models for the metamorphism of siliceous carbonates have been proposed by Metz and Trommsdorff (1968), Skippen (1971, 1974) and Slaughter, Kerrick and Wall (1975). Such models, if valid, should predict the sequence of mineral assemblages observed in the field during progressive metamorphism. That these models may be applicable to conditions in the field is suggested by the work of Trommsdorff (1972) and Hoy (1976). However, discrepancies still exist amongst the variously proposed models. Field data suggest that a composite model incorporating selected data from the various experimental data can produce a valid and reliable field model.

7.2 Experimental Model for the Metamorphism of Siliceous Dolomitic Marble

The discontinuous reactions that control mineralogical changes within siliceous carbonates during progressive metamorphism have been studied experimentally by Greenwood (1962, 1967), Metz and Trommsdorff (1968), Metz and Winkler (1969), Metz (1970), Gordon and Greenwood (1970), Skippen (1971, 1974) and Slaughter, Kerrick and Wall (1975). These reactions are also observed in the field where they have been used to map isograds (e.g., Trommsdorff 1972, Hutcheon and Moore 1973,

and Puhan and Hoffer 1974). Skippen (1971, 1974), Slaughter, Kerrick and Wall (1975), and Trommsdorff (1972) have proposed similar models based on experimental and field observation of these reactions.

The method of Skippen (1971) has been used to expand these models by considering the component KAlO_2 . The additional mineral phases potassium feldspar and phlogopite are thus included.

Pertinent phase relations in the system $\text{CaO-MgO-SiO}_2\text{-KAlO}_2\text{-CO}_2\text{-H}_2\text{O}$ can be calculated from experimentally determined equilibrium data for any six independent reactions. For phases within the $\text{CaO-MgO-SiO}_2\text{-CO}_2\text{-H}_2\text{O}$ system, the five independent reactions of Skippen (1971) were used. The KAlO_2 component was introduced by using the lower temperature limit for the data of Hoschek (1973) concerning the reaction:

Mass balanced equations for all other reactions can be derived by taking some combination of the six independent reactions (Skippen 1971). In a similar manner the equilibrium constants are linear functions and can be calculated for all the reactions by taking some linear combination of the experimentally measured constants of the six independent reactions. Within the system being considered, 17 stable reactions are necessary to establish the phase relations among the minerals

calcite, dolomite, quartz, diopside, tremolite, talc, fibroterite, phlogopite and potassium feldspar. The stable phase relations within the system $\text{CaO-MgO-SiO}_2\text{-CO}_2\text{-H}_2\text{O}$ were taken from Skippen (1974) while those involving potassium phases not coexisting with dolomite were determined by R. Moore (personal communication). Those involving potassium phases and dolomite were calculated as required.

The equilibrium constants for these reactions can be represented by an equation of the form

$$\text{ii) } \log k_N = A_n/T + B_n + C_n (P_1 - P_2)/T \text{ (Skippen 1971).}$$

Values of the constants A, B and C for the 17 stable reactions are given in Table 7.1 and were calculated with the activity of MgCO_3 fixed by the calcite-dolomite immiscibility gap. Data for the sphene reaction were obtained from Williams-Jones (1973).

Traditionally, two types of diagrams have been used to display equilibrium data. Log Fugacity diagrams as outlined by Korzhinskii (1959) have been used but are limited to situations where isothermal, isobaric conditions seem reasonable. In cases where polythermal or polybaric conditions may exist, it is necessary to consider the effects of temperature and pressure in addition to fluid composition by using isobaric T-X diagrams. The calculation of such diagrams for carbonate systems is outlined by Skippen (1971) and can be carried out by computer. (Skippen and Yzerdraat 1970).

A computer-calculated T-X_{CO₂} section, utilizing the data given in

Table 7.1 - Carbonate Reactions

	<u>Reaction</u>	<u>A*</u>	<u>B*</u>	<u>C*</u>
1	3 dol + Kspar + H ₂ O = Phlog + 3Cc + 3CO ₂	-12,393	24.879	0.2238
2	3 dol + 4Qtz + H ₂ O = Tc + 3Cc + 3CO ₂	-13,725	26.090	0.2014
2a	5Tc + 6Cc + 5Qtz = 3Tr + 6CO ₂ + 2H ₂ O	-26,787	61.290	0.9132
2b	2Tc + 3Cc = Tr + dol + CO ₂ + H ₂ O	- 4,354	11.734	0.2373
3	8Qtz + 5dol + H ₂ O = Tr + 3Cc + 7CO ₂	-31,804	63.914	0.6401
4	Rutile + Cc + Qtz = sphene + CO ₂	- 3,313	7.603	0.1190
5	5Phlog + 6Cc + 24Qtz = 5Kspar + 3Tr + 6CO ₂ + 2H ₂ O	-33,433	67.32	0.8004
6	Tr + 11dol = 8Fo + 13Cc + 9CO ₂ + H ₂ O	-83,027	132.33	0.8197
7	Tr + 3Cc + 2Qtz = 5Di + 3CO ₂ + H ₂ O	-12,281	27.620	0.5152
8	Kspar + 3Tr + 6Cc = Phlog + 12Di + 6CO ₂ + 2H ₂ O	-22,787	52.824	1.0764
9	3Tr + 5Cc = 11Di + 2Fo + 5CO ₂ + 3H ₂ O	-30,282	58.669	0.9864
10	Phlog + 2Cc + 6Qtz = Kspar + Di + 3CO ₂ + H ₂ O	-14,178	30.25	0.4692
11	Phlog + 2Di + 4Qtz = Kspar + Tr	- 1,775	2.416	-0.0460
12	dol + 2Qtz = Di + 2CO ₂	- 8,816	18.305	0.2310
13	Di + 3dol = 2Fo + 4Cc + 2CO ₂	-19,890	30.729	0.1339
14	Tr + 3Cc = 4Di + dol + CO ₂ + H ₂ O	- 3,464	9.314	0.2842
15	Phlog + 2dol + 8Qtz = Kspar + Tr + 4CO ₂	-19,408	40.382	0.41612
16	Tr + 2dol + Kspar = 4 Di + Phlog + 4CO ₂	-15,859	34.198	0.5098

* Reference pressure of 2000 bars

List of Symbols

Cc	-----	calcite
Tr	-----	tremolite
dol	-----	dolomite
Qtz	-----	quartz
Kspar	-----	potassium feldspar
Phlog	-----	phlogopite
Di	-----	diopside
Fo	-----	forsterite

Table 7.1 was produced for a total pressure of 5 kilobars - a pressure suggested by the sphalerite geobarometer as appropriate for the study area. The $T-X_{CO_2}$ section at this pressure confirms several of the trends suggested by experimental considerations at somewhat lower pressures. In particular it is of interest to note the relative positions of the reactions responsible for the first formation of diopside (reaction 7) and forsterite (reaction 6). It was shown by Skippen (1971) that at total pressures of 2 kilobars and less, reaction 7 occurs before 6 suggesting that at low pressures diopside should form prior to forsterite. Skippen (1974) suggested that at 3 kilobars the two reactions just intersect and suggested that at still higher pressures the curves may cross allowing forsterite to form before diopside. The temperature-mole fraction diagram produced in the present study (Figure 7.1) shows clearly that over a wide range of carbon dioxide-rich fluids, forsterite should form before diopside. Trommsdorff (1972) postulated a total pressure of at least 5 kilobars for the Lepontine Alps and produced a $T-X_{CO_2}$ section based on his field data that agrees well with that of the present study and which shows a large region of fluid composition where forsterite may form before diopside. Diopside at 5 kilobars total pressure may still form before forsterite at extreme CO_2 -rich fluid compositions or those that are H_2O -rich.

It is also of interest to note that the present $T-X_{CO_2}$ section indicates a greatly expanded talc field at 5 kilobars. This agrees well with the observations of Metz and Trommsdorff (1968) but in contra-

Figure 7.1 T-X_{CO₂} diagram at 5 kilobars. Stability of reactions calculated from the data given in Table 7.1. Reactions involving potassium absent phases based on data of Skippen (1974) with the activity of MgCO₃ defined by the calcite-dolomite immiscibility gap. The stability of potassium bearing phases was obtained from R. Moore (personal communication, 1976). Curves are numbered to correspond with the reaction numbers given in Table 7.1

Figure 7.1 enclosed in pocket.

diction to the recent study of Slaughter, Kerrick and Wall (1975) who suggest that the talc field decreases at higher pressures.

Trommsdorff (1972) has indicated an abundance of talc assemblages in the Alps and supports the idea of an expanded talc field at higher pressures. A similar conclusion was reached by Puhar and Hoffer (1973) in the Damara Belt of South Africa. The lack of talc, while well-documented at lower pressures (Hutcheon and Moore 1973, Hoy 1975) can only occur at higher pressure if the fluid phase is extremely CO_2 -rich. The formation of such a fluid may be the result of phlogopite formation in potassium feldspar-bearing dolomitic marbles, as mentioned by Skippen (1974).

7.3 Isoreaction-grads and Coexisting Mineral Assemblages

The distribution and interpretation of metamorphic grade in the field was traditionally accomplished by using the first appearance of a given mineral to define an isograd. When it was determined that the first appearance of a given mineral could be accomplished by several different reactions, depending upon bulk composition and the local $\text{P-T-X}_{\text{CO}_2}$ conditions, it became important to base the mapping of an isograd on a specific reaction. Such an isograd has been termed an isoreaction-grad by Winkler (1975), the term used in this study.

Isograds based on specific univariant reactions in isobaric T-X_{CO_2} space are confined to divariant areas on the P-T surface

as shown in Figure 7.3, depending on the fluid composition. In the field mineral localities defining such a divariant isoreaction-grads are not related by a unique temperature but rather represent points that may each reflect different temperatures. Carmichael (1970) was the first to clearly demonstrate, by means of intersecting isograds, the response of such isoreaction-grads to varying fluid compositions and temperatures in the field.

Skippen (1974) has pointed out that it is possible to adequately map isoreaction-grads based on mineral assemblages which are directly related to only pressure and temperature. In isobaric $T-X_{CO_2}$ space such mineral assemblages are present at invariant points marking the stable intersection of univariant reaction curves. The trace of these isobaric invariant points is constrained to a univariant line on the P-T surface as outlined in Figure 7.3. The intersection of this univariant curve with the plane of the map, defines a point in P-T space that is independent of fluid composition. Thus, an assemblage such as tremolite-diopside-quartz-calcite-dolomite, which has been used to define isoreaction-grad II in this study, is directly related to pressure and temperature in the classical sense of Tilley (1924). While the direct mapping of such an isoreaction-grad is made difficult by the scarcity of isobaric invariant mineral assemblages, it is possible to map such isoreaction-grads by bracketing them between appropriate univariant and divariant assemblages in the manner suggested by Skippen (1974).

Figure 7.3 Trace of univariant and divariant assemblages in P-T space. Univariant assemblages intersect the map at a point that is independent of fluid composition.

7.4 Isoreaction-grads in the Field

The system $\text{CaO-MgO-SiO}_2\text{-KAlO}_2\text{-CO}_2\text{-H}_2\text{O}$ has been chosen to represent carbonate rocks from the thesis area because minerals found in the field can be plotted within this system. A total of seventeen discontinuous reactions, shown in Figure 7.1 and outlined in Table 7.1, describe the stability of the phases within this system. The intersection of these seventeen reactions produces a total of eight stable invariant points (Skippen, 1971, 1974; R. Moore, personal communication).

It has been possible in the thesis area to map the trace of one isobaric invariant point, that corresponding to the assemblage calcite-dolomite-quartz-tremolite-diopside (invariant point II on Figure 7.1). This polybaric univariant isoreaction-grad was mapped, for the most part, by bracketing it in the manner suggested by Skippen (1974). The critical assemblages, assuming a CO_2 -rich fluid, that were used to bracket isoreaction-grad II are given in Table 7.2. In addition to mapping the trace of isobaric invariant point II, enough data exist to adequately map, at least locally, the following isobaric univariant reaction curves:

- (1) $3 \text{ dolomite} + \text{potassium feldspar} + \text{H}_2\text{O} \text{ --- phlogopite}$
 $\quad \quad \quad = \text{phlogopite} + 3 \text{ calcite} + 3 \text{ CO}_2$
- (3) $8 \text{ quartz} + 5 \text{ dolomite} + \text{H}_2\text{O} \text{ --- tremolite}$
 $\quad \quad \quad = \text{tremolite} + 3 \text{ calcite} + 7 \text{ CO}_2$

Table 7.2 - Upper and Lower Brackets for Isoreaction-grad II

<u>Invariant Assemblage</u>	<u>Lower Bracket</u>	<u>Upper Bracket</u>
i) calcite - dolomite - quartz - tremolite - diopside	i) quartz - dolomite ii) tremolite - quartz - dolomite - calcite	i) diopside - dolomite - calcite - tremolite ii) diopside - calcite - quartz - tremolite iii) diopside - calcite - tremolite iv) diopside - calcite - quartz v) diopside - tremolite - quartz vi) forsterite - calcite - tremolite - dolomite
		dolomite
		vii) forsterite - calcite - tremolite
		viii) forsterite - calcite - dolomite

* Assuming a CO₂ rich fluid, any diopside or forsterite bearing assemblage

must have formed at conditions above invariant point II.

(6) tremolite + 11 dolomite --- forsterite

(7) tremolite + 3 calcite + 2 quartz --- diopside

These isobaric invariant isoreaction-grads are generally stable over a range of temperatures depending upon the fluid composition. It should be noted that isoreaction-grad (6) closely approximates isothermal conditions for most fluid composition and can represent nearly univariant conditions in $\text{Pf-T-X}_{\text{CO}_2}$ space (Winkler, 1975).

The trace of these isoreaction-grads has been established regionally for each of the four map sheets comprising the thesis area (see maps in pocket). In addition they have been established in considerably more detail around the Lyndhurst pluton. The distribution of metamorphic zones within the thesis area has resulted from the mapping of these isoreaction-grads and a regional pattern of increasing metamorphic grade towards the major plutons of the area has emerged.

This regional pattern has been confirmed by the detailed study around the Lyndhurst pluton. The distribution of isobaric invariant isoreaction-grad II around the Lyndhurst pluton indicates isothermal conditions that essentially conform to the outline of the pluton.

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Isobaric univariant isoreaction-grad (7) is dependent upon variations in fluid composition and while it conforms to the outline of the pluton for most of its length, it diverges significantly from it to the north. Isoreaction-grad (3), also isobarically univariant and dependent upon the fluid composition, likewise diverges to the north. In addition, it diverges from the pluton to the northwest and southeast where substantially lower grade zones are established.

This pattern of metamorphic grade distribution is essentially the same as that suggested by the mapping of isoreaction-grads in other parts of the thesis area (excepting the Tichborne map-area). For example, the Carleton Place map sheet which is mainly of low to intermediate grade, increases rapidly in grade along its eastern, northern and western margins, in response to intrusive activities in these directions. Similarly the Perth and Westport map-areas have a distribution of isobaric invariant and univariant isoreaction-grads that suggests increasing grade towards the major granitic plutons.

The distribution of isoreaction-grads in the Tichborne map-area does not appear to be related to any specific intrusions but seems to be of more regional nature. Decreasing metamorphic grade away from a large, central high-grade (forsterite) zone is indicated.

The mapping of all isoreaction-grads and the outline of the various zones that they establish is given in Appendix C. A detailed

- description of the constraints placed upon these isoreaction-grads and their validity locally is further outlined in this appendix.

Although no rigorous theoretical models have been developed to include coexisting aluminous minerals such as clinohumite, zoisite, anorthite, muscovite, kyanite, and potassium feldspar in the T-X section, experimental data on the stability fields for many of these phases do exist. These data have been individually plotted on a T-X_{CO₂} section and are presented on Figure 7.2. Data for the reaction of tremolite + dolomite = clinohumite + calcite are from Bourne (1974) at 1 kilobar. The reaction of muscovite + calcite + quartz = zoisite + potassium feldspar is after Allen (1976), while data for the reactions zoisite = anorthite + calcite, muscovite + calcite + quartz = anorthite + potassium feldspar and muscovite + calcite + quartz = kyanite + potassium feldspar were supplied by R. Moore (personal communication 1976) at 5 kilobars. As indicated on Figure 7.2 the presence in the field of mineral phases such as clinohumite-calcite or zoisite can be used as evidence to indicate H₂O-rich equilibrium fluids. Assemblages such as anorthite (Ca-plagioclase)-calcite or anorthite-potassium feldspar are taken as evidence indicating CO₂-rich fluids. An isoreaction-grad based on the reaction muscovite + calcite + quartz = anorthite + potassium feldspar has been mapped on the Westport and Tichborne map-areas.

Figure 7.2 T-X_{CO₂} diagram displaying selected aluminous silicate stabilities. Reaction of tremolite (Tr) + dolomite (Dol) to clinohumite (Clh) + calcite (Ca) after Bourne (1974) at 1 kilobar. Reaction of muscovite (Mu) + calcite (Cc) + quartz (Q) to zoisite (Zs) + potassium feldspar (Kf) after Allen (1976). Other reactions after R. Moore (personal communication 1976).

7.5 Application of Existing Experimental Models to Field Observations

a) Lyndhurst Pluton

An initial study of rocks from the Westport map sheet suggested that isograds in the carbonates might be related to the emplacement of igneous rocks such as the Westport and Lyndhurst Plutons. It was therefore decided to study the carbonate rocks around the Lyndhurst Pluton in detail. The mineral assemblages and isograds that were observed in this study have been plotted on Map E.

A cursory study of the isograds shown on Map E indicates that isograds are related in space in a general way to the shape of the pluton. A number of complexities in the shape of isograds can be seen as, for example, to the northeast of the pluton and to the southeast in the vicinity of Singleton Lake. Such complex relationships among isograds in carbonate rocks are not unexpected because of the mixed-volatile reactions that control carbonate phase relations. Thus, a change of metamorphic grade, as reflected by a series of isograds, can be produced by changing pressure and temperature and also by changing amounts of CO_2 and H_2O in the fluid phase, as demonstrated by Carmichael (1970) and Allen (1976). The interpretation of the metamorphic grade in carbonate rocks requires that the composition of the fluid phase be considered. In particular, it is

important that the composition of the fluid phase be carefully monitored in the case of isograd II representing stability conditions for the assemblage, tremolite-diopside-calcite-dolomite-quartz.

A study of Figure 7.1 indicates that an isograd representing this assemblage is defined only for a gas phase with a high CO_2 content. The procedure suggested by Skippen (1974) for bracketing isograd II in the field is valid only for high CO_2 fluids and could lead to spurious results for assemblages equilibrated with a fluid containing mostly H_2O .

The data plotted on Figure 7.1 suggest that an appropriate point for distinguishing between high CO_2 and high H_2O fluids is a CO_2 mole fraction of 0.3. This is the point in moving to higher H_2O fluids along reaction 7 that corresponds to the temperature of invariant point II. For fluids containing more CO_2 than $X=0.3$, it is possible to bracket an isothermal, isobaric isograd corresponding to the assemblage of invariant point II. For fluids that contain less CO_2 , it is not possible to use the assemblages of reactions 7 and 3 to bracket an isothermal, isobaric isograd in the field.

To interpret the isograds in rocks around the Lyndhurst Pluton, it is necessary to demonstrate that the mineral assemblages equilibrated with either a high CO_2 or a high H_2O fluid. The evidence, as outlined below, suggests that a fluid of variable composition has been involved so that both high CO_2 and high H_2O fluids were equilibrated with

mineral assemblages near Lyndhurst. A high CO_2 fluid is indicated for much of the area and in particular for the rocks immediately surrounding the pluton. High H_2O fluids are thought to have been present near Singleton Lake and to the north and northwest in the Lower Beverley Lake area.

1) CO_2 -rich Fluids

A CO_2 -rich fluid surrounding the Lyndhurst Pluton is indicated by several lines of evidence. The existence of isobaric univariant tremolite-calcite-dolomite-quartz assemblages around the pluton indicates equilibration with a more or less CO_2 -rich fluid. Skippen (1974) shows that at 5 kilobars (Figure 7.1) this isobaric univariant assemblage must be stable at $X_{\text{CO}_2} > .65$ and $T > 530^\circ\text{C}$. The data of Winkler (1975) are extreme and allow tremolite-calcite-dolomite-quartz assemblages to be stable only at $X_{\text{CO}_2} > .85$ and $T > 600^\circ\text{C}$. Slaughter, Kerrick and Wall (1975) allow a broader stability range for this assemblage, which according to their data, can be stable from $X_{\text{CO}_2} > .22$ and $T > 465^\circ\text{C}$. Even these most liberal data allow only a very small ($X_{\text{CO}_2} = 0.22$ to 0.30) stability range for this assemblage under anything but CO_2 -rich conditions (i.e., $X_{\text{CO}_2} > .30$).

A high CO_2 fluid is further indicated by the abundance of aluminous silicate assemblages such as Ca-plagioclase-calcite and Ca-plagioclase-potassium feldspar in preference to epidote or zoisite

(Figures 7.2 and 7.4). The absence of chondrodite or epidote, except in the Lower Beverley Lake and Singleton Lake areas, is also suggestive of a high CO_2 fluid.

The conspicuous lack of serpentine or talc in rocks of suitable composition and the abundance of tremolite assemblages formed from the reaction of quartz + dolomite suggest CO_2 -rich conditions.

The production of phlogopite + calcite by reaction from potassium feldspar + dolomite involves the liberation of three moles of CO_2 for each mole of phlogopite formed. The widespread production of phlogopite observed in this area, while not conclusive, would strongly favour a CO_2 -rich fluid. Based on the available data suggesting a CO_2 -rich fluid and the lack of any mineralogical or textural data in favour of an H_2O -rich fluid (excepting the areas previously noted), it is concluded that dominantly CO_2 -rich fluid existed in the area immediately surrounding the Lyndhurst Pluton.

The nature of the thermal gradient in this area can be determined by noting that it is possible to map isoreaction-grads that are independent of fluid composition (the traces of isobaric invariant point assemblages in P-T space) if sufficient isobaric invariant assemblages are present or if such assemblages can be bracketed by appropriate isobaric univariant or divariant assemblages as outlined by Skippen (1974). Isoreaction-

Figure 7.4 Distribution of aluminous silicate assemblages within the Westport map-area. Isoreaction-grade representing the reaction muscovite + calcite quartz = anorthite + potassium feldspar is shown.

Ca-plagioclase - Potassium feldspar

Muscovite - calcite - Quartz - Ca-plagioclase - Potassium feldspar

Muscovite - calcite - Quartz

Calcite - Ca-plagioclase

Scapolite

Humite Group

Zoisite

Epidote

grad II, tracing the assemblage tremolite-diopside-quartz-calcite-dolomite across the map, has been mapped in regions suggested as reflecting CO_2 -rich conditions.

In the system $\text{CaO-MgO-SiO}_2\text{-CO}_2\text{-H}_2\text{O}$, the minerals of isoreaction-grad II are constrained to a univariant line on the P-T surface. The intersection of this univariant line with the plane of the map defines a point in P-T space that is independent of fluid composition. Thus the assemblage tremolite-diopside-quartz-calcite-dolomite defines an isoreaction-grad that is directly related to pressure and temperature in the classical sense of Tilley (1924). To the extent that additional elements such as Fe, Mn, Al, etc. are found in the minerals, isoreaction-grad II will expand into a band rather than a line on the map surface. The fact that isoreaction-grad II has been tightly constrained at a number of localities suggests that isoreaction-grad II may reasonably be treated as a line on the scale of mapping reported in this project.

The fact that isoreaction-grad II roughly parallels the pluton suggests that the distribution of pressure and temperature is at least spatially related to the pluton. Considering a pressure of 5 kilobars for this area, as suggested by the sphalerite geobarometer, the data of Skippen (1974) indicate that isoreaction-grad II reflects a temperature of about 600°C . This is in accord with the data of Slaughter, Kerrick and Wall (1975) and Metz (1973) who place the isoreaction-grad

at 620°C at 5 kilobars. Thus the 600°C isotherm, as outlined by isoreaction-grad II, varies from 1/4 mile distant from the pluton to the northwest to about 3/4 mile from it to the south and southwest.

It is possible to establish the position of isoreaction-grads (3) and (7) around the pluton. These isoreaction-grads differ from isoreaction-grad II in that they are traces of isobaric univariant reactions and in P_F -T-X space are divariant. Isoreaction-grad (7), which forms a close envelope around the pluton, is shown by Slaughter, Kerrick and Wall (1975) and Winkler (1975) as having a temperature range of between 630°C and 655°C at 5 kilobars over the range of $X_{CO_2} = .35$ to .95. This is in general agreement with the data of Skippen (1974) which, when extrapolated to 5 kilobars, suggest a slightly expanded temperature range of 600°C to 650°C over the same fluid composition range. The presence of isoreaction-grad (7) between isoreaction-grad II and the pluton indicates an increasing thermal gradient towards the pluton. The temperature increases from 600°C along the isotherm represented by isoreaction-grad II to as high as 630°C to 650°C along isoreaction-grad (7). Isoreaction-grad (3), according to the data of Skippen (1974), is stable over a temperature range of 550°C to 600°C indicating a lowering of the temperature away from the pluton. These data are approximately in keeping with the data presented by Slaughter, Kerrick and Wall (1975), but somewhat at odds with the data of Metz (1973) which show this isoreaction-grad as being stable between 600°C and 630°C with a fluid composition richer than $X_{CO_2} = .85$.

ii) H₂O-rich Fluid — Lower Beverley Lake Area

The isograd pattern in the Lower Beverley Lake area to the north and northwest of the Lyndhurst Pluton diverges significantly from the pluton and wanders complexly across the region. Such a meandering pattern is possibly the result of complex thermal gradients around plutonic activity at depth. However, no geological field evidence was observed to support such a conclusion and the aerial magnetic pattern corresponds directly to the outline of the pluton as presently observed.

It is possible too that this complex isograd pattern results from post-metamorphic folding of the isoreaction-grads. Based on the available field data, there is no supporting evidence for such a conclusion. Mineralogical and textural evidence such as minerals growing across the foliation, highly strained minerals or folded microfabrics are lacking.

An additional explanation (and perhaps the best supported) is that the isoreaction-grad pattern formed in response to a highly variable fluid composition. The composition changes in this area to a high H₂O fluid is supported by a number of lines of evidence. Mineralogically this region is characterized by an abundance of serpentine and chlorite, including a large serpentine zone at the north end of Lower Beverley Lake. Johannes (1969) and Trommsdorff and Evans (1976,

in press in Am. Jour. Sci.) show that both serpentine and chlorite-bearing assemblages are indicative of an H_2O -rich fluid. Epidote in this region is present at two localities, 069356 and 099414, where it coexists with anorthite and potassium feldspar. The intersection of the upper limit of the epidote stability field with the lower limit of the anorthite-potassium feldspar field, as shown in Figure 7.2, indicates a water-rich fluid composition of less than $X_{CO_2} = .25$ at $540^\circ C$ and 5 kilobars. The presence of chondrodite (073364) further supports the existence of a high H_2O fluid.

Texturally the area is characterized by hydrothermal textures which, by analogy with the Tichborne area, are interpreted as reflecting high temperature H_2O -rich fluid circulation.

The relationship between isoreaction-grads (3) and (7) is particularly sensitive to the composition of the fluid phase. At low temperatures, in fluids with a high H_2O content, these isograds are virtually independent of temperature and strongly dependent on the composition of the fluid phase. As the CO_2 content increases at higher temperatures, the relationship of these isograds changes on the $T-X_{CO_2}$ section and they become more clearly related to temperature and lie at a much lower angle to the X_{CO_2} axis. The divergence of these isograds from the trace of the isothermal, isobaric isograd II to the northwest of the Lyndhurst Pluton can therefore be interpreted as a change to fluids with a high H_2O content. Thus, the high angle between isograds

(3) and (7) and the isotherm represented by isograd II, is believed to result from a change to high H_2O fluids as temperatures drop away from the pluton. This pattern is then analogous to the relationship between reactions (3) or (7) and an isotherm on the $T-X_{CO_2}$ section.

The continuation of isoreaction-grad (7) into the Lower Beverley Lake area requires that isoreaction-grad (7) intersect and cross over isoreaction-grad II. The point of intersection of these two isoreaction-grads, shown on the accompanying maps, represents a unique point on the $T-X_{CO_2}$ phase diagram corresponding to the crossover of reaction curve (7) and an isothermal, isobaric line drawn through invariant point II. This occurs at $T=600^\circ C$ and $X_{CO_2}=.30$. Below this crossover point diopside forms by reaction (7) at a temperature (and in equilibrium with an H_2O -rich fluid) lower than that at which the assemblage represented by invariant point II will form. Thus the maximum temperature in the Lower Beverley Lake area is $600^\circ C$.

iii) H_2O -rich Fluid -- Singleton Lake Area

As is the case in the Lower Beverley Lake area, the Singleton Lake region displays a somewhat complex isogradic pattern that cannot be related to folded isoreaction-grads or to unusual and complex thermal gradients. Despite the fact that isoreaction-grad (1) marking the first appearance of phlogopite is present in this area and would tend to provide a CO_2 -rich fluid, there is substantial evidence to suggest

an H_2O -rich fluid. A temperature for the formation of phlogopite in the north Singleton Lake area was determined at location 111319 which represents an isobaric univariant assemblage on isoreaction-grad (1). In addition, a temperature was determined for the higher grade tremolite zone material immediately to the east at location 119320. A temperature of $513^{\circ}C$ was established for the tremolite zone, while the formation of phlogopite at location 111319 was estimated at less than $300^{\circ}C$. At 5 kilobars the data of Skippen (1974) require that tremolite form at $513^{\circ}C$ under only extreme water-rich conditions. The talc stability field is very large at this pressure and a temperature of at least $550^{\circ}C$ is necessary if tremolite is to form under even moderately CO_2 -rich conditions ($X_{CO_2} > .60$). Metz (1973) presents an even larger talc stability field, requiring a temperature in excess of $600^{\circ}C$ if tremolite is to form at $X_{CO_2} > .30$. Only the data of Slaughter, Kerrick and Wall (1975) allow tremolite to form under anything but extreme H_2O -rich conditions at $513^{\circ}C$ and even their data require the fluid to be moderately H_2O -rich ($X_{CO_2} = .30$). A lower total pressure for the area, say around 3 kilobars, would sufficiently reduce the talc stability field, even by the data of Winkler (1975), to allow tremolite, at $513^{\circ}C$, to form under a wide range of fluid compositions, including CO_2 -rich. Such a low pressure, however, would not be in keeping with the $4.75 \pm .5$ kilobars suggested by the sphalerite geobarometer or with the pressure of 4.8 to 6.7 kilobars suggested for the area by Currie (1971) and Currie and Ermanovics (1971).

The possibility of an incorrect temperature estimate needs to be considered. However, there is no good evidence, textures included, to indicate that the temperature is not accurate and it must be concluded that H₂O-rich fluids are suggested by the 513°C temperature for the tremolite-bearing assemblage.

The T-X_{CO₂} section (Figure 7.1) incorporating the component KAlO₂, produced in the present study, indicates that the formation of phlogopite at 300°C occurs in equilibrium with H₂O-rich fluids. In fact, an increase of over 200°C is necessary to produce phlogopite under even moderately CO₂-rich conditions at 5 kilobars pressure. In addition to the actual temperature determination, there is strong textural evidence, as outlined below, to support low-grade conditions in this area. Low-grade textures incorporating unrecrystallized carbonate rhombs and overgrowths upon quartz and feldspar grains, are preserved at a number of localities in this area including 111318, 123321 and 125320 (Appendix B).

It is considered very improbable that such textures would persist to temperatures as high as 500 C. Further evidence to support a rather low temperature, H₂O-rich fluid environment in this area is given by the diopside-bearing assemblage at locality 116320. If this assemblage is assumed to represent CO₂-rich conditions above the 600°C temperature of isoraction-grad II, then a very steep and unusual thermal gradient is necessary in order to preserve the seemingly

lower temperature material several hundred feet to the west, which is even closer to the pluton. If, on the other hand, an H_2O -rich fluid phase was present, the diopside could have formed at much lower temperatures (Figure 7.1) as suggested by the other evidence.

The presence of aluminous silicate minerals such as chondrodite and epidote in the north Singleton Lake area is shown in Figure 7.3 and, as mentioned earlier, is indicative of water-rich conditions. Other aluminous silicate assemblages in this area include Ca-plagioclase and potassium feldspar. The stability field of this assemblage in $T-X_{CO_2}$ space intersects the dolomite-potassium feldspar-phlogopite-calcite reaction curve, which is mapped in this area as isoreaction-grad (1), at a unique point. At 5 kilobars this point of intersection, as shown in Figure 7.2, occurs at a temperature of $545^{\circ}C$ and a fluid composition of $X_{CO_2} = .75$. Such conditions are in contrast with both the low temperatures and water-rich fluid conditions postulated for this area on the basis of geothermometry, mineralogical and textural evidence. This conflict appears to reflect highly local variations in temperature and/or fluid composition which cannot be resolved with the available data. A more detailed investigation of this area is warranted. Tentatively, the north Singleton Lake region is interpreted as a water-rich, low-temperature environment, requiring that isoreaction-grad II pass to the west of this region as shown on accompanying maps C and E.

b) Carleton Place Map-Area

The Carleton Place map-area is characterized by an abundance of low-grade tremolite-bearing marble which contains small patches of unreacted quartz-dolomite. The dominantly low-grade tremolite "plain" is bounded by higher-grade metamorphism along its western, eastern and northern margins. In a style of metamorphism similar to that established around the Lyndhurst Pluton, the increasing metamorphic grade appears to be related to specific plutonic masses.

The large zones of quartz-dolomite and tremolite-bearing material that compose the bulk of the Carleton Place map-area are interpreted as reflecting original low-grade equilibrium conditions. Low-grade sedimentary features such as preserved overgrowths on quartz and feldspar grains (see plate 3F), unrecrystallized sedimentary dolomite rhombohedrons, rounded to subrounded grains of quartz which retain a clastic character (see plate 3A, B, C) and the presence of unrecrystallized sedimentary textures in most of the low-grade assemblages (see plate 3C, 3E) are taken to indicate that the area has never been subjected to a grade of metamorphism higher than that presently observed. In addition to the textural evidence and the calc-silicate mineral assemblages which are taken as indicating low-grade conditions, the aluminum silicate assemblages, which consist of muscovite-calcite-quartz and anorthite-calcite (see Figure 7.5) also are consistent with low-grade metamorphic conditions (Figure 7.2).

The isobaric invariant five-mineral assemblage tremolite-diopside

quartz-calcite-dolomite, present in the southern part of the Carleton Place map sheet, indicates a high CO_2 fluid as none of the existing equilibrium models (Metz and Trommsdorff, 1968; Skippen, 1974; Slaughter, Kerrick and Wall, 1975) allows this assemblage on the water-rich part of the T-X diagram. The presence, at locality 921037, of the two isobaric univariant assemblages quartz-dolomite-tremolite-calcite and tremolite-calcite-quartz-diopside is also compatible with CO_2 -rich conditions, assuming that the presence of these two assemblages can be taken to indicate a virtually isothermal, isobaric point close to invariant point II on Figure 7.1.

The aluminous assemblage of Ca-plagioclase-calcite which, as shown on Figure 7.5, is present in the Carleton Place map-area rather than epidote or zoisite, similarly suggests conditions more to the CO_2 -rich side of the T-X diagram. That the low-grade area is CO_2 -rich is further indicated by the absence of talc in potassium-poor dolomitic rocks. Talc should be abundant in rocks of such composition if H_2O -rich fluids prevailed.

In summary, the major part of the Carleton Place map-area is interpreted as reflecting low-grade metamorphic conditions, the region never having attained a higher metamorphic grade. The area is further interpreted as containing mineral assemblages formed in equilibrium with CO_2 -rich fluids.

Figure 7.5 Distribution of aluminous silicate assemblages
within the Carleton Place map-area.

Ca-plagioclase - potassium feldspar	●
Muscovite - calcite - quartz - Ca-plagioclase - Potassium feldspar	●
Muscovite - Calcite - Quartz	■
Calcite - Ca-plagioclase	▲
Scapolite	▼
Humite group	□
Zoisite	○
Epidote

Given that a CO_2 -rich fluid is indicated for the major part of the Carleton Place map-area, it is reasonable, lacking evidence to the contrary, to suggest that the development of the higher grade zones along the margin of the low-grade areas also reached equilibrium with such a fluid. Accordingly isoreaction-grad II has been mapped within these higher grade zones. It is possible that H_2O -rich fluids may have been established in these higher grade zones. Carmichael (1970), Allen (1976) and others have shown that higher grade zones may develop around some plutons as a result of changing fluid compositions as the pluton is approached. It is usually very difficult to distinguish the effects of changing fluid composition from the effects of increasing temperature but both possibilities must be kept in mind while interpreting the metamorphic grade from the distribution of mineral paragenesis. However, within the high-grade zones of the Carleton Place map-area, evidence, as outlined in the following sections, to support an H_2O -rich fluid is, for most part, lacking and a CO_2 -rich fluid is more probable in most cases.

Eastern Metamorphic Zone

Isoreaction-grad II, along the eastern margin of the Carleton Place marble belt, outlines a north-south trending zone of increasing metamorphic grade eastward towards the monzonite intrusions along the Mississippi River. Isoreaction-grad II, it was noted, can reflect isothermal conditions if the total pressure remains constant. At 5 kilobars the data of Skippen (1974), Slaughter, Kerrick and Wall (1975) and Winkler (1975) indicate that isoreaction-grad II reflects a

temperature of about 600°C under very CO_2 -rich fluid conditions ($X_{\text{CO}_2} = .98$). The 600°C isotherm then, may be interpreted from isoreaction-grad II as running north-south along the eastern margin of the Carleton Place marble belt. Further to the east increased temperatures are indicated by isoreaction-grad (6) which, as pointed out by Winkler (1975), can act as an indication of temperature principally because of its very shallow slope in T - X_{CO_2} space. The data of Skippen (1974) place the stability of this reaction between 600° and 625°C at 5 kilobars pressure. This narrow temperature range is maintained over a range of fluid composition from $X_{\text{CO}_2} = .38$ to $X_{\text{CO}_2} = .98$. As expected, isoreaction-grad (6) in this eastern zone roughly parallels isoreaction-grad II reflecting a series of parallel isotherms increasing in temperature to the east.

Isoreaction-grad (7) representing the first appearance of diopside is also present in this area. Unlike isoreaction-grads II and (6), it has a substantial temperature variation with changing fluid composition and cannot be used to accurately reflect changing metamorphic grade. According to the data of Skippen (1974) the spatial relationship of isoreaction-grad (7) to isoreaction-grad (6) at 5 kilobars is strongly a reflection of the fluid composition. At extremely high X_{CO_2} fluid compositions (greater than $X_{\text{CO}_2} = .94$) diopside will form prior to forsterite and isoreaction-grad (6) will be on the up-grade side of isoreaction-grad (7). At intermediate fluid compositions ($X_{\text{CO}_2} = .60$ to $.94$) at this pressure, diopside forms at higher temperatures

than forsterite. Unfortunately, the validity of these data cannot be tested in this area. The distribution of forsterite and diopside assemblages can be interpreted in this zone to indicate that either diopside or forsterite formed first. The relative position of isoreaction-grads (6) and (7), shown on accompanying map A, is based mainly on evidence from portions of this zone in the Perth map-area, which tends to favour forsterite as the higher-temperature phase.

Isoreaction-grad (3), representing the isobaric univariant reaction (3), defines the low-grade side of isoreaction-grad II at the northern and southern extremities of this zone. This isoreaction-grad is strongly dependent upon variations in fluid composition and as expected, does not closely follow the isothermal isoreaction-grad II. The nature of the fluid phase can be gained from a temperature of 478°C obtained for an isobaric univariant assemblage on isoreaction-grad (3) located at locality 028004. This temperature, for the assemblage tremolite-calcite-dolomite-quartz is somewhat inconsistent with the experimental data at 5 kilobars. Skippen (1974) and Winkler (1975), because of the large talc stability fields, indicate that the observed reaction cannot occur at such a low temperature at any fluid composition. This would suggest that either the temperature is too low or that the pressure is too high. The possibility of the temperature being excessively low needs to be considered, especially when it is recognized that the area immediately surrounding the locality 028004 shows extensive retrograde alteration towards the H_2O -rich side of the $T-X_{CO_2}$ section.

Alteration of tremolite to talc, diopside to chlorite-serpentine, and forsterite to serpentine is extensive. The abundance of talc and serpentine in this zone, however, appears related only to retrograde phenomena. No primary talc or serpentine suggesting water-rich prograde conditions was observed. The strong evidence of retrograde alteration in this area may indicate that the observed temperature is too low because of re-equilibration of calcite during the retrograde alteration. However, the sample section chosen for temperature determination displays very minimal alteration and has a well-crystallized mosaic texture. It should have yielded a reasonably accurate temperature. The validity of this low temperature is supported by low temperatures determined in the surrounding regions (895033, 920035) which also display inconsistencies with high pressure data of Skippen (1974) and Winkler (1975). The temperatures and observed assemblages are consistent with the experimental data of these workers at a somewhat reduced pressure, around 3 kilobars. Slaughter, Kerrick and Wall (1975) determined a talc field that decreases in size with increasing pressure and is consistent with the observed assemblages at the temperatures indicated. The fluid composition suggested by Slaughter, Kerrick and Wall for the observed assemblage at 5 kilobars and 478°C is water-rich at $X_{\text{CO}_2} = .25$. If the fluid phase is considered water-rich, the diopside and forsterite assemblages in this region cannot be considered as necessarily indicating temperatures higher than isoreaction-grad II and the position of the isoreaction-grad cannot be determined. This problem, like the difficulties with the data of Skippen (1974) and Winkler (1975) can be resolved if a lower temperature is assumed. A

pressure of 3 kilobars at 478°C indicates a CO_2 -rich fluid ($X_{\text{CO}_2} = .70$) consistent with the observed assemblage no matter which set of experimental data is used. A pressure of 3 kilobars also makes the observed assemblages and temperatures from other parts of the area consistent with the experimental data. It would appear reasonable that the assumption of a 5 kilobar pressure, while valid in the southern portion of the thesis area, is too high for the northern section. At 3 kilobars isoreaction-grads II and (6) indicate isothermal conditions of approximately 540°C and 560 to 580°C respectively (Skippen, 1974).

Northern Metamorphic Zone

Isoreaction-grad II in the northern part of the Carleton Place map-area outlines an east-west trending high-grade envelope around the southern margin of the Pakenham Dome. Higher temperatures closer to the pluton are suggested by diopside-bearing assemblages which form a broad zone surrounding the Dome.

Temperatures have been determined at several localities on the low-grade side of isoreaction-grad II and in at least two instances, are unusually low. A temperature of 428°C was determined at locality 921037 in rocks which contain both a quartz-dolomite-calcite-tremolite assemblage and a quartz-tremolite-calcite-diopside assemblage. Isoreaction-grads (3) and (7), both highly dependent upon fluid composition, intersect at this locality. Isoreaction-grad II

must also pass through this locality, thereby creating an inconsistency between the 540°C temperature indicated for this locality by isoreaction-grad II and the 428°C temperature suggested by the geothermometer for the assemblage quartz-calcite-tremolite-dolomite. Reaction (3) should not occur at 3 kilobars even under extremely water-rich fluid conditions at 428°C . A possible explanation as to why the determined temperature may be too low is given by the slope of the dolomite-calcite solvus as shown in Figure 7.8. It is obvious that for calcites having an initially low magnesium content (corresponding to a low metamorphic temperature) the loss of a given mole fraction of magnesium (ΔX_{Mg}) will cause a relatively large drop (ΔT_2) in the indicated temperature. A corresponding loss of magnesium (ΔX_{Mg}) from a high temperature, high magnesium calcite will result in a much smaller drop (ΔT_1) in the indicated temperature. It is expected therefore that temperatures from lower grade metamorphic terrains will have a greater tendency to deviate negatively from the true temperature.

A temperature of 390°C was determined for the same assemblage (tremolite-calcite-quartz-dolomite) located $1\frac{1}{2}$ miles to the west at location 895033. Similarly low temperatures of 407°C and 418°C at localities 920035 and 885025 were determined for unreacted quartz-dolomite assemblages. Although this isobaric divariant assemblage can exist at these low temperatures over a wide range of fluid compositions (.09 to $1.0 X_{\text{CO}_2}$), the temperatures are considered somewhat low considering their close proximity to isoreaction-grad II. It is

Figure 7.8 - Calcite - dolomite solvus. The loss of a given amount of MgCO_3 from calcite (ΔX_{mg}) causes a large temperature discrepancy (ΔT_2) on an originally low magnesian calcite while a relatively small temperature discrepancy (ΔT_1) is caused in a high magnesian calcite. Temperatures determined in high-grade (temperature) zones should more closely approximate the original equilibrium temperature than those temperatures determined in low-grade terrains.

possible that a very steep thermal gradient is present in this area and that temperatures only a short distance away from isoreaction-grad II are in fact very low. The steep thermal gradients that would be necessary for the formation of tremolite if such low temperatures for unreacted quartz-dolomite are assumed are not indicated in this region. The style of metamorphism in the Carleton Place area indicates that the formation of tremolite occurs in response to only slight changes in the local fluid composition and temperature. Gradients of 100°C or more over a few hundred or thousand feet are not indicated for the majority of the low-grade area and it is thought that, in general, the unreacted quartz-dolomite existed at temperatures close to that necessary for reaction (3) to proceed. It is concluded that rather than indicating steep thermal gradients, the temperatures in the Carleton Place area indicate lower than true metamorphic temperatures.

Western Metamorphic Zone

Isoreaction-grad II indicates an increase in metamorphic grade to the west along the western margin of the map sheet. A dioritic to granodioritic intrusive complex is mapped in this region. Isoreaction-grad II is shown as being marginal to this intrusion more to be consistent with the style of metamorphism elsewhere than to conform to concrete petrographic data which are minimal in this zone.

Higher temperatures westward towards the intrusive complex are

indicated by both diopside (837958, 840954) and forsterite assemblages in this direction. The majority of assemblages in this area are tremolite-bearing only and, unfortunately, are inconclusive with regard to the increase in metamorphic grade. Isoreaction-grad (6), which can act as a temperature indication (Winkler, 1975) is defined at only one locality (835027). The presence of wollastonite (Tatlock Quarry) and idocrase (837958) close to the pluton confirm the contact nature of the metamorphism in this zone.

The fluid phase, in at least the central part of this zone, is indicated as being H_2O -rich by the presence of chondrodite which, according to the data of Bourne (1974) is stable only on the H_2O -rich side of the T-X diagram. Ca-plagioclase-calcite is also present in this region (Figure 7.2) but the stability field of this assemblage extends over a range of fluid compositions overlapping partly with that of chondrodite (Richard Moore, 1976, personal communication) and cannot be used to define a definite fluid composition.

Southern Metamorphic Zone

A north-south trending high-grade area 2 miles west of Lanark is outlined by isoreaction-grad II. No apparent source of the metamorphic gradient is present and the cause of this zone is not understood. It is possible that a heat source is present at a shallow depth but no geological or geophysical evidence exists to support such a conclusion. It was suggested that this zone may

represent a Fluorine-rich area, reducing substantially the temperature at which the observed assemblages could have formed (Skippen, 1976 - communication). However, fluorine analysis of the material in the area did not show systematic fluorine enrichment and the problem of what causes the increasing grade in this area remains unsolved.

Isoreaction-grad II is defined in the northern part of this zone by three occurrences of the isobaric invariant assemblage: quartz-calcite-tremolite-dolomite-diopside which at 3 kilobars defines a temperature of about 540°C. Isoreaction-grad (7) although isobarically univariant and hence dependent upon fluid composition closely parallels isoreaction-grad II over most of its length indicating a fairly constant fluid composition. As isoreaction-grad (7) defines at fluid composition of $X_{\text{CO}_2} = .97$ at the isobaric invariant point 2, it is suggested this fluid composition is maintained over most of this zone.

Isoreaction-grad II in the southern half of this zone (north-western Perth sheet) is not defined by isobaric invariant assemblages but rather is bracketed between lower grade quartz-dolomite assemblages and higher grade diopside-bearing assemblages. The constraints placed on the isoreaction-grad in this area, especially to the west, are not tight. It is difficult to establish a relationship of isoreaction-grads (7) and II in this region making it difficult to comment upon the question of a fluid composition gradient. There is some slight deviation of the two isoreaction-grads in the vicinity of

of location 874807 presumably caused by a local fluctuation in fluid composition.

Two temperatures of 449° and 478°C were determined at locations 868808 and 891807 respectively. Both of these temperatures were for tremolite-calcite-dolomite isobaric divariant assemblages and hence are not especially useful for determining a precise fluid composition. The experimental data of Skippen (1974) at 3 kilobars indicate that the assemblage tremolite-dolomite-calcite exists at these temperatures only under an H_2O -rich fluid ($X_{\text{CO}_2} = .35$). Winkler, (after Metz, 1973 and 1975) because of the greatly expanded talc field, does not show it stable under any fluid composition at the temperatures indicated. Slaughter, Kerrick and Wall (1975) (extrapolated to 3 kilobars) depict this assemblage at 478°C as being stable over a considerable range of fluid compositions including those up to $X_{\text{CO}_2} = .75$. These data are more in keeping with the determined temperatures. The data of Skippen (1974) would suggest a CO_2 -rich fluid if the indicated temperatures were only a few tens of degrees higher.

Low Grade Areas in the Carleton Place Map Sheet

The large central region of the Carleton Place map-area is dominated by a "sea" of tremolite-bearing marbles. The first appearance of tremolite can be observed in a number of localities where the reaction of quartz-dolomite to produce tremolite has not

yet gone to completion (899849, 888894, 855937, 854938, 923004, etc.). Isoreaction-grad (3) representing isobaric univariant reaction (3), Figure 7.1, encloses large patches of unreacted quartz-dolomite. This isoreaction-grad, which is dependent upon fluid compositions, wanders circuitously across the map sheet. In general, however, it tends to delineate low-grade areas which trend more or less parallel to the surrounding isotherm patterns. Isoreaction-grad (3) in outlining both the Clyde River and Lanark low-grade regions travels over most of its length roughly parallel to isoreaction-grad II, which suggests that in most cases the fluid composition remains constant over considerable distances.

Temperatures as determined by the calcite-dolomite solvus geothermometer upon either quartz-dolomite or quartz-dolomite-tremolite-calcite assemblages are consistently low. They have been determined at the following localities: 920035 = 407°C ; 921037 = 428°C ; 895033 = 390°C ; 885025 = 418°C and 028004 = 478°C . It is thought that these temperatures are probably somewhat lower than the true metamorphic maximum but they do serve to indicate that the region as witnessed by the mineral parageneses, is a low temperature environment.

c) Perth Map-Area

Isoreaction-grads in most of the Perth map-area are apparently controlled by the distribution of plutons. High-grade metamorphic zones

surround the major intrusive bodies, leaving discontinuous low-grade zones and patches in regions removed from the plutons. The northern Perth area is essentially a continuation of the metamorphic zones noted in the Carleton Place map-area. The northwestern-most part of the map sheet is a continuation of the southern metamorphic zone of the Carleton Place map-area. Somewhat to the east of this zone is the continuation of the eastern metamorphic zone of the Carleton Place sheet which becomes the Bennett Lake metamorphic zone in the Perth region.

Bennett Lake Metamorphic Zone

Isoreaction-grad II, continuing southwestward from the Carleton Place map sheet, runs along Bennett Lake outlining a higher grade zone which increases in grade eastward towards the syenitic intrusion two miles east of the lake. Isoreaction-grad (6), as was the case in the Carleton Place area, roughly parallels isoreaction-grad II on the high-grade side, also indicating increasing temperature eastward towards the intrusion. A temperature of 573°C was determined for isoreaction-grad (6) on the isobaric univariant assemblage at location 906788. This temperature is completely consistent with the data of Skippen (1974) at 3 kilobars, and indicates a CO_2 -rich fluid ($X_{\text{CO}_2} = .70$). The data of Winkler (1975) place reaction (6) well above 620°C for CO_2 -rich fluids. Such data are inconsistent with the temperature of 573°C determined for this reaction in the field. The basic disagreement between the data of Skippen (1974) and that presented by Winkler (1975) appears to be

involved with the presence of fluorine in the starting material used by Metz. Skippen (1976 - personal communication) has shown that his talc data can be adjusted to fit that of Metz by considering the influence of fluorine upon the tremolite and talc reactions. The effect of fluorine upon the topology of the T-X_{CO₂} section is to greatly increase the stability of those phases which accommodate fluorine. In the case of reaction (6) it is suspected that the high temperature for this reaction suggested by Winkler is due entirely to the expansion of the tremolite field by fluorine. Removal of the fluorine effect would reduce reaction (6) to lower temperatures somewhere close to those suggested by Skippen (1974). The data of Skippen (1974) and Winkler (after Metz, 1973, 1975) appear quite compatible when the influence of fluorine is considered.

Isoreaction-grad II and isoreaction-grad (6) are interpreted as reflecting the 540°C and 570 ± 10°C isotherms respectively at a total pressure of 3 kilobars. Isoreaction-grad (7) is interpreted as passing between isoreaction-grad II and (6). This is based mainly on the observation that diopside is forming prior to forsterite. Isoreaction-grad (7) travels roughly parallel to isoreaction-grads II and (6) indicating a fairly constant fluid composition, presumably CO₂-rich.

A high-grade zone is present on the east side of the intrusion, opposite the Bennett Lake zone. The northern and central parts of this

eastern zone are characterized by high-grade forsterite-bearing assemblages, indicating that isoreaction-grad II is present farther to the east. However, there is another intrusion in this direction which also appears to be influencing this area. The metamorphic aureoles from the two intrusions appear to overlap in this region resulting in a metamorphic region of a grade higher than isoreaction-grad II. To the south of this overlap zone, isoreaction-grad II is present enclosing a lower grade quartz-dolomite area. The presence of seemingly low-grade quartz-dolomite so close to the Bennett Lake intrusive body is interpreted as indicating high temperature, CO_2 -rich conditions. The data of Skippen (1974), Slaughter, Kerrick and Wall (1975), and Winkler (1975) all indicate that quartz-dolomite is stable up to, and in fact a few degrees beyond, the temperature indicated by isoreaction-grad II, if the fluid is extremely CO_2 -rich. The formation of such a CO_2 -rich fluid must have occurred at fairly low temperatures to prevent reaction (3) from taking place. The production of a CO_2 -rich fluid is usually accomplished by a decarbonation reaction which as it proceeds builds up a progressively enriched CO_2 fluid. The reaction involving the production of phlogopite from potassium feldspar-dolomite is the only decarbonation reaction occurring before the formation of tremolite from quartz-dolomite. A CO_2 -rich fluid built up from this reaction ensures that the as yet unreacted quartz-dolomite remains stable to temperatures around that represented by isoreaction-grad II. Phlogopite is a common constituent in marbles from this area (present at the localities 855675, 864693) and could

reasonably account for the presence of a CO_2 -rich fluid in this area.

It is interesting to speculate on the possibility of a CO_2 -rich fluid being derived from decarbonation reactions taking place in the surrounding area. If the Perth Pluton were intruded slightly before or at the same time as the intrusion along Bennett Lake, a CO_2 -rich fluid could have been derived from metamorphism around the Perth Pluton. A generally CO_2 -rich environment into which the Bennett Lake material could have been intruded may have been produced by the Perth Pluton and would have enabled the observed quartz-dolomite to remain stable close to the Bennett Lake intrusion as presently observed. Immediately south of this quartz-dolomite region the pattern of metamorphic isograds becomes increasingly complex. Small intrusive bodies are scattered over this area and it is difficult without more detailed investigation to separate the metamorphic influence of each body. In general, the metamorphic grade as outlined by isoreaction-grad II appears to be increasing away from the central quartz-dolomite area. Both isoreaction-grads (6) and (7) are present to the west of isoreaction-grad II indicating an increase in grade in this direction, presumably in response to the Bennett Lake intrusion and/or a small body immediately south of it. The grade also increases eastward toward the Perth Pluton. Unfortunately, there is no carbonate material exposed in this direction and the increasing grade must be inferred from indications of increasing grade towards the pluton along its southwestern, southern and eastern margins.

A temperature determined from the isobaric univariant forsterite assemblage west of the quartz-dolomite area, at location 834662 indicates that reaction (6) took place at about 520°C. Skippen (1974) indicates that at 3 kilobars and 520°C reaction (6) (Skippen's reaction 32) is stable at a fluid composition of $X_{\text{CO}_2} = .15$. Such an H₂O-rich fluid composition indicates a dramatic change from the CO₂-rich environment suggested by the quartz-dolomite assemblages adjacent to the intrusion along Bennett Lake. It would appear that if this temperature is valid (there is some retrograde alteration in this sample so that some Mg may have been removed yielding a somewhat low temperature) the H₂O-rich fluid is only local as a more CO₂-rich fluid composition is indicated at location 860653; ½ mile to the east. A temperature of 473°C at this locality indicates that reaction (3) occurred at a fluid composition of $X_{\text{CO}_2} = .65$ (Skippen, 1974). A fluid even richer in CO₂ ($X_{\text{CO}_2} = .70$) is suggested for this reaction if the data of Slaughter et al. (1975) are considered. Taking account of the evidence, it appears that the fluid composition in this area varies from very CO₂-rich (greater than $X_{\text{CO}_2} = .90$) along the Bennett Lake intrusion to moderately CO₂-rich ($X_{\text{CO}_2} = .60$ to $.70$) southward around Christie Lake. A locally more H₂O-rich fluid may be indicated westward in the vicinity of locality 834662.

Tay River - Otty Lake Metamorphic Zone

Isoreaction-grad II outlines a roughly east-west trending

zone running from the Tay River in the west to Otty Lake in the east. The metamorphic grade is increasing to the north possibly in response to the plutonic body west of Perth. The extent of the plutonic activity is difficult to determine. Aeromagnetic data imply that a large ($3\frac{1}{2}$ mile diameter) intrusive body at a shallow depth is located 3 miles west of Perth.

Isoreaction-grad II is interpreted as representing isothermal conditions of around 540°C . Increasing temperature northward towards the plutonic activity is suggested by a diopside zone which occurs on the high-grade side of isoreaction-grad II. Isoreaction-grad (7) is defined at only a few scattered localities and is not extensive enough to allow an estimate to be made of just how constant the fluid composition is in this zone.

Unreacted quartz-dolomite assemblages at the north end of Christie and Pike Lakes, and at the east side of Otty Lake, indicate a decreasing metamorphic gradient away from the Perth area. Temperatures of less than 350°C were determined for the quartz-dolomite assemblages north of Christie and Pike Lakes (857634, 948621). Even if somewhat low, these temperatures serve to illustrate that low-grade material can exist in areas removed from the plutonic influence.

It was determined earlier that isoreaction-grad (3) north of Christie Lake reflected a fluid composition of between $X_{\text{CO}_2} = .60$

to .70. In most other areas of the zone this isoreaction-grad appears to remain fairly parallel to isoreaction-grad II and most probably reflects a similar fluid composition.

Westport Metamorphic Zone

The southern portion of the Perth map-area and the extreme northern Westport map-area is occupied by the high-grade metamorphic aureole surrounding the Westport plutonic complex. Isoreaction-grads II, (6), (7) and (3) outline a broad, high-grade zone which at its widest point extends $3\frac{1}{2}$ miles north of the pluton. Isoreaction-grad II has been mapped only on the north side of the complex and closer to the pluton gives way to isoreaction-grads (7) and (6). Isothermal conditions of approximately 540°C at 3 kilobars are interpreted for isoreaction-grad II in this zone. Isoreaction-grad (6) defining the first appearance of forsterite, has been indicated by Winkler (1975) as being a reasonable indicator of temperature. At 3 kilobars isoreaction-grad (6) indicates a temperature of between 560° and 580°C over a fluid composition range of $X_{\text{CO}_2} = .30$ to .95 (Skippen, 1974). In spite of the fact that large plutons can be characterized by steep thermal gradients and are correspondingly enveloped by closely spaced isobarically invariant isoreaction-grads, (i.e., Lyndhurst Pluton) the distribution of isotherms north of the Westport Plutons is very broad and fairly high temperatures are indicated several miles north of the pluton outline. This broad

expansion of isotherms, especially those in the Pike Lake area, north of the pluton may reflect fluid composition around the intrusion. There is strong evidence in this region to suspect that water-rich fluids were prevalent at least during retrograde metamorphism. Hydrothermal textures and abundant retrograde alteration of diopside and forsterite to serpentine-chlorite mixtures are characteristic of this region. However, it is strongly suggested that this water-rich fluid circulation was a late stage phenomenon. A temperature of 378° was determined for a forsterite assemblage at location 902568 while a temperature of 359°C is indicated for an isobaric invariant assemblage on isoreaction-grad II (981563). It is obvious that the hydrothermal textures and abundant retrograde alteration in this area reflect a low temperature period of magnesium removal, probably late stage fluid circulation. However, calcites in rocks with similar textures in the northern Perth and Tichborne areas have maintained a high magnesium content and this in contrast to the present area were formed as a result of high temperature, probably prograde fluid circulation.

That water-rich fluids were present during prograde metamorphism is suggested by the presence of chondrodite west of Pike Lake (see Figure 7.6). Ca-plagioclase-calcite assemblages are also present in the immediate area and while not definitive of the fluid composition, are compatible as mentioned previously, with an H_2O -rich fluid. The extent of chondrodite has not been determined nor is it known how far to the north water-rich fluid circulation may have

Figure 7.6 Distribution of aluminous silicates within the
Perth map-area.

Ca-plagioclase - Potassium feldspar

Muscovite - Calcite - Quartz - Ca-plagioclase - Potassium feldspar

Muscovite - Calcite - Quartz

Calcite - Ca-plagioclase

Scapolite

Humite group

Zoisite

Epidote

extended (prograde circulation). However, it is possible that the H_2O -rich fluid conditions suggested by chondrodite extended considerably northward. This could make the large diopside zone north of Pike Lake indicative not of high temperatures distant from the pluton but rather indicative of an expanded H_2O -rich fluid circulation in this direction. The interpretation of isoreaction-grad II as shown north of Pike Lake would not be valid in such a situation and its position should be viewed with the possibility of H_2O -rich fluid circulation in this area kept in mind.

Although knowledge of the metamorphism on the south side of the plutonic complex is limited because of the scarcity of marble in this direction and the presence of the Rideau Lake fault immediately south of the intrusions, it does appear that the metamorphic zones are much narrower in this direction than they are to the north. The diopside and forsterite zones are at most 1 km. from the pluton and generally closely envelope the plutons. No low-grade material is present on this side of the pluton and it has not been possible to outline isoreaction-grad II. It has been possible to map isoreaction-grad (6) which is interpreted as indicating roughly isothermal conditions of between $560^{\circ}C$ and $580^{\circ}C$. This isotherm is approximately parallel to the outline of the Rideau Lake Pluton and is terminated to the south by the Rideau Lake fault.

Otter Lake Metamorphic Zone

The Otter Lake region, situated in the southeast corner of the

Perth map-area, and characterized by an extensive area of low-grade quartz-dolomite assemblages, is bounded on the north and east by a diopside and forsterite zone respectively. The quartz-dolomite assemblages are characterized by low-grade textures. Temperatures of less than 320°C have been determined at the quartz-dolomite localities of 089574, 095567 and 104563. Such low temperatures are considered appropriate both for the quartz-dolomite assemblage and for the low-grade textures observed at most localities in this zone.

The low-grade zone shows an increase in metamorphic grade to the north as indicated by isoreaction-grad II, which separates a diopside zone to the north from the lower grade quartz-dolomite material to the south. Presumably isoreaction-grad II reflects isothermal conditions of around 540°C at 3 kilobars, with the diopside material to the north indicating slightly higher temperatures. Isoreaction-grad (7) is constrained by only two localities and hence is not extensive enough to enable the relationship between it and isoreaction-grad II to be established. It does appear from abundant serpentine alteration and development of hydrothermal textures, that H_2O -rich fluids were present during late stage cooling. It has not been possible to estimate the fluid composition present during prograde metamorphism and the assumption has been made in the mapping of isoreaction-grad II that the fluid was moderately CO_2 -rich (greater than $X_{\text{CO}_2} = .40$ at 3 kilobars).

An increase in grade to the east and to the southeast is indicated by isoreaction-grads II and (6). Forsterite assemblages are present at several localities in this zone and usually show abundant serpentine alteration. The cause of this increase in grade appears to be intrusive activity just east of Otter Lake. A small granitic body can be observed projecting out from under the Paleozoic cover and presumably there may be more igneous rock hidden beneath the Paleozoic cover.

Isoreaction-grad II and (6) are closely spaced and parallel indicating a thermal gradient increasing to the east. Although the presence of forsterite, which has been used to bracket isoreaction-grad II, usually indicates high temperatures over a wide range of fluid compositions (Skippen, 1974; Winkler, 1975) there is some textural evidence in this area to suggest that the forsterite may have formed at considerably reduced temperatures. Location 114571 contains abundant serpentine alteration, some definitely pseudomorphing forsterite and diopside, in a hydrothermal texture.

This hydrothermal texture also contains zoned rhombs of carbonate. The presence of carbonate rhombs is considered characteristic of low temperature and they have been observed to disappear with even the most rudimentary recrystallization. Such rhombs are present in the nearby quartz-dolomite area where their presence is expected. The evidence that forsterite and diopside formed at low temperatures is

consistent only with extremely H_2O -rich fluid conditions. Water-rich conditions are indicated by the presence of chondrodite occurrences (Figure 7.6) in the northeast corner of the Westport map-area. However, immediately to the southwest of these chondrodite localities, Ca-plagioclase-potassium feldspar is stable in preference to muscovite-calcite-quartz, suggesting higher temperature, more CO_2 -rich conditions. This area presents several problems and inconsistencies and should be further studied.

d) Westport Map-Area

The Westport map-area, like the Carleton Place and Perth map-areas to the north, is characterized by high-grade metamorphic aureoles around the major plutons. Lower grade remnants are present in areas removed from the influence of the intrusive activity. In general four metamorphic subdivisions can be recognized. Two of these, around the Westport and Lyndhurst Plutons, have been previously discussed. The remaining metamorphic zones include the Red Horse-Charleston Lake region and the Crow Lake pluton area.

Red Horse-Charleston Lake Metamorphic Zone

The area of relatively low-grade metamorphism, north of Singleton Lake in the Lyndhurst Pluton area, in addition to increasing in grade towards the Lyndhurst Pluton also increases in grade eastward.

towards Red Horse and Charleston Lakes. While this area has not been extensively investigated during the present study, an increasing metamorphic grade in this direction is indicated. Wynne-Edwards (1967) confirms the high-grade nature of this area and reports extensive diopside and serpentine after forsterite in the Charleston Lake area.

The increasing grade in this direction is indicated by the presence of isoreaction-grad II which runs north-south along the west side of Red Horse Lake. By analogy with the Lyndhurst Pluton isoreaction-grad II is interpreted as reflecting isothermal conditions of about 600°C at 5 kilobars. Isoreaction-grad (7) is present on the up-grade side of isoreaction-grad II and in a CO_2 -rich environment reflects temperatures of between 600° and 650°C , depending upon the local fluid composition (Skippen, 1974; Slaughter, Kerrick and Wall, 1975). Unfortunately, isoreaction-grad II in this region is poorly constrained and the relationship between the fluid composition dependent isoreaction-grad (7) and the isothermal isoreaction-grad II cannot be determined with any degree of accuracy. The assumption of a CO_2 -rich fluid seems reasonable for this area especially in view of the abundance of phlogopite, the formation of which would favour a CO_2 -rich environment. A small area of granite exposed at the eastern side of Charleston Lake indicates intrusive activity in that direction which may be the cause of the high-grade metamorphism. Considerably more study of this area is necessary before any further conclusions can be reached.

Crow Lake Pluton - Opinicon Lake Metamorphic Zone

The Crow Lake Pluton is located 2 to 2½ miles west of the Lyndhurst Pluton in a relatively carbonate-free terrain. While investigation of the metamorphic effect of this pluton in the present study is restricted to a band of marble 2 miles west, in the Opinicon Lake area, the metamorphism of pelitic rocks immediately surrounding the pluton has been studied by Currie (1971) and Currie and Ermanovics (1971). They concluded that temperatures and pressures adjacent to the pluton were in the order of 640°C to 755°C and 4.8 to 6.7 kilobars. This is in good agreement with the metamorphic conditions suggested by temperature and phase relations in the carbonates which indicate marginally lower temperatures of around 575°C to 600°C at 5 kilobars.

Isoreaction-grad II, reflecting the 600°C isotherm at 5 kilobars, is interpreted as running mainly parallel to the outline of the Crow Lake Pluton. The northern extremity of the isoreaction-grad deviates from the pluton, although this may be accounted for by the presence of chondrodite south of Newboro Lake (Figure 7.3) which reflecting H₂O-rich fluid conditions would make isoreaction-grad II invalid in this direction.

The close proximity of the isobaric univariant assemblages represented by isoreaction-grad (3) and (7), which share at least one common location (943369), suggest that the two reactions are occurring

under similar conditions, most probably around those indicated by isobaric invariant point II on Figure 7.1. A temperature of 573°C at location 931382 indicates that reaction (3) is occurring under CO_2 -rich conditions close to that of isoreaction-grad II. The temperature of 600°C at 5 kilobars interpreted for isoreaction-grad II is in excellent agreement. A substantially lower temperature of 279°C was determined for the quartz-dolomite assemblage at location 940376. This temperature is abnormally low relative to the generally high temperature environment interpreted for this immediate area. Textural investigation of the section analyzed indicates that the calcite occurs as unusual rounded aggregates distinctly segregated within a dominantly mosaic framework. The exact significance of this segregation is not understood but it is thought that it in some way reflects a calcite re-equilibrated at lower than peak metamorphic temperatures. In view of the unusual texture of this sample and the abnormally low temperature with respect to the surrounding environment, this temperature has been ignored.

There has been no temperature determined for the diopside zone but assuming a CO_2 -rich fluid, the data of Skippen (1974) and Slaughter, Kerrick and Wall (1975) indicate that isoreaction-grad (7) will occur over the temperature range 600° to 650°C . Considering the close proximity of isoreaction-grads (7), II and (3), which intersect at locality 943369, it is most likely that isoreaction-grad (7) represents a temperature range closer to 600°C than to 650°C . (No

large variations in X_{CO_2} are indicated). In the southern section of this zone isoreaction-grads (I) and II are not well constrained and isoreaction-grad (I) could easily reflect a greater variation in the fluid composition.

The diopside zone indicated in the Opinicon Lake area is also present north of the pluton in the Sand Lake area. It is based on only one locality, which does not allow an interpretation to be made about the nature or extent of the metamorphic grade north of the pluton.

An isoreaction-grad based on the aluminous-silicate reaction of muscovite-calcite-quartz reacting to anorthite-potassium feldspar, has been mapped in this area as outlined in Figure 7.4. It runs somewhat irregularly north to south, roughly parallel to the calc-silicate isoreaction-grads previously outlined. The up-grade assemblage of Ca-plagioclase-potassium feldspar occurs on the east side of the isoreaction-grad indicating higher temperatures towards the pluton. As shown in Figure 7.2, the assemblage anorthite-potassium feldspar is stable only above $550^{\circ}C$ at 5 kilobars and only in the range of fluid compositions $X_{CO_2} = 0.20$ to 0.70 . This is consistent with conditions expressed by the calc-silicate isoreaction-grads.

e) Tichborne Map-Area

The Tichborne map-area, including the western edge of the

Westport sheet, is characterized by high-grade regional metamorphism. Direct plutonic influence upon the metamorphic style is minimal. The mapped region is almost entirely high-grade. The metamorphism decreases outward from a central forsterite zone through successive zones of diopside and tremolite. Material of sufficiently low-grade to bracket isoreaction-grad II on the low-grade side is present at only two localities so that control on isoreaction-grad II is minimal in this region. The trend of isotherms, however, can be inferred from isoreaction-grad (6) (Winkler, 1975) which is reasonably well-constrained in this area.

The central forsterite zone of the Tichborne map-area extends eastward into the Devil Lake area of the Westport sheet. The high-grade metamorphism indicated by forsterite on the west side of the lake decreases eastward. Isoreaction-grad II is present in the central part of the lake and separates the lower grade tremolite-bearing rocks on the east from the higher grade forsterite to the west. The presence of an isobaric univariant tremolite assemblage on the low-grade side of isoreaction-grad II at location 844382, suggests a fairly CO_2 -rich fluid. The data of Skippen (1974) and Winkler (1975), showing substantial talc stability fields, require CO_2 -rich fluids in order for the isobaric univariant tremolite assemblage to be stable. Slaughter, Kerrick and Wall (1975), who show a decreasing talc stability field with increasing pressure, allow this assemblage to be stable over a much wider range of fluid compositions, including those that are

H₂O-rich ($X_{\text{CO}_2} = .25$). The possibility of an H₂O-rich fluid needs to be considered in view of the fact that serpentinization and the development of hydrothermal textures are so abundant. Temperatures in excess of 600°C at location 667340 and 722344 were determined from thin sections displaying hydrothermal textures. It appears that hydrothermal textures can accurately reflect peak metamorphic temperatures. Unfortunately, neither isoreaction-grad (3) nor (7), which are strongly fluid composition-dependent, are extensive enough to allow the compositional gradient to be estimated in this region.

The forsterite zone present in the western section of the Devil Lake area expands greatly to the west and occupies a large part of the central Tichborne map-area. Isoreaction-grad (6), which outlines this zone, has been shown by Winkler (1975) to be a reasonable indication of temperature if the pressure is known. A pressure of 5 kilobars was determined for this area by the sphalerite geobarometer, enabling isoreaction-grad (6) to be used to approximate isothermal conditions. The data of Skippen (1974) expanded to 5 kilobars (Figure 7. 1) indicate that isoreaction-grad (6) reflects a temperature of between 600° and 625°C for a variation of X_{CO_2} between .38 and .98.

A temperature of 602°C was determined at location 667340 for an isobaric univariant assemblage on isoreaction-grad (6). At 5 kilobars this would suggest a fluid of the composition $X_{\text{CO}_2} = .40$. It would also suggest, according to the data of Skippen (1974) that forsterite formed prior to diopside. However, the evidence suggests

that this is not the case and that diopside formed prior to forsterite because localities 798492 and 798467 contain the assemblage tremolite-dolomite within the diopside zone. The temperature is very critical in this case and a decrease of only 15°C is sufficient to allow the order of formation of forsterite and diopside to reverse. Considering the problems of the calcite-dolomite geothermometer, it is not unreasonable to suspect that the temperature as determined may be 15°C in error.

A temperature of 670°C was determined at locality 722344 for a forsterite-calcite-dolomite assemblage. This temperature is consistent with all available experimental data and indicates the high temperatures that have been reached in this zone.

Isoreaction-grad (6) indicates that the isotherms in the Tichborne area trend roughly northeast to southwest. The metamorphic grade decreases away from the forsterite zone both to the northwest and southeast. The decreasing metamorphic grade to the northwest is indicated by the substantial diopside and tremolite zones in this direction.

Isoreaction-grad (7), which has a temperature range of between 600° and 650°C depending upon the local fluid composition, is roughly parallel to isoreaction-grad (6) in this region indicating very little variation in the fluid composition within this zone.

To the southeast the decrease in metamorphic grade is marked by isoreaction-grad (7) and locally by isoreaction-grad II. Isoreaction-grad (7) parallels isoreaction-grad (6) over its entire length, indicating a uniform fluid composition. Isoreaction-grad II also runs parallel to isoreaction-grad (6) as would be expected as both are approximately isothermal. Unfortunately, isoreaction-grad II is constrained at only two localities and is not extensive enough to allow a valid interpretation of the isotherms in this region.

However, it does serve to indicate the decreasing grade to the southeast. Isoreaction-grad (3) is also defined in this area although only at locality 752331, thus it is not extensive enough to permit an interpretation of the fluid composition.

At the southwest extremity of the Tichborne area, the central forsterite zone is undefined. Isoreaction-grad (6) indicates a decrease in grade towards the southwest, which is confirmed by the presence of isoreaction-grad II in this direction also. Isoreaction-grad (3) is defined by only one locality (665322) and like the other isoreaction-grads in this area, is not extensive enough to allow an interpretation of the metamorphic grade to the southwest.

Figure 7.7 shows the distribution of aluminous silicate assemblages in the Tichborne area. In general the high-grade nature of this region is reflected by Ca-plagioclase-potassium feldspar or

Ca-plagioclase-calcite assemblages. One occurrence of muscovite-calcite-quartz, located in the tremolite zone east of White Lake, is consistent with the lower metamorphic grade. Insufficient data exist to map an isoreaction-grade based on the muscovite-calcite-quartz reaction to Ca-plagioclase-potassium feldspar, although as shown in Figure 7.7, it has some local expression.

Figure 7.7^o Distribution of aluminous silicates within the
Tichborne map-area

Ca-plagioclase - Potassium feldspar ●

Muscovite - Calcite - Quartz - Ca-plagioclase - Potassium feldspar ●

Muscovite - Calcite - Quartz ■

Calcite - Ca-plagioclase ▲

Scapolite ▼

Humite group □

Zoisite }

Epidote }

○

CHAPTER 8 CONCLUSIONS

In the carbonate rocks of the Grenville Supergroup within Southern Ontario, it is possible to map isoreaction-grads based on selected siliceous carbonate reactions. The following isoreaction-grads have been mapped (see accompanying maps in back pocket):

- (1) 3 dolomite + potassium feldspar + H_2O ----- phlogopite
 = phlogopite + 3 calcite + 3 CO_2
- (3) 8 quartz + 5 dolomite + H_2O ----- tremolite
 = tremolite + 3 calcite + 7 CO_2
- (6) tremolite + 11 dolomite ----- forsterite
 = 8 forsterite + 13 calcite + 9 CO_2 + 3 H_2O
- (7) tremolite + 3 calcite + 2 quartz ----- diopside
 = 5 diopside + 3 CO_2 + 2 quartz
- (II) calcite-dolomite-quartz-tremolite-diopside

Isoreaction-grad II is of particular interest because it traces out an isobaric, isothermal line in contrast to the remaining isoreaction-grads which are controlled not only by pressure and temperature but also by fluid composition. This thesis presents the first demonstration that this type of isoreaction-grad can be mapped in carbonate rocks.

The importance of being able to map these isoreaction-grads in the carbonate rocks can be illustrated by reference to the Westport

map-area. Wynne-Edwards (1967a) concentrated mainly on the pelitic assemblages and concluded that the area had attained metamorphism of upper amphibolite to granulite facies. By considering carbonate rocks in addition to the pelitic rocks it has been possible to demonstrate that a much wider range of metamorphic grade exists within this map sheet. In particular, the presence of the assemblage potassium feldspar-dolomite near the village of Lyndhurst indicates conditions of greenschist facies and reveals that the range of metamorphic grade in fact varies from greenschist to granulite facies.

The mapping of isoreaction-grads in considerable detail around the Lyndhurst pluton in the Westport map sheet has demonstrated that a spatial relationship exists between the position of isoreaction-grads in carbonate rocks and the outline of the pluton. The reasons for this relationship are not completely understood. Contact metamorphism can produce such relationships but may not apply in the present case. For example, a juxtaposition of low-grade rocks (potassium feldspar-dolomite) and high-grade rocks (diopside-quartz-calcite) near the village of Lyndhurst could not likely result from variations in heat supply from a cooling pluton. Such rapid changes in metamorphic grade can be more easily explained by variations in the $\text{CO}_2/\text{H}_2\text{O}$ ratio in the fluid phase. Such variations in fluid composition have also been invoked to explain a very complex pattern of isoreaction-grads in rocks along the northwestern edge of the pluton. The geological reasons for such rapid changes of fluid composition are not known but it is possible that regional migration of fluids through the rocks

has been influenced by the pluton, thus accounting for the observed spatial relationships.

Mapping of isoreaction-grads on a regional scale in the Carleton Place, Perth, and Westport (east half) map sheets has demonstrated that a substantial variation in metamorphic grade exists in the carbonate rocks which in several instances is spatially related to plutonic rocks.

The northern portion of the thesis area is characterized by an extensive region of low-grade metamorphism. This low-grade "plain" appears to be a repetition of the low-grade area in the Hastings Basin. This low-grade zone most probably continues northwest of the thesis area where low-grade assemblages have been reported in the mafic rocks (J.M. Moore, Jr., personal communication). High-grade isoreaction-grads in the Carleton Place and Perth map-areas are, for the most part, spatially related to the outlines of the major plutons and are present only in the vicinity of such plutonic rocks. This is reminiscent of relationships observed in other parts of the Grenville province (Engel and Engel (1959), Lumbers (1967), Wynne-Edwards (1969), Carmichael (1970)). The influence of more mafic plutonic masses is less apparent although in the case of the western metamorphic zone of the Carleton Place map-area, they may be important.

The southern part of the thesis area comprising the Westport-Tichborne map-areas can be divided into two segments roughly coincident with those of Wynne-Edwards (1976a). The eastern zone contains several remnant low-grade areas with higher-grade isoreaction-grads often spatially related to the major plutons of the area (i.e., Lyndhurst pluton). Both temperatures and pressures increase within this zone towards the western metamorphic zone.

The western metamorphic segment is characterized by a difference in style and degree of metamorphism from that evident in the eastern zone. The metamorphism is upper amphibolite to granulite facies (diopside-forsterite-calcite) and the metamorphism is of a regional style with no obvious relationship to plutonic bodies. The western metamorphic zone seems typical of the metamorphic style thought to be characteristic of the Frontenac Axis.

The determination of temperatures within the carbonate rocks was accomplished by using the calcite-dolomite geothermometer. All previous calcite-dolomite solvus data were corrected to a common pressure of 5 kilobars. The following curve has been fitted to these data.

$$\text{Temp} = 474.46 + 82.24 X - 5.11 X^2 + .17 X^3 - .0022 X^4$$

This equation was used to derive the temperatures from electron micro-probe analysis of 29 coexisting calcite-dolomite pairs.

The approach taken has not been entirely successful apparently because of re-equilibration of carbonate compositions during cooling. This is particularly the case for rocks which display "hydrothermal" textures but even some rocks with mosaic textures yield temperatures that are inconsistent with published phase diagrams. However, for the majority of specimens the estimated temperatures are consistent with the phase diagram at 5 kilobars which has been produced in this study. This lends support to the estimated pressure of 4.75 to 5 kilobars that has been indicated by sphalerite geobarometry, although a somewhat lower pressure of 3 kilobars is indicated as being more consistent with the phase relations and temperatures that have been determined in the northern part of the thesis area.

It has been demonstrated in the present study that several distinct textural types of carbonate frameworks exist in the siliceous carbonate rocks. Distinct textures can be related to the metamorphic history of the rocks. For example, areas of low-grade can be correlated with textural features that are sedimentary in origin. Although the majority of rocks display mosaic textures certain localities have textures that suggest extensive modification of pre-existing metamorphic textures. These have been referred to as hydrothermal textures. There is a correlation between the development of such textures and phase assemblages that indicate a high H_2O content of the fluid phase. Such relationships between textural correlation and metamorphic history of carbonate rocks should receive more careful study in the future.

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APPENDIX A COMPUTER PROGRAMS

- a) Field Data Interpretation
 - i) Ewert
 - ii) Mischief
- b) Solubility of magnesite component in calcite
corrected for pressure effects

EWERT

Program description and manual

This program, like its counterpart MISCHIEF, is available in the archives of the Computing Centre and can be called into core memory by using the instructions listed sub 2 and 3, below. This operation is much faster than compilation from the source statements.

Purpose

To interpret coded records of geological observations and to list these records in readable form.

Input

A deck of coded records, as described in more detail in the write-up of the program MISCHIEF.

Output

A list of printed records, containing all the geological information that has gone into the coded records. These printed records will generally occupy several printlines each. Visual separation of the printed records is achieved by the insertion of blank lines between them.

Although the program does not provide diagnostic messages to signal input errors, any code number that is found to be unrealistically high, such as a strike value greater than 360, will generate the translation ERR and thus alert the user. Also, non-numerical code numbers accidentally punched in an input card will be noted by the computer software and cause the processor to print a warning of the type: "ILLEGAL NUMERICAL INPUT CHARACTER. FIELD TERMINATED. The non-numerical value is then automatically replaced by zero, and the translation generated by the program EWERT will

correspond to the usual translation of a zero input code character.

Setup

1. :JOB.....
- 1a. (Only when more than about fifty pages of output are to be expected; otherwise, the job can be run in class 9)
:LIMIT
2. :ARCH
3. GET EWERT.46710009
4. : RUN (LMN,EWERT,46710009)---
5. :DATA
6. Variable format card as described under MISCHIEF
7. Deck of data cards containing the coded records of geological observations.

Specifying Criteria for the Selection of Records

A master card, to be set up by the user,

- a) specifies by sequence number which item(s) must be scrutinized in each record;
- b) which value of that item (or of these items) has to be found to make a given record eligible for decoding and printing.

The organization of the master card is such that the item number is always followed by its critical value, before any other item number is specified. With certain exceptions, up to ten different items can be so specified, or up to ten critical values can be specified for one item (in the latter case, the item number must be repeated, e.g., : 18 2 18 3 18 4 et cetera

Items numbered 1-6 cannot be used as selection criteria.

Items numbered 13-16 form an exception to the rule in that up to ten items can be requested; if more than one of these exceptional

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items is specified in the master card, only the first of these will actually be used. Items 13-16 differ from all others in that a range, rather than a single value, must be specified for them. This is done in the form of a four-digit number; the first two digits represent the lower limit of the range, the last two digits represent the upper limit of that range. These limits are included in the range when the scanning is done.

For items other than 13-16, the search procedure is non-specific, that is, if more than one item is requested for scanning, records will be drawn out, decoded and printed regardless of whether only one, or several criteria are met. The printout will not show on which criterion the record was actually selected.

Output

A list showing, for each selected record, the sample (or station) number and several key characteristics such as colour and granularity.

Page headings, composed in part from the input itself, will show on which criterion (or on which criteria) the records were scanned.

Sub-headings indicate which kind of rock property is shown in the column underneath them.

Program Setup

1. :JOB
- 1a. :LIMIT (needed only in case more than 10 pages of output are to be expected; otherwise, omit the LIMIT card and submit the job as a "class 9 job".
2. :ARCH
3. GET MISCHIEF.46710009
4. :RUN (LMN,MISCHIEF,45710009)
5. :DATA
6. The so-called variable format card with a specification of the format in which data cards must be read. For the present organization of the input, this card must contain:

(1X,6A3,6I1,4I2,8I1,I3,4(2I1,I3,I2),I3,I2,2I1,I1)
7. The criteria specification card, as described on page 2 of this manual. The integers in this card must be separated by at least one blank space (except in the case where lower and upper limits are specified for any of the items numbered 13 through 16)
8. The data deck, as described on page 1 of this manual under the heading INPUT.

```

1. DIMENSION CDDOUT(50,15,4),KARAK(100),READFH(20),PLINE(30),GEOL(3),
2. SAMNO(4),SHEET(3),INTGER(361)
3. COMMON/AAA/CDDOUT,INTGER
4. CALL EBFSLT(199S)
5. INTEGER CDDOUT,PLINE,GEOL,SAMNO,SHEET,BLANK
6. DATA BLANK/4H /
7. DATA GEOL/4HOGEO,4HLOGI,4HST: /
8. DATA SAMNO/4H SA,4HMPLE,4H NUM,4HBER /
9. DATA SHEET/4H MA,4HHP SH,4HSHEET /
10. READ 1,READFH
11. 1 FORMAT(20A4)
12. IPAG=1
13. LINES=50
14. DO 2 I=24,30
15. PLINE(I)=BLANK
16. 2 CONTINUE
17. DO 30 M=1,48
18. READ READFH,(KARAK(I),I=1,46)
19. N=0
20. IF(KARAK(44))4,6,4
21. 4 READ 5,KARAK(100),KARAK(47)
22. 5 FORMAT(2I2)
23. KARAK(46)=100+KARAK(46)+KARAK(100)
24. GO TO 7
25. 6 KARAK(47)=0
26. 7 DO 8 I=1,3
27. PLINE(I)=GEOL(I)
28. 11=1+5
29. PLINE(11)=SAMNO(1)
30. 11=1+11
31. PLINE(11)=SHEET(1)
32. 8 CONTINUE
33. PLINE(4)=KARAK(1)
34. PLINE(5)=KARAK(2)
35. PLINE(9)=SAMNO(4)
36. PLINE(10)=KARAK(3)
37. PLINE(11)=KARAK(4)
38. PLINE(15)=KARAK(5)
39. PLINE(16)=KARAK(6)
40. PLINE(17)=BLANK
41. LBLCK=18
42. 9 IF(N=16)31,32,33
43. 31 M=7

```

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66	GO TO 20
67	IF P=15, PLINK
68	IF P=15, PLINK
69	IF P=15, PLINK
70	IF P=15, PLINK
71	IF P=15, PLINK
72	IF P=15, PLINK
73	IF P=15, PLINK
74	IF P=15, PLINK
75	IF P=15, PLINK
76	IF P=15, PLINK
77	IF P=15, PLINK
78	IF P=15, PLINK
79	IF P=15, PLINK
80	IF P=15, PLINK
81	IF P=15, PLINK
82	IF P=15, PLINK
83	IF P=15, PLINK
84	IF P=15, PLINK
85	IF P=15, PLINK
86	IF P=15, PLINK
87	IF P=15, PLINK
 

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129.	19L02=BLANK+1
130.	23 CONTINUE
131.	PLTFFILBLANK=BLANK
132.	19L02=BLANK+1
133.	IF (LPLOK=2) 120,24,74
134.	24 IF (LI-CS=1) 26,25,25
135.	25 PRINT 12,IPAG
136.	IPAG=IPAG+1
137.	LI=ES=3
138.	26 IF (PLINE111E,3EELL11) GO TO 35
139.	PRINT 11,PCIRL
140.	60 11 39
141.	15 P=LI 15,ELINE
142.	LI=ES-LINE+1
143.	40 LI=ES-LINES+1
144.	GO 27 142,130
145.	PLPFIJ)=BLANK
146.	27 CONTINUE
147.	PLPFIJ)=9LAK
148.	ELP=2
149.	28 CONTINUE
150.	14L02=719,22,29
151.	19 LRLP=BLANK+1
152.	PRINT 11,(PLPFIJ),1,1,ELP,LI
153.	LI=ES-LINE+1
154.	29 CONTINUE
155.	39 CALL EXIT
156.	END

158.

[illegible]

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172	1 40 115-44MLINE-44AY10-44H	
173	2 40 12-44MLINE-44MATR-44H	
174	3 40 15-44MLINE-44MATR-44H	
175	4 40 18-44MLINE-44MATR-44H	
176	5 40 19-44MLINE-44MATR-44H	
177	DATA (CCDDUT(35,1,1),J=1,4),I=1,15//	
178	1 40 115-44MLINE-44AY10-44H	
179	2 40 12-44MLINE-44MATR-44H	
180	3 40 15-44MLINE-44MATR-44H	
181	4 40 18-44MLINE-44MATR-44H	
182	5 40 19-44MLINE-44MATR-44H	
183	DATA (CCDDUT(1,1,1),I=26,37),J=1,41//	
184	1 40 12-44MLINE-44MATR-44H	
185	2 40 15-44MLINE-44MATR-44H	
186	3 40 18-44MLINE-44MATR-44H	
187	4 40 19-44MLINE-44MATR-44H	
188	5 40 19-44MLINE-44MATR-44H	
189	DATA (CCDDUT(35,1,1),J=1,4),I=1,15//	
190	1 40 115-44MLINE-44AY10-44H	
191	2 40 12-44MLINE-44MATR-44H	
192	3 40 15-44MLINE-44MATR-44H	
193	4 40 18-44MLINE-44MATR-44H	
194	5 40 19-44MLINE-44MATR-44H	
195	DATA (CCDDUT(35,1,1),J=1,4),I=1,15//	
196	1 40 115-44MLINE-44AY10-44H	
197	2 40 12-44MLINE-44MATR-44H	
198	3 40 15-44MLINE-44MATR-44H	
199	4 40 18-44MLINE-44MATR-44H	
200	5 40 19-44MLINE-44MATR-44H	
201	DATA (CCDDUT(35,1,1),J=1,4),I=1,15//	
202	1 40 115-44MLINE-44AY10-44H	
203	2 40 12-44MLINE-44MATR-44H	
204	3 40 15-44MLINE-44MATR-44H	
205	4 40 18-44MLINE-44MATR-44H	
206	5 40 19-44MLINE-44MATR-44H	
207	DATA (CCDDUT(35,1,1),J=1,4),I=1,15//	
208	1 40 115-44MLINE-44AY10-44H	
209	2 40 12-44MLINE-44MATR-44H	
210	3 40 15-44MLINE-44MATR-44H	
211	4 40 18-44MLINE-44MATR-44H	
212	5 40 19-44MLINE-44MATR-44H	
213	DATA (CCDDUT(35,1,1),J=1,4),I=1,15//	
214	1 40 115-44MLINE-44AY10-44H	
215	2 40 12-44MLINE-44MATR-44H	
216	3 40 15-44MLINE-44MATR-44H	
217	4 40 18-44MLINE-44MATR-44H	
218	5 40 19-44MLINE-44MATR-44H	

[illegible]

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252.	1	4H251	4H252	4H253	4H254	4H255	4H256	4H257	4H258
259.	1	4H259	4H260	4H261	4H262	4H263	4H264	4H265	4H266
260.	2	4H267	4H268	4H269	4H270	4H271	4H272	4H273	4H274
261.	DATA	10	11	12	13	14	15	16	17
262.	1	4H271	4H272	4H273	4H274	4H275	4H276	4H277	4H278
263.	2	4H279	4H280	4H281	4H282	4H283	4H284	4H285	4H286
264.	3	4H287	4H288	4H289	4H290	4H291	4H292	4H293	4H294
265.	4	4H297	4H298	4H299	4H300	4H301	4H302	4H303	4H304
266.	5	4H307	4H308	4H309	4H310	4H311	4H312	4H313	4H314
267.	6	4H317	4H318	4H319	4H320	4H321	4H322	4H323	4H324
268.	7	4H325	4H326	4H327	4H328	4H329	4H330	4H331	4H332
269.	8	4H334	4H335	4H336	4H337	4H338	4H339	4H340	4H341
270.	9	4H343	4H344	4H345	4H346	4H347	4H348	4H349	4H350
271.	10	4H352	4H353	4H354	4H355	4H356	4H357	4H358	4H359
272.	11	4H362	4H363	4H364	4H365	4H366	4H367	4H368	4H369
273.	12	4H372	4H373	4H374	4H375	4H376	4H377	4H378	4H379
274.	13	4H382	4H383	4H384	4H385	4H386	4H387	4H388	4H389
275.	14	4H392	4H393	4H394	4H395	4H396	4H397	4H398	4H399
276.	15	4H402	4H403	4H404	4H405	4H406	4H407	4H408	4H409
277.	16	4H412	4H413	4H414	4H415	4H416	4H417	4H418	4H419
278.	17	4H422	4H423	4H424	4H425	4H426	4H427	4H428	4H429
279.	18	4H432	4H433	4H434	4H435	4H436	4H437	4H438	4H439
280.	19	4H442	4H443	4H444	4H445	4H446	4H447	4H448	4H449
281.	20	4H452	4H453	4H454	4H455	4H456	4H457	4H458	4H459
282.	21	4H462	4H463	4H464	4H465	4H466	4H467	4H468	4H469
283.	22	4H472	4H473	4H474	4H475	4H476	4H477	4H478	4H479
284.	23	4H482	4H483	4H484	4H485	4H486	4H487	4H488	4H489
285.	24	4H492	4H493	4H494	4H495	4H496	4H497	4H498	4H499
286.	25	4H502	4H503	4H504	4H505	4H506	4H507	4H508	4H509
287.	26	4H512	4H513	4H514	4H515	4H516	4H517	4H518	4H519
 				

MISCHIEF

Program description and manual

This program is available in compiled form, and can be called into core memory from the archives of the Carleton University computing centre by using the instructions listed below (sub 2 and 3) in the paragraph on the set-up.

As the source program contains a large data block, its compilation from cards is costly. Use of the stored program (called a load module) avoids this costly step.

The user should be aware that the load module will eventually be deleted, but will remain available for balance of an academic year.

Purpose

To find and interpret geological information, presented to the program in the form of a deck of coded data records, and to print such records in readable form if they satisfy one or more user-specified criteria.

Input

A deck of cards containing records consisting of numerically coded geological observations in a specified sequence and in a specified format.

An individual record may comprise either one, or two, of these data cards.

If any record consists of two cards, the 44th item on the first card must have a finite value (i.e. the corresponding card columns may not be left blank or punched as zeros).

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The first card, which may be the only card of an individual record, may contain up to 46 items but the 46th item, if it is present, will be read as the first digit of a three-digit number, the remaining two digits of which are to be found in the first two columns of the second card. In its present form, the program will try to find only one more item on this second card, namely, a two-digit code number immediately following the two digits in columns 1 and 2. Thus, the input format for the second card, if this card is required, is fixed: it must always be (2I2).

The first card, however, offers some flexibility. It must be capable of containing 46 items, but the space allotted to each of these items can be varied according to the user's requirements. Hence, the user must provide a so-called variable format card immediately after the :DATA card, as shown under the heading SETUP.

The first six items in the first card of a record may be alpha-numeric; items 1-2 contain the name of the geologist (used in page headings); items 3 and 4 represent the sample number, and 5-6 represent the map sheet number.

MISCHIEFPurpose

To find and print records which satisfy one or more specified criteria.

Input

A deck of data cards containing records consisting of coded observations. Each record may comprise either one, or two data cards. If there is a second card to any record, the 44th item on the first card may not be left blank or filled in as zero. The first card can contain up to 46 items, and the 46th item, if present, is understood to be the first digit of a three-digit number, the rest of which will appear in columns 1 and 2 of the second card. The second card may contain one more item immediately following its first entry; it has the reading format (2I2) and thus only four columns of it will be read.

The format of the first card is free (the user specifies this format himself in a so-called variable format-card) as long as the above-mentioned conditions are met.

Items 1 through 6 of the first card are used for page headings and station identification. Items 1 and 2 form the name of the user, items 3 and 4 represent the station or sample number, and items 5 and 6 represent the map number. They are followed by observations coded in numerical form.

Criteria for Selecting Records

A master card, set up by the user, specifies by number which item(s) must be scrutinized in each record, and which value of that item (or those items) will satisfy the requirements, so the record can be printed.

To set up this master card, enter the sequential number of the item concerned, e.g. 18, then leave a blank space, and enter the value required, e.g. 3. After this, another item may be specified in the same card, followed by its required value, and so on, up to a maximum of ten items. These items do not have to be different items: one can also specify, e.g. 17 1 17 2 18 3 18 5 etc. to draw out records containing samples with various properties such as either grey or brown rocks, etc.

Items 1 to 6 cannot be used for search purposes; items 13-16 fall into a class by themselves because they allow scanning the data for a range of properties. The restriction in this case is, that only one item may be specified in the master card, indicated by its number, say 16, and followed by a four-digit number, the first two digits of which indicate the lower limit; the last two the upper limit of the range. These limits themselves are understood to be part of the range.

The search procedure is non-specific in case more than one property has been specified in the master card, i.e. any record satisfying any of several specified search criteria will be printed.

Output

A list of all sample numbers, together with some key characteristics, for samples satisfying one or more search criteria. The program provides its own headings and sub-headings, partly derived from the input deck itself.

Program Setup

1. :JOB

1a. :LIMIT ... in case more than about ten pages of output are expected; otherwise, omit this card and submit the job as a class 9 job.

2. :ARCH
3. GET MISCHIEF. 46710009
4. :RUN (LMN,MISCHIEF,46710009)
5. :DATA
6. The variable format, which could be the one used up to now:

(1X,6A3,6I1,4I2,8I1,I3,4(2I1,I3,I2),I3,I2,2I1,I1)

It takes care of the first card of each record; the program itself will try to read a second card, if present, in (2I2).

7. The criteria specification card, e.g.

17 3 18 2 19 3

The above specifications would bring out all records of observations where inclusions were found, where the rock colour is light grey, and/or where the texture is described as granulated.

8. These seven (or eight) cards are followed by the data deck.


```

5 DC 3 J=1,NCRIT
  KJ=K(J)
  IF(KARAK(KJ)=KXITER(J))9,95,9
  9 CONTINUE
  GO TO 30
95 IF(L=EX)12,3,12
12 IF(L=ES,EG,0) GO TO 34
  IF(L=ES,LT,41) GO TO 33
  3 KARAK(50)=KARAK(5)
  KARAK(60)=KARAK(6)
  10EX=1
24 PRINT 31,KARAK(1),KARAK(2),KARAK(3)
25 FORMAT(1H1,'GEOLOGIST: ',2A2,8X)
  GO TO (311,313,315,317),NCRIT
311 I=K(1)
  J=KXITER(1)
  IF(J=EG,0) J=15
  PRINT 312,CODOUT(I,J,L),L=1,4
  312 FORMAT(20X,'SEARCH FOR LOCALITY
  GO TO 319
313 I=K(1)
  J=K(2)
  J=KXITER(1)
  IF(J=EG,0) J=15
  J=KXITER(2)
  IF(J=EG,0) J=15
  PRINT 314,CODOUT(I,J,L),L=1,4
  314 FORMAT(20X,'SEARCH FOR LOCALITY
  GO TO 319
315 I=K(1)
  J=K(2)
  J=K(3)
  J=KXITER(1)
  IF(J=EG,0) J=15
  J=KXITER(2)
  IF(J=EG,0) J=15
  J=KXITER(3)
  IF(J=EG,0) J=15
  PRINT 316,CODOUT(I,J,L),L=1,4
  J=K(1),L=1,4
  316 FORMAT(20X,'SEARCH FOR LOCALITY
  1/0R '4447')
  GO TO 319

```


3

OF/DE

5

```
317 I=X(1)
      I2=X(2)
      I3=X(3)
      J=X(4)
      IF(IJ2=0) J=15
      J2=X(5)
      IF(IJ2=0) J2=15
      J3=X(6)
      IF(IJ3=0) J3=15
      PRINT 318,(CDOOUT1,J/L),L=1,4),(CDOOUT12,J2,L),L=1,4),(CDOOUT13
      1,J3),L=1,4)
318 FORMAT(1X,'SEARCH FOR LOCALITIES WHERE 'A4,' AND/OR 'A4,' AND
      1/OR 'A4A/18X,'A/O/ OR OTHER CRITERIA APPLY')
319 IF(INDEX.LT.0) GO TO 321
      PRINT 32
32 FORMAT(1H,'STATION SAMPLES COLOUR LUT(CP QUALITY',2X,
      1 'C/C SIZE TEXTURE DIST. OF MINERALS',2X,
      2 'RUCK VARIABILITY',1H ,27(4H***))//)
      IPAG=IPAG+1
      LINES=7
33 CALL PAUT
      IF(OUT=IFOUND+1
      LINES=LINES+2
      GO TO 30
100 K3=WRITER(1)
      KLO=K3/100
      KHI3=K3-100*KLO
      IF(KHI3=0) GO TO 102
      PRINT 101,KLO,KHI3
101 FORMAT(10P,PLEASE RESTATE YOUR SEARCH AIM: YOU ASKED FOR PERCENTAGES
      1 FRUIT,14,1 UP TO,14/)
      GO TO 16
102 HEAD HEADFH,(KAK(KJ),J=1,46)
      KADU=K4+1
      IF(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,187,188,189,190,191,192,193,194,195,196,197,198,199,200,201,202,203,204,205,206,207,208,209,210,211,212,213,214,215,216,217,218,219,220,221,222,223,224,225,226,227,228,229,230,231,232,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284,285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,345,346,347,348,349,350,351,352,353,354,355,356,357,358,359,360,361,362,363,364,365,366,367,368,369,370,371,372,373,374,375,376,377,378,379,380,381,382,383,384,385,386,387,388,389,390,391,392,393,394,395,396,397,398,399,400,401,402,403,404,405,406,407,408,409,410,411,412,413,414,415,416,417,418,419,420,421,422,423,424,425,426,427,428,429,430,431,432,433,434,435,436,437,438,439,440,441,442,443,444,445,446,447,448,449,450,451,452,453,454,455,456,457,458,459,460,461,462,463,464,465,466,467,468,469,470,471,472,473,474,475,476,477,478,479,480,481,482,483,484,485,486,487,488,489,490,491,492,493,494,495,496,497,498,499,500,501,502,503,504,505,506,507,508,509,510,511,512,513,514,515,516,517,518,519,520,521,522,523,524,525,526,527,528,529,530,531,532,533,534,535,536,537,538,539,540,541,542,543,544,545,546,547,548,549,550,551,552,553,554,555,556,557,558,559,560,561,562,563,564,565,566,567,568,569,570,571,572,573,574,575,576,577,578,579,580,581,582,583,584,585,586,587,588,589,590,591,592,593,594,595,596,597,598,599,600,601,602,603,604,605,606,607,608,609,610,611,612,613,614,615,616,617,618,619,620,621,622,623,624,625,626,627,628,629,630,631,632,633,634,635,636,637,638,639,640,641,642,643,644,645,646,647,648,649,650,651,652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,670,671,672,673,674,675,676,677,678,679,680,681,682,683,684,685,686,687,688,689,690,691,692,693,694,695,696,697,698,699,700,701,702,703,704,705,706,707,708,709,710,711,712,713,714,715,716,717,718,719,720,721,722,723,724,725,726,727,728,729,730,731,732,733,734,735,736,737,738,739,740,741,742,743,744,745,746,747,748,749,750,751,752,753,754,755,756,757,758,759,760,761,762,763,764,765,766,767,768,769,770,771,772,773,774,775,776,777,778,779,780,781,782,783,784,785,786,787,788,789,790,791,792,793,794,795,796,797,798,799,800,801,802,803,804,805,806,807,808,809,810,811,812,813,814,815,816,817,818,819,820,821,822,823,824,825,826,827,828,829,830,831,832,833,834,835,836,837,838,839,840,841,842,843,844,845,846,847,848,849,850,851,852,853,854,855,856,857,858,859,860,861,862,863,864,865,866,867,868,869,870,871,872,873,874,875,876,877,878,879,880,881,882,883,884,885,886,887,888,889,890,891,892,893,894,895,896,897,898,899,900,901,902,903,904,905,906,907,908,909,910,911,912,913,914,915,916,917,918,919,920,921,922,923,924,925,926,927,928,929,930,931,932,933,934,935,936,937,938,939,940,941,942,943,944,945,946,947,948,949,950,951,952,953,954,955,956,957,958,959,960,961,962,963,964,965,966,967,968,969,970,971,972,973,974,975,976,977,978,979,980,981,982,983,984,985,986,987,988,989,990,991,992,993,994,995,996,997,998,999,1000)
      KADU=KADU+1
107 IF(KAK(KJ).LT.KLO) GO TO 102
      IF(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,187,188,189,190,191,192,193,194,195,196,197,198,199,200,201,202,203,204,205,206,207,208,209,210,211,212,213,214,215,216,217,218,219,220,221,222,223,224,225,226,227,228,229,230,231,232,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284,285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,345,346,347,348,349,350,351,352,353,354,355,356,357,358,359,360,361,362,363,364,365,366,367,368,369,370,371,372,373,374,375,376,377,378,379,380,381,382,383,384,385,386,387,388,389,390,391,392,393,394,395,396,397,398,399,400,401,402,403,404,405,406,407,408,409,410,411,412,413,414,415,416,417,418,419,420,421,422,423,424,425,426,427,428,429,430,431,432,433,434,435,436,437,438,439,440,441,442,443,444,445,446,447,448,449,450,451,452,453,454,455,456,457,458,459,460,461,462,463,464,465,466,467,468,469,470,471,472,473,474,475,476,477,478,479,480,481,482,483,484,485,486,487,488,489,490,491,492,493,494,495,496,497,498,499,500,501,502,503,504,505,506,507,508,509,510,511,512,513,514,515,516,517,518,519,520,521,522,523,524,525,526,527,528,529,530,531,532,533,534,535,536,537,538,539,540,541,542,543,544,545,546,547,548,549,550,551,552,553,554,555,556,557,558,559,560,561,562,563,564,565,566,567,568,569,570,571,572,573,574,575,576,577,578,579,580,581,582,583,584,585,586,587,588,589,590,591,592,593,594,595,596,597,598,599,600,601,602,603,604,605,606,607,608,609,610,611,612,613,614,615,616,617,618,619,620,621,622,623,624,625,626,627,628,629,630,631,632,633,634,635,636,637,638,639,640,641,642,643,644,645,646,647,648,649,650,651,652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,670,671,672,673,674,675,676,677,678,679,680,681,682,683,684,685,686,687,688,689,690,691,692,693,694,695,696,697,698,699,700,701,702,703,704,705,706,707,708,709,710,711,712,713,714,715,716,717,718,719,720,721,722,723,724,725,726,727,728,729,730,731,732,733,734,735,736,737,738,739,740,741,742,743,744,745,746,747,748,749,750,751,752,753,754,755,756,757,758,759,760,761,762,763,764,765,766,767,768,769,770,771,772,773,774,775,776,777,778,779,780,781,782,783,784,785,786,787,788,789,790,791,792,793,794,795,796,797,798,799,800,801,802,803,804,805,806,807,808,809,810,811,812,813,814,815,816,817,818,819,820,821,822,823,824,825,826,827,828,829,830,831,832,833,834,835,836,837,838,839,840,841,842,843,844,845,846,847,848,849,850,851,852,853,854,855,856,857,858,859,860,861,862,863,864,865,866,867,868,869,870,871,872,873,874,875,876,877,878,879,880,881,882,883,884,885,886,887,888,889,890,891,892,893,894,895,896,897,898,899,900,901,902,903,904,905,906,907,908,909,910,911,912,913,914,915,916,917,918,919,920,921,922,923,924,925,926,927,928,929,930,931,932,933,934,935,936,937,938,939,940,941,942,943,944,945,946,947,948,949,950,951,952,953,954,955,956,957,958,959,960,961,962,963,964,965,966,967,968,969,970,971,972,973,974,975,976,977,978,979,980,981,982,983,984,985,986,987,988,989,990,991,992,993,994,995,996,997,998,999,1000)
      KADU=KADU+1
108 IF(LINES=0) GO TO 110
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IF(LINES*LT*91) GO TO 112
109 KARAK(50)=KARAK(5)
    KARAK(50)=KARAK(6)
    INDEX=1
110 PRINT J1,(KARAK(I),I=1,2),(KARAK(I),I=5,6),I=10,16
    PRINT I11,KLOW,KHIGH,(CDDOUT(KJ,I),I=3,4)
111 FORMAT(20X,'SEARCH FOR LOCALITIES WITH',I3,' TO',I3,' PERCENT OF 0
    1RAINS IN SIZE CLASS ',I2A*')
    PRINT J2
    IF(AU=IPAG+1)
        LINES=7
112 CALL PRNUT
    IF(DU=IFDUN+1)
        LINES=LINES+2
    GO TO 102
113 IF(IFOUND)320,320,16
320 INDEX=1
    GO TO 104
321 PRINT I4,KARD
14 FORMAT(1H0,'NO SUCH STATIONS FOUND IN DECK OF',I4,' DATA CARDS')
16 CALL EXIT
END

SUBROUTINE PRNUT
    DIMENSION CDDOUT(60,15,4),KARAK(100),READF(20),PRNTFM(20),K(10),
    1 KRITER(10),INTGER(361)
    CONTINUE/AAA/CDDOUT,INTGER
    CDDOUT=KARAK/READF/PRNTFM,K,KRITER
    LC=KARAK(9)
    IF(LJ=EU,0) LC=15
    LS=KARAK(10)
    IF(LJ=EU,0) LS=15
    LV=KARAK(11)
    IF(LJ=EU,0) LV=15
    LW=KARAK(17)
    IF(LJ=EU,0) LW=16
    LC=KARAK(18)
    IF(LC=EU,0) LC=15
    LT=KARAK(19)
    IF(LT=EU,0) LT=15
24 PRINT J1,KARAK(3),KARAK(4),KARAK(7),(CDDOUT(I5,LC,J),J=1,3),
    1 (CDDOUT(I9,LJ,J),J=1,4),(CDDOUT(I0,L6,J),J=3,4),
    2 (CDDOUT(I5,LT,J),J=1,4),(CDDOUT(I7,L0,J),J=1,4),
    3 (CDDOUT(I1,LV,J),J=1,4)

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[illegible]

5 4M R4HUSTY,4M /
DATA (CUDOUT(15,15),J),J=1,15) /
1 4MNO CATHOLUR,4M 110,4M /
DATA (CUDOUT(15,15),J),J=1,15) /
1 544HRECK /
DATA (CUDOUT(19,1),J),J=1,15) /
1 4MQU14MGRAN,4MULAK,4M /
2 4MUNAN,4MUBLA,4MSTIC,4M /
3 4M GR44MULAS,4MTEU,4M /
4 4M 4MSPH1,4M11C,4M /
5 4MPJ2,4MIRI,4M11C,4M /
6 4MPUP,4M1RO,4MCLAS,4M11C,4M 22,4M /
DATA (CUDOUT(19,15),J),J=1,15) /
1 4MNO T4MEXTU,4MKE N4MOTEC /
DATA (CUDOUT(20,1),J),J=1,15) /
1 4M 4MAUGE,4M /
2 4M F4MLASE,4M /
3 4M R4MIBU,4M /
4 4M S4MTEA,4M /
5 4M TL4MSTI,4M /
6 4MCLAS,4MCLAS,4M11C,4M /
7 4M SE4MVERA,4M /
8 4M SE4MVERA,4M /
9 4M DREA,4M 1,4M 20,4M /
DATA (CUDOUT(20,15),J),J=1,15) /
1 4MNO 4MTE,4MTEAT,4MNOTC /
DATA (CUDOUT(23,1),J),J=1,15) /
1 4MDB1,4M1SA,4MTE 5,4M 10,4M /
2 4MDB1,4M1SA,4MTE 1,4M 10,4M 50,4M /
3 4MOS1,4M1SA,4MTE 5,4M 10,4M 50,4M /
4 4MDB1,4M1SA,4MTE 5,4M 10,4M 50,4M /
DATA (CUDOUT(21,15),J),J=1,15) /
1 64 4MNOT,4M M1G,4M11C,4M /
DATA (CUDOUT(22,1),J),J=1,15) /
1 4MSTY,4M1R1,4M11C,4M /
2 4M2-TY,4MPE 4M4M8 F4M1HOLDS,4M /
3 4MSTY,4MPE 4M4M8 F4M1HOLDS,4M /
4 4M KI,4M4M8 24,4MND,4M /
5 4M B4M4M8 F4M1HOLDS,4M /
6 4M D4M1VER,4M11C,4M 22,4M /
DATA (CUDOUT(22,15),J),J=1,15) /
1 4MNO 4M4M8 F4M1HOLDS,4MNOTC /
DATA (CUDOUT(23,1),J),J=1,15) /

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1 4M < 1340 DE,4HGRE,4MS
2 4M10>44H5 DE,4HGRE,4MS
3 4M > 44H5 DE,4HGRE,4MS 4444H
DATA ((C000UT(24,1,J),J=1,4),I=1,15)/
1 44TRI,4MAE 44H 44H
2 44400,44VES 44H 44H
3 44IVE,44KSE 44H3LAC,44FEA,4444H
DATA ((C000UT(24,15,J),J=1,4)/
1 44H0 444LAC 44FEA,44H NT0
DATA ((C000UT(25,1,J),J=1,4)/444ZIH,44HUTH 44H0,44HFT,44H/
DATA ((C000UT(26,1,J),J=1,4),I=1,15)/
1 44 SO,44HPLAN,44HES 44H
2 44 S1,44HPLAN,44HES 44H
3 44 S2,44HPLAN,44HES 44H
4 44 S3,44HPLAN,44HES 44H
5 44 S4,44HPLAN,44HES 44H 4444H
DATA ((C000UT(27,1,J),J=1,4),I=1,15)/
1 44(BED,44HJND,44H) 44H
2 44(LA,44HINAT,44HION),44H
3 44(GE,44HISSO,44HMSITY,44H)
4 44(CV,44HCHP,44H,LAY,44HNG),
5 44(CSC,44HCHP,44H,LAY,44HNG),
6 44(NE,44HMISS,44H OR 44HSC),
7 44(LA,44HINAT,44HED) 44H
8 44(STR,44HEAKY,44H) 44H 2344H
DATA ((C000UT(1,1,J),J=22,29),J=1,4)/
1 44 AZ,44H DIP,244H OF 244HPL,44H244H,FT,44H/
DATA ((C000UT(30,1,J),J=1,4),I=1,15)/
1 44 SO,44HPLAN,44HES 44H
2 44 S1,44HPLAN,44HES 44H
3 44 S2,44HPLAN,44HES 44H
4 44 S3,44HPLAN,44HES 44H
5 44 S4,44HPLAN,44HES 44H 4444H
DATA ((C000UT(31,1,J),J=1,4),I=1,15)/
1 44(BED,44HJND,44H) 44H
2 44(LA,44HINAT,44HION),44H
3 44(GE,44HISSO,44HMSITY,44H)
4 44(CV,44HCHP,44H,LAY,44HNG),
5 44(CSC,44HCHP,44H,LAY,44HNG),
6 44(NE,44HMISS,44H OR 44HSC),
7 44(LA,44HINAT,44HED) 44H
8 44(STR,44HEAKY,44H) 44H 2344H
DATA ((C000UT(1,1,J),J=22,23),J=1,4)/

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1 4M A2,4M CIP,244M OF 224HPLIN,244M FTR/
DATA (ICODOUT(13,1,J),J=1,4),I=1,15)/
1 4M L1,4HLINE,4HATIO,4H /
2 4M L2,4HLINE,4HATIO,4H /
3 4M L3,4HLINE,4HATIO,4H /
4 4M L4,4HLINE,4HATIO,4H /
5 7M L5,4HLINE,4HATIO,4H / 9044M
DATA (ICODOUT(35,1,J),J=1,4),I=1,15)/
1 4M L1,4HLINE,4HATIO,4H /
2 4M L2,4HLINE,4HATIO,4H /
3 4M L3,4HLINE,4HATIO,4H /
4 4M L4,4HLINE,4HATIO,4H /
5 7M L5,4HLINE,4HATIO,4H / 9044M
DATA (ICODOUT(39,1,J),J=1,4),I=1,15)/
1 4M L1,4HLINE,4HATIO,4H /
2 4M L2,4HLINE,4HATIO,4H /
3 4M L3,4HLINE,4HATIO,4H /
4 4M L4,4HLINE,4HATIO,4H /
5 7M L5,4HLINE,4HATIO,4H / 9044M
DATA (ICODOUT(11,1,J),I=36,37),J=1,4)/
1 4M TR,4H PL,244M OF 224HPLIN,244M FTR/
DATA (ICODOUT(13,1,J),J=1,4),I=1,15)/
1 4M L1,4HLINE,4HATIO,4H /
2 4M L2,4HLINE,4HATIO,4H /
3 4M L3,4HLINE,4HATIO,4H /
4 4M L4,4HLINE,4HATIO,4H /
5 7M L5,4HLINE,4HATIO,4H / 9044M
DATA (ICODOUT(39,1,J),J=1,4),I=1,15)/
1 4M L1,4HLINE,4HATIO,4H /
2 4M L2,4HLINE,4HATIO,4H /
3 4M L3,4HLINE,4HATIO,4H /
4 4M L4,4HLINE,4HATIO,4H /
5 7M L5,4HLINE,4HATIO,4H / 9044M
DATA (ICODOUT(11,1,J),I=40,41),J=1,4)/
1 4M TR,4H PL,244M OF 224HPLIN,244M FTR/
DATA (ICODOUT(13,1,J),I=42,43),J=1,4)/
1 4M TR,4H PL,244M OF 224HFULC,244M AX18/
DATA (ICODOUT(14,1,J),J=1,4),I=1,15)/
1 4M SC,4HPLAN,4HES /
2 4M S1,4HPLAN,4HES /
3 4M S2,4HPLAN,4HES /
4 4M S3,4HPLAN,4HES /
5 4M S4,4HPLAN,4HES /

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      4  4H233 4H234 4H235 4H236 4H237 4H238 4H239 4H240
      5  4H241 4H242 4H243 4H244 4H245 4H246 4H247 4H248 4H249
      6  4H250 4H251 4H252 4H253 4H254 4H255 4H256 4H257 4H258
      7  4H259 4H260 4H261 4H262 4H263 4H264 4H265 4H266 4H267
      8  4H268 4H269 4H270
DATA (INTEG(1),1,271,361)/
      1  4H271 4H272 4H273 4H274 4H275 4H276 4H277 4H278 4H279
      2  4H280 4H281 4H282 4H283 4H284 4H285 4H286 4H287 4H288
      3  4H289 4H290 4H291 4H292 4H293 4H294 4H295 4H296 4H297
      4  4H298 4H299 4H300 4H301 4H302 4H303 4H304 4H305 4H306
      5  4H307 4H308 4H309 4H310 4H311 4H312 4H313 4H314 4H315
      6  4H316 4H317 4H318 4H319 4H320 4H321 4H322 4H323 4H324
      7  4H325 4H326 4H327 4H328 4H329 4H330 4H331 4H332 4H333
      8  4H334 4H335 4H336 4H337 4H338 4H339 4H340 4H341 4H342
      9  4H343 4H344 4H345 4H346 4H347 4H348 4H349 4H350 4H351
      0  4H352 4H353 4H354 4H355 4H356 4H357 4H358 4H359 4H360
      1  4HERR

```

END

11X,6A3,6I1,4I2,6I1,13,4(2I1,19,12),13,12,2I1,11)

16 1125

179
SOLUBILITY OF MAGNESITE COMPONENT IN CALCITE CORRECTED FOR PRESSURE EFFECTS W. EVERT 1975

1.	EXTERNAL DERIV
2.	LOGICAL IS
3.	J=12329 TINDEX/OUT
4.	CORR=1/2*(A+1)/T
5.	DATA TINDEX/SA, 605, 697, 705, 734, 762, 788, 796, 800, 820, 780, 850, 900,
6.	C 925, 1059, 1150, 1167, 1177, FALSE, /
7.	ALT=ES=C
8.	TM=0.1
9.	M=103
10.	DO 100 J=1, 16
11.	I=110000X(1) + 273.
12.	PRINT 3598
13.	PRINT 100000
14.	IF 100.
15.	IF 100.
16.	IF 100.
17.	IF 100.
18.	IF 100.
19.	IF 100.
20.	IF 100.
21.	IF 100.
22.	IF 100.
23.	IF 100.
24.	IF 100.
 

10 SUBQ OF THE 5150001F2A,9,DEL,IMAX,3,IER)

11 LOGICAL ILM

12 511=0

13 5=0

14 5=0

15 5=0

16 5=0

17 5=0

18 5=0

19 5=0

20 5=0

21 5=0

22 5=0

23 5=0

24 5=0

25 5=0

26 5=0

27 5=0

28 5=0

29 5=0

30 5=0

31 5=0

32 5=0

33 5=0

34 5=0

35 5=0

36 5=0

37 5=0

38 5=0

39 5=0

40 5=0

41 5=0

42 5=0

43 5=0

44 5=0

45 5=0

46 5=0

47 5=0

48 5=0

49 5=0

50 5=0

51 5=0

52 5=0

53 5=0

54 5=0

55 5=0

56 5=0

57 5=0

58 5=0

1. FUNCTION DERIV(X)

2. CONTINUE

3. ARG=X*(1-X)

4. DELTA=

5. DELTA=(1-31*X+3150*-X+X*(0143611/12*(X*X-X)+1.0)

6. VCC=36.02+00038*X+0002*X*X

7. VCC=26.4275+07236*X+0009988*X*X

8. VCC=64.34

9. DELTA=(12*X+1.0)*(VCC/ARG-2.0*DELTA)/(VCC+VCC*VD)

10. RETURN

11. END

APPENDIX B CALCITE ANALYSIS, PETROGRAPHIC, TEXTURAL AND

X-RAY DATA

- a) Calcite analysis
- b) Regional petrographic data
- c) Regional textural data
- d) Detailed petrographic data
- e) Detailed textural data
- f) X-ray data

183

	ox.wt.% Ca	ox.wt.% Mg	ox.wt.% Fe	ox.wt.% Mn	ox.wt.% C	Total ox.wt.%	Mole % MgCO ₃
981563-2	56.30	.38	.09	.11	44.6	101.49	0.9
	55.42	.54	.09	.11	44.07	100.23	1.3
	54.39	.88	.09	.11	43.64	99.11	2.2
931382-1	53.61	1.29	.11	.00	43.48	98.49	3.2
	54.04	1.44	.14	.02	43.98	99.61	3.6
	53.54	1.32	.14	.02	43.45	98.46	3.3
	53.22	1.68	.14	.02	43.60	98.65	4.2
	52.57	1.98	.14	.02	43.42	98.12	5.0
931382-1	52.15	2.73	.28	.36	43.91	99.44	6.8
	52.91	2.30	.31	.41	44.03	99.96	5.7
	52.27	2.42	.15	.18	43.66	98.68	6.0
	52.18	2.26	.15	.18	43.42	98.21	5.7
940376-3	56.26	.13	.09	.11	44.29	100.89	0.3
	55.27	.14	.09	.11	43.53	99.16	0.4
	55.06	.42	.09	.11	43.66	99.33	1.0
	55.31	.33	.09	.11	43.77	99.62	0.8
	55.39	.26	.09	.11	43.75	99.61	0.7
943369-3	56.81	.06	.09	.12	44.65	101.72	0.1
	55.66	.14	.11	.16	43.83	99.90	0.4
	56.90	.20	.11	.16	44.88	102.26	0.5
	54.60	.09	.11	.16	42.94	97.90	0.2
764359-1	54.05	1.04	.13	.14	43.55	98.92	2.6
	55.44	1.07	.15	.19	44.67	101.51	2.6
	54.75	1.15	.15	.18	44.22	100.46	2.8
	55.13	1.27	.15	.18	44.65	101.39	3.1
	55.04	1.27	.15	.18	44.58	101.23	3.1
	55.14	1.22	.16	.18	44.60	101.30	3.0
	54.77	1.20	.16	.18	44.29	100.60	3.0
	53.66	1.21	.16	.18	43.42	98.63	3.0
697352-2	53.73	2.15	.09	.11	44.51	100.61	5.3
	53.37	2.08	.09	.11	44.15	99.81	5.1
	54.07	1.95	.09	.11	44.56	100.79	4.8
722344-1	52.95	2.57	.09	.11	44.36	100.09	6.3
	54.59	2.15	.09	.11	45.18	102.13	5.2
	52.39	3.30	.09	.11	44.72	100.62	8.0
	52.25	4.36	.09	.11	45.77	102.59	10.4
119320-1	54.55	1.69	.09	.11	44.65	101.1	4.1
	52.03	2.04	.09	.11	43.06	97.35	5.2
	53.14	1.25	.09	.11	43.06	97.66	3.2
111319-1	56.26	.30	.09	.11	44.47	101.24	0.7
	55.10	.47	.09	.11	43.75	99.53	1.2
	54.73	.33	.09	.11	42.31	98.59	0.8
	56.77	.34	.09	.11	44.91	102.22	0.8
887293-1	53.88	1.87	.26	.36	44.33	100.70	4.6
	52.87	1.60	.09	.11	43.23	97.90	4.0
	52.58	1.61	.09	.11	43.02	97.42	4.1

184

	ox.wt.% Ca	ox.wt.% Mg	ox.wt.% Fe	ox.wt.% Mn	ox.wt.% C	Total ox.wt.%	Mole % MgCO ₃	184
906788-4	54.90	.02	.09	.11	43.10	98.23	.10	
	55.14	.05	.09	.11	43.32	98.71	.10	
	55.04	.04	.09	.11	43.23	98.52	.10	
	55.32	.06	.09	.11	43.48	99.08	.20	
	54.79	.26	.09	.11	43.28	98.54	.70	
	55.05	.05	.09	.11	43.25	98.56	.10	
061674-1								
hydro thermal	53.54	1.60	.09	.11	43.76	99.1	4.0	
	50.96	3.22	.09	.11	43.50	97.88	8.1	
	49.10	4.55	.09	.11	43.50	97.36	11.4	
061674-1								
recrystal-	53.71	.36	.09	.12	42.54	96.82	0.9	
lized	53.46	.43	.09	.11	42.42	96.52	1.1	
	53.86	.43	.09	.11	42.74	97.23	1.1	
	53.29	.44	.09	.11	42.30	96.23	1.1	
	53.28	.47	.09	.11	42.32	96.27	1.2	
834662-3								
	51.07	2.07	.09	.11	42.34	95.68	5.3	
	52.30	1.20	.09	.11	42.36	96.07	3.1	
	51.52	1.85	.09	.11	42.44	96.02	4.8	
	51.92	1.81	.09	.11	42.71	96.64	4.6	
	51.76	1.98	.09	.11	42.79	96.74	5.1	
860653-1								
	52.57	1.72	.28	.36	43.13	98.06	4.3	
	52.40	1.69	.09	.11	42.96	97.24	4.3	
	52.28	1.71	.09	.11	42.89	97.08	4.3	
	52.37	1.59	.09	.11	42.83	97.00	4.1	
	52.93	1.31	.09	.11	42.96	97.41	3.3	
	52.89	1.19	.09	.11	42.81	97.10	3.0	
857634-1								
	54.30	.64	.09	.11	43.31	98.45	1.6	
	54.63	.12	.09	.11	43.00	97.95	0.3	
	53.93	.12	.09	.11	42.45	96.70	0.3	
948621-1								
	54.97	.16	.09	.11	43.31	98.65	0.4	
	54.29	.29	.09	.11	42.92	97.71	0.7	
	54.29	.18	.09	.11	42.80	97.47	0.4	
089574-1								
	54.18	.37	.09	.12	42.92	97.68	0.9	
	54.58	.12	.09	.11	42.96	97.86	0.3	
	53.68	.16	.09	.11	42.29	96.34	0.4	
902568-3								
	54.24	.56	.09	.12	43.17	98.18	1.4	
	54.52	.33	.09	.11	43.14	98.19	0.8	
	54.99	.16	.09	.11	43.32	98.68	0.4	
	54.60	.28	.09	.11	43.15	98.23	0.7	
	54.00	.88	.09	.11	43.34	98.43	2.2	
	53.66	1.00	.09	.11	43.19	98.05	2.5	
	54.00	.68	.09	.11	43.12	98.00	1.7	
095567-1								
	54.55	.24	.09	.11	43.07	98.06	0.6	
	54.03	.60	.09	.11	43.05	97.86	1.5	
	53.79	.20	.09	.11	42.43	96.64	0.5	
	53.28	.55	.09	.11	42.41	96.44	1.4	
	53.64	.30	.09	.11	42.42	96.56	0.8	
104563-2								
	55.79	.17	.09	.11	43.97	100.13	0.4	
	56.68	.26	.09	.11	44.76	101.9	0.6	
	54.57	.32	.09	.11	43.17	98.27	0.8	

	ox.wt.% Ca	ox.wt.% Mg	ox.wt.% Fe	ox.wt.% Mn	ox.wt.% C	Total ox.wt.%	Mole % MgCO ₃
921037-1	53.61	1.37	.09	.11	43.56	98.75	3.4
	53.41	1.30	.09	.11	43.33	98.24	3.3
	53.55	1.34	.09	.11	43.49	98.58	3.4
	53.41	1.37	.09	.11	43.40	98.39	3.4
	53.62	1.33	.09	.11	43.53	98.69	3.3
920035-2	54.45	1.20	.28	.21	44.04	100.18	3.0
	55.22	.50	.28	.21	43.87	100.00	1.2
	55.76	.68	.28	.21	44.50	101.42	1.7
	54.92	.73	.29	.21	43.89	100.03	1.8
895033-1	54.22	1.09	.51	.45	43.74	100.02	2.7
	54.42	1.05	.51	.45	43.85	100.29	2.6
	54.97	.90	.51	.46	44.11	100.94	2.2
	55.21	.92	.50	.46	44.33	101.42	2.3
	53.57	.97	.51	.46	43.10	98.6	2.4
885025-1	54.49	.70	.09	.12	43.52	98.92	1.8
	53.96	1.30	.09	.11	43.76	99.23	3.2
	54.51	.93	.09	.11	43.79	99.43	2.3
	54.85	.92	.09	.11	44.04	100.02	2.3
	55.18	1.28	.09	.11	44.70	101.36	3.1
	55.05	1.19	.09	.11	44.49	100.94	2.9
	55.29	.83	.09	.11	44.29	100.62	2.0
	54.03	.85	.09	.11	43.33	98.42	2.1
	53.45	1.18	.09	.11	43.23	98.07	3.0
028004-3	54.46	1.58	.09	.11	44.46	100.71	3.9
	53.48	1.64	.09	.11	43.76	99.08	4.1
	53.35	1.54	.09	.11	43.54	98.64	3.9
028004-3	54.19	1.75	.09	.01	44.43	100.42	4.3
	55.03	1.16	.09	.01	44.45	100.70	2.9
	55.16	1.12	.09	.01	44.50	100.84	2.7
	53.21	1.75	.09	.01	43.67	98.68	4.4
868808-2	54.53	1.14	.09	.11	44.04	99.91	2.8
	55.01	1.54	.09	.11	44.85	101.61	3.8
	55.10	1.15	.09	.11	44.49	100.95	2.8
	54.42	1.41	.09	.11	44.25	100.29	3.5
	55.04	1.48	.09	.11	44.81	101.53	3.6
	54.96	1.30	.09	.11	44.55	101.01	3.2
	54.31	1.34	.09	.11	44.08	99.95	3.3
	54.61	1.29	.09	.11	44.26	100.37	3.2
891807-1	54.51	.49	.09	.12	43.32	98.53	1.2
	53.64	1.01	.09	.11	43.20	98.06	2.5
	53.67	1.02	.09	.11	43.22	98.12	2.6
	54.26	.48	.09	.11	43.10	98.05	1.2
	54.36	.41	.09	.11	43.10	98.07	1.0
	52.81	1.74	.09	.11	43.34	98.10	4.4
	54.28	.57	.09	.11	43.22	98.28	1.4
	54.77	.51	.09	.11	43.54	99.04	1.3
906788-1	53.01	1.92	.09	.11	43.70	98.84	4.8
	53.78	2.82	.09	.11	45.28	102.09	6.8

[illegible]

SPECIMEN NUMBER	CALCITE	DOLomite	QUARTZ	DIOPSIDE	TREMOLITE	SERPENTINE	FORSTERITE	TALC	TORMALINE	APATITE	SPHENE	SPINEL	RTILITE	PLAGIOCLASE	KAPAR	CHLORITE	PHLOG.	MUSCOVITE	SEPIOLITE	SCAPOLITE	CHONDRODITE	EPIDOTE
716344-5	1	90				05								01								
669345-1	70	15	02		03									02								
669345-2	80	05	02	01	10									02								
932347-1	01		30											10								
932347-1a	60		15		05									01								
115347-1a	75		02											01								
083350-1	01		30											01								
083350-2	01		30											20								
749351-1	80		10											05								
749351-3	85		10			02																
697352-2	70	05			10	15	05										03					
697352-2	60				05	15	15										03					
702353-1	70		05		10									10								
753353-1	20	40				40											01					
706357-1	70				10									20			05					03
706357-2	40	20			03									20								
770358-2	85		02		05			01			001			02			02					
770358-2	85		05		03			02						01			05					
764359-1	65	20			05	03								03				02				
764359-1	80	02		03		02	03											10				
764359-1	75	15			01	01		01														
936359-1	85		01		01			001									02	05				
087360-1	80		15											03	05	01	01			02		
087360-2	75		15											02	01							
942365-1	80		05	01	01					01	01			05	10							
942365-1	70		05											02	05	01						
942365-1a	80		05	03							01			02	03	01	01	01				
125365-1	70		05									10		05	02	01	03					
089366-2	60		15	10							02			05	08		01	01	01			02
944367-4	01		25											10	03							
011368-3	75		05	10	10			02								01		05				
011368-3	55			25	03											01	05					
011368-3	65		10	15	05			01			02			03						02	01	
118368-1	85	01	05														02	01				
943369-2	50		05	25	15													01				
943369-3	02	80	05													01		01				
018371-1	85		10		01						01			05	01		01					
018371-3	90		05											01								
090374-3	60		15	10	05						02			05	05		01			02		
090374-1	65		10	10	02						02			03	03		01			03		
061375-3	70		01	02	15									01				01				
940376-3	01	90	02																			
824377-2	01	80				05						01				05	02					
821377-3	70	05				20											02	01				
111378-1	50		20			15					02			03	10			02		01		
935380-1	85		10		01						01								01			
935380-6	65		05						03		01	01		10	05	05	01		02			
824380-2		90				01										03	02					
824380-3		100																				
843380-1	75		02					03						05		02	03			15		
111381-1a	60		02	20		02					02			05						05		
X 785381-1	50	35			01	10						03		03					01			
844382-2	75	03	05		03	01								05		02	02			05		
844382-3	01	80	05											01			03					
X 931382-2	60	15	03		05							05		10							05	
931382-3	80													15		05						
787389-1	01	95				03		01										01				
849390-1		90				05		02									03					
741403-2	90		05		02						01							01				
754415-1	02		20	05	02						01			30	45		02					
754415-3	80										01			15			01					
709433-1		70				25											10					
792436-1	70	05		20	03												02					
792436-3	01	75		01				08											07	10		
792436-2	05	60		01	01			20						01				02	02	02		
798442-1	01	85				02											13	10				
798442-3	01	90						02			01							03				
780445-1	02										02			30								
780445-2	50	40			05			01			01							02				
781447-1	70	10			20													02				

SPECIMEN NUMBER	CLARITE	DOLomite	QUARTZ	DIOPSIDE	TREMOLITE	SERPENTINE	POSTERITE	TALC	JOURMALINE	APATITE	SPHENE	SPINEL	ROUTLE	PLAGIOCLASE	KSPAR	CHLORITE	PHLOG.	MUSCOVITE	SERICITE	SCAPOLITE	CHONDRODITE	EPIDOTE
764449-2	75	—	01	10	—	—	—	—	—	—	01	—	—	10	05	—	10	—	—	—	—	—
779451-1	75	—	20	—	—	—	—	—	—	—	—	—	—	20	55	—	10	—	—	—	—	—
754451-3	60	10	—	01	10	15	—	05	—	—	01	—	—	—	—	—	—	—	—	—	—	—
798451-1	80	—	05	03	—	—	—	01	—	—	01	—	—	01	—	—	—	—	—	—	—	—
763455-1	—	—	15	05	25	—	—	—	—	—	—	—	—	09	05	—	—	—	—	—	—	—
763455-2	80	—	05	03	01	—	—	—	—	—	—	—	—	02	—	—	—	—	—	—	—	—
778457-1	80	10	—	02	03	—	—	—	—	—	—	—	—	01	—	01	—	—	—	—	—	—
770459-3	95	—	02	—	—	—	—	—	—	—	001	—	—	01	01	—	—	—	—	—	—	—
766459-1	90	02	—	05	01	—	—	—	—	—	—	—	—	01	01	01	—	—	—	—	—	—
764459-3	80	—	01	—	02	—	—	—	—	—	01	—	—	01	03	02	01	—	—	—	—	—
777460-1	85	—	03	03	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
791460-2	85	05	—	—	05	—	—	—	—	—	—	—	—	—	—	—	02	—	—	—	—	—
791460-4	80	05	—	02	01	—	—	—	—	—	—	—	—	—	—	—	—	01	—	—	—	—
780460-3	50	40	—	—	01	—	—	—	—	—	—	—	—	02	—	—	—	01	—	—	—	—
804464-2	—	85	—	—	01	05	—	—	—	—	—	03	—	—	—	—	—	01	—	—	01	—
779466-3	85	03	—	—	05	—	—	—	—	—	—	—	—	—	—	—	—	03	—	—	—	—
798467-1	—	90	—	—	03	—	—	01	—	—	—	—	—	—	—	—	03	—	—	—	01	—
801468-3	—	80	—	—	05	05	—	05	—	—	01	—	—	—	—	—	—	02	—	—	—	—
783469-2	80	10	01	02	02	—	—	—	—	—	01	—	—	—	—	—	—	03	—	—	—	—
931489-1	30	50	—	—	—	—	—	—	—	—	—	—	—	05	01	—	—	10	—	—	—	—
927490-2	70	—	—	20	—	—	—	—	—	—	01	—	—	—	—	—	—	05	01	—	—	—
927490-2	—	60	—	30	—	—	—	—	—	—	—	—	—	—	—	—	—	02	—	—	—	—
947497-2	20	50	—	—	—	—	—	15	—	—	—	—	—	—	—	—	15	—	—	—	—	—
955510-1	65	—	10	—	—	—	—	20	—	—	—	—	—	05	—	—	—	—	—	—	—	—
793514-4	80	—	02	—	01	02	—	—	—	—	02	—	—	10	01	01	—	01	01	—	—	—
753514-3	80	—	01	—	05	—	—	—	—	—	01	—	—	10	—	—	—	01	—	—	—	—
070516-1	50	—	20	—	—	—	—	—	—	—	—	—	—	10	05	05	—	—	02	—	—	—
070516-2	10	—	10	—	—	—	—	—	—	—	01	—	—	40	30	03	—	—	01	—	—	—
110520-2	90	—	—	—	01	02	—	—	—	—	—	02	—	—	—	02	—	—	—	—	01	—
110520-3	50	40	—	—	01	02	—	—	—	—	—	01	—	—	—	02	—	—	—	—	—	—
958521-2	90	—	01	—	—	—	—	—	—	—	—	—	—	02	—	02	—	—	—	—	—	—
071523-1	75	—	20	—	—	—	—	—	—	10	—	—	—	02	01	—	—	—	—	—	02	—
071523-2	70	—	15	—	—	—	—	—	01	—	01	—	—	05	—	—	—	—	—	—	—	—
071523-2	85	—	10	—	—	—	—	—	—	—	—	—	—	02	—	01	—	—	—	—	—	—
071523-2	70	—	15	—	01	—	—	—	—	—	—	—	—	05	—	—	—	—	—	—	—	—
795524-3	85	—	—	03	10	—	—	01	—	—	01	—	—	—	—	—	02	—	—	—	—	—
958525-2	95	—	—	—	02	—	—	—	—	—	001	—	—	—	—	—	—	02	—	—	—	—
962537-1	05	70	—	—	—	20	—	—	—	—	—	02	—	—	—	01	02	—	—	—	—	—
970543-1	80	10	—	—	02	—	—	—	—	—	—	01	—	—	—	01	02	—	—	—	03	—
974546-1	60	20	—	—	01	15	—	—	—	—	—	02	—	—	—	—	—	02	—	—	—	—
974546-3	70	10	—	—	01	—	—	—	—	—	—	—	—	—	—	—	15	—	—	—	—	—
104549-1	80	10	—	—	—	05	—	—	—	—	—	—	—	—	—	—	03	—	—	—	—	—
975549-2	40	—	—	—	30	—	—	—	—	—	—	—	—	30	—	—	02	—	—	—	—	—
104549-1a	—	55	—	—	—	40	—	—	—	—	—	01	02	—	—	—	05	—	—	—	—	—
104549-3	—	95	01	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—
108549-2	01	90	02	—	—	—	—	—	—	—	—	—	—	—	—	—	01	01	02	—	—	—
975550-2	45	35	—	—	—	20	—	001	—	—	—	—	—	—	—	—	—	01	—	—	—	—
073558-2	05	50	40	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
073562-2	90	—	03	—	—	—	—	—	—	01	—	—	—	01	—	—	—	01	—	—	—	—
981563-2	01	95	01	—	—	—	—	—	—	—	—	—	—	—	—	—	—	01	—	—	—	—
104563-2	05	85	—	—	—	—	—	—	—	—	—	—	—	—	—	03	01	—	—	—	—	—
104563-3	02	95	—	—	—	—	—	—	—	—	—	—	—	—	—	03	01	—	—	—	—	—
094567-1	01	90	03	—	—	01	—	—	—	—	—	—	—	—	—	—	02	—	—	—	—	—
094567-1	02	90	01	—	—	—	—	—	—	—	—	—	—	—	—	01	02	—	—	—	—	—
095567-1	02	85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
902568-2	01	70	—	—	—	05	—	10	—	—	—	—	—	—	—	—	10	—	—	—	—	—
902568-2	—	75	—	—	—	05	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—	—
902568-3	40	50	—	—	—	02	—	05	—	—	—	—	—	—	—	02	—	—	—	—	—	—
114571-2	—	60	—	—	—	35	—	—	—	—	—	—	—	—	—	—	—	01	—	—	—	—
114571-3	01	90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	02	—	—	—	—
114571-4	05	80	01	—	—	—	—	01	—	—	—	—	—	—	—	—	05	—	—	—	—	—
072571-1	80	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	05	—	—	—	—	—
072571-1	80	15	01	—	—	—	—	—	—	—	—	—	—	—	—	—	02	—	—	—	—	—
072571-2	90	05	01	—	—	—	—	—	—	—	—	—	—	—	—	—	02	—	—	—	—	—
072571-2	80	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	02	—	—	—	—
907571-3	—	70	—	—	—	25	—	02	—	—	—	03	—	—	—	—	—	—	—	—	—	—
089574-2	05	85	05	—	—	—	—	—	001	—	—	—	—	—	—	—	—	—	—	—	—	—
916578-1	80	—	—	10	10	—	—	—	—	—	—	—	—	03	—	—	05	—	—	—	—	—
916578-2	45	50	—	—	10	02	—	01	—	—	—	—	—	—	—	—	02	—	—	—	—	—

SPECIMEN NUMBER	EPIDOTE	CHONDRITE	SCAPOLITE	SERICITE	MUSCOVITE	PHLOG.	CHLORITE	KSPAR	PLAGIOCLASE	RTILE	SPINEL	SERENE	APATITE	TOLMINE	TALC	POSSIDITE	SERPENTINE	IMOLITE	DIOPSIDE	QUARTZ	DOLomite	CALCITE
076590-1	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
076590-2	80	15	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
076590-2	01	95	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
817590-3	75	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
927591-1	80	05	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
825594-1	90	001	02	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
930595-1	75	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
930595-2	80	01	02	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
099600-1	80	10	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
099600-2	85	15	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
937602-2	80	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
937602-3	50	05	20	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
079605-1	01	60	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
078613-1	01	98	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
795620-2	80	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
948621-1	01	95	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
948621-2	20	60	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
952629-1	85	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
952629-1	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
952629-2	90	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
952629-3	60	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
952629-4	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
857634-1	01	95	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
860653-1	90	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
842662-2	80	01	03	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
834662-3	35	35	01	02	25	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
026662-2	75	01	15	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
029669-1	75	01	02	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
029669-2	75	01	15	03	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
839672-1	85	01	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
839672-1	80	01	05	03	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
839672-2	50	05	15	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
061674-1	01	80	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
074675-1	10	85	03	01	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
074675-3	01	20	01	35	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
855675-1	05	90	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
859688-1	01	75	15	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
886709-4	02	90	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
887709-1	30	20	01	01	15	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
877716-1	01	85	01	03	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
877716-2	90	01	01	03	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
820731-3	40	40	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
838752-3	10	01	05	20	40	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
845753-1	60	15	01	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
850754-1	85	01	02	02	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
845755-5	80	01	01	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
906788-1	70	15	01	02	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
906788-2	70	20	01	01	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
906788-4	30	65	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
828790-2	01	01	20	40	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
862791-1	01	85	01	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
861791-2	20	20	01	60	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
866794-1	90	05	01	001	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
866794-2	70	30	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
875795-1	03	90	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
875795-2	65	10	01	03	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
894798-3	65	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
887800-1	85	05	01	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
891807-1	85	01	01	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
874807-2	20	01	01	80	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
877807-1	80	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
877807-2	70	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
868808-2	10	02	01	85	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
894814-2	90	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
900824-4	80	10	01	05	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
873844-1	01	90	01	02	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
873844-1	01	95	01	03	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
870847-1	01	85	01	10	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
876847-2	01	70	01	30	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01

SPECIMEN NUMBER	CALCITE	DOLomite	QUARTZ	DIOPTASE	TRIMOLITE	SERPENTINE	FORSTERITE	TALC	TOUMALINE	APATITE	SPHENE	SPINEL	ROUTLE	PLAGIOCLASE	KSPAR	CHARITE	PHLOG.	MUSCOVITE	SERICITE	SCAPOLITE	CHONDRODITE	EPIDOTE
882849-1	10	30	01	20	50	1	1	02	1	1	1	1	1	1	1	1	1	1	1	1	1	1
882849-2	03	70	01	1	15	1	1	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1
875849-1	02	88	1	1	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
899849-1	10	70	02	1	10	1	1	02	1	1	1	1	1	1	1	1	03	1	1	1	1	1
903852-1	85	10	02	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
903852-2	85	10	02	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
891853-1	20	40	02	10	20	1	1	05	1	1	1	1	1	1	1	1	01	1	1	1	1	1
891853-2	10	75	05	1	02	1	1	01	1	1	1	1	1	1	1	1	01	1	1	1	1	1
867858-1	1	95	01	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
867858-2	88	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
915866-1	50	30	01	1	1	1	1	1	1	1	01	1	1	1	1	1	02	1	1	1	1	1
915866-2	88	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
871878-2	80	10	01	1	1	1	1	1	1	1	1	1	1	1	1	1	03	1	1	1	1	1
883890-1	50	10	05	1	15	1	1	15	1	1	1	1	1	1	1	01	02	1	1	1	1	1
896892-1	01	60	02	10	15	1	1	05	1	1	1	1	1	1	1	1	02	1	1	1	1	1
873894-1	90	05	01	1	1	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
888894-1	20	40	01	1	15	1	1	25	1	1	1	1	1	1	1	1	01	1	1	1	1	1
888894-2	02	70	10	1	10	1	1	05	1	1	1	1	1	1	1	1	01	1	1	1	1	1
887900-2	05	90	1	1	10	1	1	02	1	1	1	1	1	1	1	1	03	02	02	1	1	1
901902-1	45	45	1	1	1	1	1	1	1	1	1	1	1	1	1	1	05	1	1	1	1	1
939915-1	65	25	1	1	05	1	1	1	1	1	1	1	1	01	1	1	05	1	1	1	1	1
844922-2	80	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
861931-2	01	95	01	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
880935-1	80	05	1	1	10	1	1	1	1	1	01	1	1	1	1	1	01	1	1	1	1	1
880935-2	60	1	1	1	01	1	1	1	1	1	1	1	1	1	1	1	15	20	1	1	1	1
854938-7	1	98	1	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
893939-1	01	70	1	1	20	1	1	05	1	1	1	1	1	1	1	1	1	1	1	1	1	1
893939-3	01	95	1	1	1	1	1	01	1	1	1	1	1	02	1	01	1	1	01	1	1	1
025947-2	20	30	1	1	15	25	1	1	1	1	1	1	1	1	1	1	05	1	1	05	1	1
840954-3	01	80	1	02	05	1	1	1	1	1	1	1	1	1	1	1	02	1	02	1	1	1
837958-3	75	15	1	1	01	1	1	1	1	1	01	1	1	1	1	01	10	1	1	03	1	1
837958-4	80	1	1	1	05	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
837958-5	10	01	1	80	02	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
837958-7	85	05	01	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
837958-7	85	05	01	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
010963-1	90	01	01	1	05	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
932963-1	50	20	01	1	25	1	1	1	1	1	1	1	1	01	1	1	01	1	1	1	1	1
932963-2	01	95	1	1	03	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
900964-1	85	05	1	1	10	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
900964-1	70	05	1	1	20	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
900964-1	70	05	1	1	15	1	1	05	1	1	1	1	1	1	1	1	02	1	1	1	1	1
900964-2	30	1	55	1	10	1	1	1	1	1	1	1	1	1	1	01	05	1	1	1	1	1
895974-2	95	02	02	1	1	1	1	1	1	1	01	1	1	1	1	1	02	1	1	1	1	1
943975-1	90	05	01	1	1	1	1	1	1	1	1	1	1	02	1	1	01	01	1	1	1	1
907979-1	80	10	1	1	1	1	1	1	1	1	1	1	1	01	1	1	01	02	1	1	1	1
907979-2	70	15	01	1	1	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
891984-1	90	05	1	1	02	1	1	1	1	1	01	1	1	1	1	1	02	1	1	1	1	1
042984-1	80	1	05	05	1	1	1	1	1	1	1	1	1	02	1	1	65	1	1	1	1	1
885986-1	85	05	01	1	1	1	1	1	1	1	01	1	1	1	1	1	01	1	1	1	1	1
885986-2	95	02	1	1	1	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
954986-1	90	05	1	1	1	1	1	1	1	1	01	1	1	1	1	1	02	1	1	1	1	1
042989-2	01	1	01	70	02	1	1	25	1	1	01	1	1	1	1	1	10	1	1	1	1	1
884992-1	85	10	1	1	01	1	1	1	1	1	01	1	1	01	1	1	02	1	1	1	1	1
884992-2	90	05	1	1	01	1	1	1	1	1	01	1	1	1	1	1	02	1	1	1	1	1
912995-2	90	03	01	1	1	1	1	1	1	1	1	1	1	1	1	1	03	1	1	1	1	1
961995-1	85	10	02	1	1	1	1	1	1	1	1	1	1	1	1	1	03	1	1	1	1	1
035997-1	95	01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
063997-2	55	1	25	1	03	01	1	05	1	1	01	1	1	10	1	1	02	1	02	1	1	1
979998-1	02	90	1	1	05	1	1	02	1	1	1	1	1	1	1	1	02	1	1	1	1	1
032000-1	90	05	01	1	03	1	1	01	1	1	1	1	1	1	1	1	01	1	1	1	1	1
029002-2	30	40	1	1	05	1	1	10	1	1	1	1	1	1	1	05	1	1	1	1	1	1
028004-1	70	1	02	1	15	1	1	1	1	1	01	1	1	1	1	1	01	1	1	05	1	1
028004-2	90	05	1	1	01	1	1	1	1	1	1	1	1	1	1	1	01	1	1	1	1	1
028004-3	85	05	03	1	03	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
923004-1	10	60	05	1	10	1	1	15	1	1	1	1	1	1	1	1	02	1	1	1	1	1
025008-1	1	95	01	1	01	1	1	1	01	1	1	1	1	1	1	1	01	1	1	1	1	1
024010-2	20	30	1	1	05	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
880012-2	90	03	05	1	1	1	1	1	1	1	1	1	1	1	1	1	02	1	1	1	1	1
876016-1	85	10	03	1	1	1	1	1	1	1	10	1	1	1	1	1	02	1	1	1	1	1

SPECIMEN NUMBER	CALCITE	DOLomite	QUARTZ	DIOPside	TREMOLITE	SERPENTINE	FORSTERITE	TALC	TOURMALINE	APATITE	SPHENE	SPINEL	RTITLE	PLAGIOCLASE	KAPAR	CHLORITE	PHLOG.	MUSCOVITE	SERICITE	SCAPOLITE	CHONRODITE	EPIDOTE
927018-1	05	01			85																	
036020-1		90	01																			
036020-2		80																				
835023-2	30	55																				
885025-1	80	05	01		02																	
042026-4	01	60				35					01											
895033-1	80	05			16						02											
895033-2	70	20	01		03						01											
920035-2	80	10	03																			
921037-1	02	90	01		05					01												
921037-3	50		20	15	15																	
921037-4	70		20	02	05						01											
968041-1	70	20									01											
976049-1	90	03	01		01						01											
861066-1	10	10	01								01											
969068-1	70		10		03						01			25								
009079-1	01	95														01						
980081-2	80		01		05																	
984087-1	65	30			02																	
878141-1	01	50			30												10					

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Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
123281-1	--	2a	--		L--Tr Qtz Cc=Di Tr & Di Chloritized	--	Silicates abundant. Tr poikiloblastic.
113282-1	--	2a	--		---	--	Very coarse grained. Tr Qtz mixtures growing into Cc.
113282-1	--	2a	--		Plag altered to a green chloritic mixture	--	Coarse grained.
131288-1	--	2a	--		L--Tr Cc Qtz=Di	--	Di rimmed by Tr. An example of Qtz Tr Cc reacting to Di.
069288-2	--	2b	3f		Di slightly altered to chloritic mixture	--	-----
107291-1	--	2a	--		---	--	Inclusion, mainly Qtz Plag in composition.
107291-2	--	2b	--		Feldspar altered to a chloritic mixture	--	Small patches of Qtz Dol starting to react.
071291-1	--	2a,b	--		---	--	Poikiloblastic Tr contains inclusions of Qtz Cc.
897293-1	--	2b	--		---	--	Good rainbow twinning.
107299-1	--	2a	--		L--Qtz Dol=Tr Cc still a little Qtz-Dol	--	---
107299-3	--	2a	--		Tr altered to Talc Cc	--	Fine grained.
021300-1	--	2a,b	--		---	--	Myrmekitic feldspar. Aggregates of polygonal Qtz.
898303-1a	--	2b	--		Feldspar altered to a green chloritic mixture	--	Carbonate grains rimmed by serp.
107303-2	--	2a,e	--		Plag & Di altered along cleavage to chloritic mixture	--	Di, Tr, Cc, Kspar, all in contact but no Phlog.
105311-1	--	2b	--		Tr altered to talc Cc	--	Myrmekitic feldspar.
105311-1a	--	--	3b,d		---	--	Inclusion.
908313-1	--	2b	--		Plag altered to a green chloritic mixture.	--	Aggregates of fine grained polygonal Qtz.
126317-2	--	2b	--		---	--	Coarse grained.
911318-1a	--	2b	3b		---	--	-----
118319-1	--	2a	--		L--Kspar Dol = Phl Cc	--	Texture appears low grade. Polygonal Qtz.
111319-1	1	--	--		---	--	Fine grained dirty carbonate.
111319-3	1	minor 2b	--		L--Kspar Dol = Phl Cc	--	Sulphide common along fractures.
908319-1	--	2b	3f		Kspar altered to a brown mixture?	--	Polygonal Qtz. Kspar often rimmed by Qtz and no reaction to Phlog.
119320-1	--	--	--		---	--	-----
123320-1	--	2b	--		---	--	Inclusion. No carbonate. Silicates very wildly in grain size.

Sample No.	Unrecrystallized Sedimentary	Mosaic	Recrystallized Deformational	Reaction	Hydrothermal	Remarks
123320-2	--	2b	--	Plag altered to a green chloritic mixture	--	-----
123320-3	--	2a	--	4-Qtz Dol = Tr Cc	--	Silicates form dominate framework. Small rounded patches of fine grained material possibly Qtz reacting to Tr. Inclusion. No carbonate.
048323-1	--	--	3b,f	Feldspar altered to scapolite & sericite	--	Wide variation in grain size. Well recrystallized. Phlog Di in contact.
048323-2	--	2a	--	h--reaction involving Qtz & mica -- reactants too fine grained.	--	Inclusion.
914324-1	--	2a	--	Plag altered to sericite Tr altered to talc	--	Fine grained aggregates of polygonal Qtz. Aggregates of polygonal Qtz.
913326-1	--	2a,b	--	Plag altered to sericite Tr altered to talc	--	Coarse grained. Qtz unrecrystallized {pigeons; aggregates}
913326-1a	--	2b	--	4-Qtz Tr Cc = Di	5b	Qtz fine grained polygonal aggregates.
913326-1b	--	2a	--	Feldspar altered to chloritic mixture	--	Inclusion. Calc-silicates silicates dominate framework.
038326-1	--	2b	--	h--Qtz Dol = Tr Cc	--	Aggregates of polygonal Qtz.
746327-1	--	--	--	Round patches of brown alteration product from ?	--	Reaction occurring in a few fine grained patches although some distinct Tr present.
038328-1	--	2a	--	h--Qtz Dol = Tr Cc	--	Rhomb of dolomite abundant.
024331-1	--	2a	--	h--Qtz Dol = Tr Cc	--	Section fresh - little or no alteration.
024331-2	--	2e,b	--	h--Qtz Dol = Tr Cc	--	Polygonal Qtz.
024331-3	--	2a	--	h--Qtz Dol = Tr Cc	--	-----
752331-2	--	2b	--	Round patches of brown alteration product from ?	--	-----
917331-1	--	2a	--	h--Qtz Dol = Tr Cc	--	-----
665332-2	--	2b	--	h--Qtz Dol = Tr Cc	--	-----
665332-1	1	2b	--	? altered to serp	--	-----
034332-1	--	2a	--	-----	--	-----
911333-1a	--	2b	--	-----	--	-----
919333-1a	--	2b	--	-----	--	-----
919333-1b	--	2a	--	-----	--	-----
919333-1c	--	2b	--	-----	--	-----
917333-1	--	2a	--	Feldspar altered to sericite & chlorite	--	-----

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Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational	Deformational			
517333-1a	--	--	3b	--	gone to chlorite	--	Inclusion. Some mymerkitic feldspar.
028333-1	--	2b	3b	--	Slight alteration of plagioclase to chlorite & sericite	--	Mymerkitic feldspar.
028333-2	--	2a,b	--	--	-----	--	Plagioclase slightly altered but kspars clean.
028333-3	--	--	3b,f	--	-----	--	-----
920334-1	--	2b,c	--	--	Feldspar altered to chloritic patches	--	Inclusion. Silicates dominate & display a wide range in grain size.
920334-1a	--	2b,e	--	--	-----	--	Inclusion. Polygonal Qtz.
068336-1	--	2a,b	--	--	Plagioclase altered to green chloritic mixture	--	Inclusion. Mymerkitic feldspar.
068336-3	--	--	3b	--	-----	--	Plagioclase altered, kspars clean.
066337-2	1	minor 2b	--	--	Plagioclase altered to green chloritic mixture	--	Inclusion. Good Di crystals.
764337-1	--	2e,b	--	--	Di altered to Tr	--	Mymerkitic feldspar.
764337-2	--	2e	--	--	Tr altered to talc	--	Rhombs of dolomite. Carbonate cloudy & no twinning.
667340-2	--	2b	--	--	-----	--	Di generally fresh.
667340-1	--	--	--	--	Fo altered to serp	5b	No carbonate. Perthitic feldspar.
120341-2	2a,b	--	--	--	Spinel altered to chlorite	--	Tr & Fo in contact. Fo still fresh
122342-3	--	2a	--	--	-----	--	With only slight serpentinization.
928343-1	--	2a	--	--	-----	--	Calcite cloudy and dirty - dolomite forms good clean, recrystallized 'islands'.
928343-1a	--	2a	--	--	-----	--	Good clean Di generally.
709343-2	--	2b	--	--	-----	5b	Mymerkitic feldspar. Aggregates of polygonal Qtz.
722344-1	--	2b	--	--	-----	--	Mymerkitic feldspar. Polygonal Qtz.
716344-5	--	2a	--	--	Fo altered to serp	5b	Cloudy carbonate as in hydrothermal texture but is slightly recrystallized.
669345-1	--	--	--	--	-----	--	Fo still fresh.
669345-2	--	2a,b	--	--	4-Qtz Dol = Tr Cc	--	Small round patches of fine grained carbonate.
932347-1	--	2a,b	--	--	Tr Cc Qtz = Di	--	Not well recrystallized.
932347-1a	--	2a,b	--	--	Plagioclase altered to green chloritic material	--	Reaction just started
115347-1a	--	2a	--	--	-----	--	Polygonal aggregates of Qtz. Tr appear close to Qtz dol reaction.
083350-1	--	2e	--	--	-----	--	Coarse grained.
083350-2	--	2b	--	--	-----	--	Inclusion.
083350-2	--	2b	--	--	-----	--	Inclusion.
083350-2	--	2b	--	--	-----	--	Mymerkitic feldspar.
083350-2	--	2b	--	--	-----	--	Inclusion.

Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
083350-3	--	2e	--		Feldspar altered to sericite	--	Myeritic feldspar.
749351-1	--	2a,f	--		Tr altered slightly to chlorite	--	Fe staining.
749351-3	--	--	3a,b,f		---	--	---
697352-2	--	2a to 5b	--		Tr altered to serp	--	Crystal outlines of sep after Tr and Fo.
697352-2	--	2b	--		Fo altered to serp	5b	Texture not hydrothermal.
702353-1	--	2b	--		Fo altered to serp	--	Very coarse grained.
753353-1	--	--	--		---	--	Tr poikiloblastic.
706357-1	--	--	--		Serp pseudomorph of fo.	5	Carbonate dirty.
706357-2	--	2a,c	--		---	--	---
770358-2	--	2a	--		Tr altered to talc	--	Minor 'fe' in staining.
770358-2	--	2a,f	--		Tr altered to talc	--	Clean, well recrystallized carbonate.
764359-1	--	2b	--		---	--	Tr not well formed.
764359-1	--	2b	3b		Fo altered to serp	--	---
764359-1	--	2a	--		Fo altered to serp	5b	Locally some well recrystallized areas.
936359-1	--	--	3f,b		Tr altered to talc	--	Calcite badly twinned and cloudy.
087360-1	1/5	--	3b		Tr altered to talc	5/1	Carbonate cloudy.
087360-2	1	2b	--		---	--	Texture either 1 or 5!
942365-1	--	2b	--		Plag altered to chlorite	--	Partly recrystallized but carbonate still very cloudy.
942365-1a	--	2b	--		h--Cc Qtz Tr = Di	--	Dolomite rhombs still present.
942365-1	--	2a	--		---	--	---
125365-1	--	2b,c	--		Plag altered to chlorite mixture	--	Di just starting to form.
089366-2	--	2a,b	--		---	--	'Aggregates of Qtz strained.
944367-4	--	2b	3b		---	--	Coarse grained.
011368-3	--	2a,c	--		h--Qtz Dol = Tr Cc	--	Abundant 'fe' staining.
011368-3	--	2a	--		---	--	Reaction areas & good crystals present.
011368-3	--	2a	--		---	--	Both Di & Tr present as individual grains.
113368-1	1	2b	--		---	--	All good clean crystals.
943369-2	--	2a	--		---	--	Looks low grade. Rhombs still present.
943369-3	--	2a	--		---	--	Calcite forms aggregates in dolomite.

Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
018371-1	---	2a	3f	---	---	---	---
018371-3	---	2b	3f	4--Tr Cc Qtz = Di	---	---	Myerkitic feldspar. Di inside Tr.
090371-3	---	2a	---	Di altered to chlorite	---	---	---
090371-1	---	2a	---	4--Tr Cc Qtz = Di	---	---	Both Di & Tr as indiv. crystals.
061375-3	---	2a,b	---	---	---	---	Di often rimmed by Tr.
940376-3	1	---	---	Spinel altered to chlorite	---	---	Rhomb still present.
824377-2	---	2b	---	Di altered to serp	---	---	Good pseudomorphs of serp after diopside.
821377-3	---	2b	---	Serp after Di	---	---	Serp apparently after Di.
111375-1	---	---	---	? altered to serp.	5b	---	Good crystal outlines.
935380-4	---	2a	3f,a	---	---	---	Good serp areas but cannot really tell original mineral.
935380-6	---	2b	---	Plag altered to chlorite mixture. Tr altered to talc	---	---	Polygonal aggregates of Qtz.
824385-2	---	2a,b	---	---	---	---	Sulphides abundant.
82-380-3	---	2b	---	---	---	---	Polygonal Qtz.
843380-1	---	2b	---	Tr altered to talc	---	---	Good clean carbonate.
111381-1a	---	2a	---	Plag altered to chlorite, sericite	---	---	Coarse grained but not well recrystallized.
765381-1	---	2b	---	Di altered to serp and chlorite, plag -- scapolite.	---	---	---
844382-2	---	2a,b	---	Tr dol = Fo Cc	---	---	Di alteration somewhat hydrothermal in nature.
844383-3	1	2b,c	---	Fo altered to serp	---	---	Poorly recrystallized - serp patches contain talc.
931382-2	---	2a	---	Tr altered to talc	---	---	---
931382-3	---	2a	---	4--Qtz Dol = Tr Cc	---	---	Cloudy carbonate poorly recrystallized.
767389-1	---	2a	---	4--Qtz Dol = Cc Tr	---	---	Appears to be two generations of Tr.
849392-1	---	2b	---	Plag altered to chlorite	---	---	Tr rims chondrodite.
741403-2	---	2b	---	Pseudomorphs of talc & serp after Di	---	---	Chlorite alteration along grain boundaries.
754415-3	---	2b	---	---	---	---	Gone talc growing along cleavage traces in carbonate.
754415-1	---	2a,b	---	---	---	---	---
769433-1	---	---	3d,f	? altered to serp	5	---	Good clean, recrystallized carbonate.
							Very coarse grained.
							Silicates dominate
							Serp veins cut across calcite grains.

Sample No.	Unrecrystallized Sedimentary	Recrystallized Mosaic	Deformational	Reaction	Hydrothermal	Remarks
792436-1	--	2b	--	---	--	Good clean Di. Polygonal aggregates of Qtz.
792436-3	--	--	3b,d	Di altered to talc & sericite	--	Micas mainly basal sections
792436-2	--	2a,b	--	Di altered to talc	--	Talc retrograde after Tr.
798442-1	--	--	--	---	5a,b	Di in centre of talc patches.
798442-3	--	2b	--	Tr altered to talc	--	Poikiloblastic Tr - primary Cc doubtful.
780445-1	--	2	--	---	--	-----
780445-2	--	2b	--	---	--	Inclusion. Myrmekitic feldspar.
781447-1	--	--	--	4---Dol Qtz = Tr Cc	5a,b	Most of section fresh.
764449-2	--	2a,b	--	---	--	Poikiloblastic Tr.
798454-1	--	2b	--	Di altered to chlorite-serp mixture	--	Calcite ill-defined and cloudy.
754451-3	--	2b,e	minor 3b	Tr altered to talc	--	Dolomite well recrystallized.
779451-1	--	2	--	Di altered to serp	--	Well recrystallized. Coarse grained.
763455-1	--	2	--	---	--	Coarse grained.
763455-2	--	2a,b	--	Di altered to chlorite	--	Inclusion. No carbonate.
778457-1	--	2b	3b	---	--	Abundant 'fe' staining.
770459-3	--	2b	--	---	--	Inclusion. No carbonate.
766459-1	--	2b	--	---	--	'Fe' staining common.
764459-3	--	2b	--	---	--	Abundant 'fe' staining esp. along fractures and cleavage traces.
777460-1	--	2a	--	Plag altered to chloritic mixture	--	Good clean carbonate.
791460-2	--	2a,f	--	---	--	Coarse grained.
791460-4	--	2a,f	--	Di altered to Tr & talc	--	Carbonate very dirty.
783460-3	--	2a,b	--	4---Qtz Dol = Tr Cc	--	Good isolated Di.
804464-2	--	2b	--	Tr altered to serp	--	Good mosaic texture. Very coarse grained.
779466-3	--	2b	--	---	--	Tr fresh.
793467-1	--	2a,f	--	Tr altered to talc	--	Dolomite crystals emplaced by calcite.
801468-3	--	2b	--	---	--	Small rounded aggregates of Qtz-Tr-Cc.
783469-2	--	2b,c	--	---	--	Good clean carbonate.
	--		--	---	--	Tr Dol in contact with serp.
	--		--	---	--	Serp appears to be after Fo.
	--		--	---	--	Tr Dol = Fo Cc?
	--		--	---	--	Di surrounded by Tr.

Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
931489-1	--	2b	3f	---	---	---	Di & Tr fresh and as individual grains.
927490-2	--	2b	minor, 3b	---	---	---	Large irregular areas of talc possibly primary.
927490-2	--	2b	--	---	---	---	Possibly primary talc?
947497-2	--	2b	--	---	---	---	Minor carbonate only eaten into by extensive talc development.
955510-1	--	2a	--	---	---	---	Coarse grained.
793514-4	--	2b	--	---	---	---	Myrmekitic feldspar.
793514-3	--	2b	--	---	---	---	Calcite veins cut across dolomite.
070516-1	--	2a	--	---	---	---	Cloudy calcite due to exsolution, not hydrothermal alteration.
070516-2	--	2a	3f	Feldspar -- Scapolite	5b	---	
110520-2	--	2b	--	Serp alteration	5b?	---	
110520-3	--	2b	--	Di or Tr altered to serp	---	---	
958521-1	--	2b	3e,f	Feldspar altered to green chloritic mixture	---	---	
071523-1	--	2b	3f	---	---	---	Qtz shows marked strain and is very polygonal.
071523-2	--	2b	3f	---	---	---	Qtz has very undulose extinction.
071523-2	--	--	3b,d,f	---	---	---	Qtz aggregates not recrystallized.
071523-2	--	--	3b,f,d	---	---	---	Strained Qtz common.
795524-3	--	2a,c	--	---	---	---	Di & Tr in contact but no apparent reaction.
958525-2	--	2a	--	---	---	---	Very coarse grained.
962537-1	--	2a	--	Spinel altered to chlorite	---	---	Despite serp no good evidence of hydrothermal alteration.
970543-1	--	2a	--	Fo altered to serp??	---	---	
974546-1	--	2a	3a	Tr altered to serp?	---	---	Tr Dol in contact with serp.
974546-1	--	2b	--	Possibly Tr-Fo-serp?	---	---	
974546-3	--	--	3b,d	---	---	---	Fresh forsterite.
104549-1	--	2b	3b	---	---	---	Coarse grained.
975549-2	--	2a	--	---	---	---	Rounded to irregular serp patches possibly after Fo.
104549-1a	--	--	3d,b	---	---	---	
104549-3	--	2b,c	--	Spinel altered to chlorite	---	---	No evidence of hydrothermal alteration.
108549-2	--	2a	--	Fo to serp?	---	---	
975550-2	--	2a,b	--	---	---	---	Bounded serp after Fo?
073558-2	--	2a	3b	---	---	---	Large aggregates of strained Qtz. Possibly Kspar Dol in contact.

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Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
073562-2	--	2a,b	--	----	----	--	Good clean carbonate, well twinned.
104563-3	1	--	--	----	----	5b	Chlorite alteration along fractures. Talc 'trees' present.
981563-2	--	2a	--	----	----	--	Carbonate cloudy but well re-crystallized.
094567-1	--	2b	--	----	----	--	Weird inclusions possibly phosphate?
094567-1	1	--	1	----	----	--	-----
095567-1	--	--	--	----	----	5a	-----
902568-2	--	--	3b	----	----	5a	-----
902568-3	--	--	3a,b	----	----	5a	Fibrous talcrite present.
114571-2	--	--	3a	----	----	5b	Serp after Fo? Texture not typical hydrothermal.
114571-3	--	2a	--	----	----	5a	Serp appears to be after diopside.
114571-4	1	--	--	----	----	5b	Texture looks low grade -- rhombs of dol present.
072571-1	--	2b,c	--	----	----	--	-----
072571-1	--	2a	--	----	----	--	Qtz - Dol in contact.
072571-2	--	2a	--	----	----	--	Qtz - Dol in contact.
072571-2	--	--	--	----	----	5b	Serp appears to be after diopside.
907571-3	--	--	--	----	----	--	Some vague crystal outlines.
089574-2	1	--	--	----	----	--	Polygonal Qtz aggregates.
850574-2	--	2b,c	--	----	----	--	Tr rims Di. Di - phlog in contact.
916578-1	--	2b,c,e	--	----	----	--	-----
916578-2	--	2b	--	----	----	--	-----
076590-1	--	2a	--	----	----	--	-----
076590-2	1	--	--	----	----	--	-----
076590-2	--	--	--	----	----	5a	-----
817590-3	--	2a	--	----	----	--	Calcite displays overgrowths.
927591-1	--	2a	3f	----	----	--	Calcite not primary but present as fracture fillings.
825592-1	--	2a,b	--	----	----	--	Tr rims Di.
930595-1	--	2b	--	----	----	--	Qtz still as unrecrystallized areas.
				----	----	--	Very coarse grained.
				----	----	--	Appears to be the reaction
				----	----	--	Qtz dol = Tr Cc.
930595-2	--	2a	--	----	----	--	-----
099600-1	--	2b	--	----	----	--	Di rimmed by Qtz.

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Sample No.	Unrecrystallized Sedimentary	Mosaic	Recrystallized Deformational	Reaction	Hydrothermal	Remarks
099600-2	--	2b	--	----	--	Not well recrystallized. Qtz still polygonal.
937602-2	--	2a	--	Plaz altered to sericite and scapolite	--	-----
937602-3	--	--	--	Serp alteration areas	5b	Serp present as pseudomorphs
073605-1	--	--	--	Alteration areas of undeterminable composition possibly serp or chlorite	5b	-----
073613-1	--	2a	3a	Feldspar altered to mixture of chlorite and/or serp	--	Fibrous growth around feldspar areas
735625-2	--	--	3b	----	--	Dolomite rhombs in calcite areas.
93621-1	1	--	--	----	--	Coarse grained.
93621-2	--	2b	--	----	--	-----
93629-1	--	2b	--	4--Tr Cc Qtz = Di	--	Not well recrystallized. Almost hydrothermal.
93629-2	--	2b	--	----	--	-----
93629-3	--	2b	--	4--Tr Cc Qtz = Di	--	Very cloudy carbonate. Tr with Qtz centre and Dol rims.
93629-4	--	--	3b,c,d	----	--	-----
93631-1	--	2a,b	--	4--Qtz Dol = Tr Cc	--	-----
93653-1	--	2f	--	Di altered to chlorite/serp mixture	--	-----
93662-2	--	2a	--	Fo altered to serp	5b	-----
93662-3	--	2b	--	Tr altered to talc	--	Tr & Di indiv. crystals
029662-2	--	2b	--	----	--	-----
029669-1	--	2b	--	Tr altered to talc	--	Coarse grained. Rainbow twinning common.
029669-2	--	2b,f	--	----	--	Possible forsterite?
93675-1	--	2a	--	----	--	Tr & Di indiv. grains.
93675-2	--	2a	--	----	--	Chlorite alteration along fractures.
061675-1	--	--	--	----	--	Poorly crystallized.
93675-2	1	2b	--	----	--	Qtz shows wavy extinction.
93675-3	1	2c	3b	----	--	Little carbonate.
93675-4	--	2a	3a,e	----	--	'Fe' staining abundant.
93675-5	--	2a,b	--	----	--	Qtz-Dol in contact. Qtz fibrous.
93675-6	--	2a,b	--	----	--	Irregular areas of talc. Abundant 'Fe' and graphite along grain boundaries.
93675-7	--	2b	--	----	--	-----
93675-8	--	2b	--	----	--	-----
 

Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic.	Deformational				
877716-2	1	2b	--	---	---	--	Poorly recrystallized.
820731-3	--	2a	3f	---	4--Tr Cc Qtz = Di	--	Calcite very cloudy.
838752-3	--	2c	--	---	Di altered to Tr.	--	Tr often with Qtz centre.
					Tr gone to talc		Di more altered than indiv. Tr areas.
845793-1	--	2a	--	---	Feldspar altered to sericite & chlorite	--	-----
850754-1	--	2a	--	---	---	--	Di with Tr rims.
					---	--	Excellent 2a texture.
845755-5	--	2b,c	--	---	---	--	Tr with Qtz centres.
906738-1	--	2b,c	--	---	---	--	Serp as round to irregular areas.
906738-2	--	2b,c	--	---	---	--	Inclusion.
906738-4	--	2b,d,e	--	---	Tr altered to talc	--	Inclusion.
828790-2	--	2b	--	---	Tr altered to talc	--	Calcite poorly crystallized.
862791-1	--	2b	3b	---	---	--	Dolomite well crystallized.
862791-2	--	2b,a	--	---	---	--	Carbonate dirty.
866794-2	--	2b	--	---	---	--	Coarse grained.
866794-1	--	2b	--	---	Plag slightly altered to sericite-chlorite.	--	-----
875795-1	--	2b,c	3e,f	---	---	--	Calcite cloudy and poorly crystallized.
875795-2	--	2b	3f	---	---	5b	Serp appears to be after Fo.
894798-3	--	2b	--	---	---	--	Possibly Qtz Dol = Tr Cc†
					Tr slight alteration to talc	--	Tr good and fresh. Fine grained.
837800-1	--	2a	--	---	---	--	-----
891807-1	--	--	3b,f	---	---	--	Idioblastic Tr.
874207-2	--	2c	--	---	---	--	-----
877807-1	--	2a	3f	---	---	--	-----
877807-2	--	2a,e	--	---	---	--	-----
863608-2	--	2b	--	---	---	--	-----
894214-2	--	2b	3b	---	---	--	Dolomite embayed by calcite.
882817-1	--	2b	--	---	---	--	Good clean, well recrystallized carbonate.
900824-4	--	2a	3b	---	Tr altered to talc	--	Tr surrounded by Cc in a Dol host.
873844-1	--	2a	--	---	---	--	Abundant graphite. Fine grained.
873844-1	--	2a	--	---	Tr altered to talc	--	-----
870847-1	--	2a,b	--	---	4--Tr Cc Qtz = Di	--	No diopside in this section although
876847-2	--	2a	--	---	Tr altered to talc	--	882849-1 has considerable.
882849-1	--	2a	--	---	---	--	-----
882849-2	--	2a	--	---	---	--	-----

Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
875849-1	--	2a,b	--	Tr altered to talc	---	--	---
899849-1	--	2a	3f	4--Qtz Dol = Tr Cc	---	--	---
903852-1	--	2b	--	4--possible reaction	---	--	---
903852-2	--	2b	3b	Qtz Dol = Talc Cc	---	--	Qtz Dol in contact. Maybe Tr was formed and reacted to talc
891853-1	--	2a	--	4--Qtz dol = Tr Cc	---	--	---
891853-2	--	2a	--	Tr Cc Qtz = Di	---	--	Qtz - Dol in contact yet same outcrop has Di water rich?
867853-1	--	2a,b	--	---	---	--	---
867853-2	--	2a,b	--	---	---	--	---
915666-1	--	2a	--	---	---	--	---
915866-2	--	2b	3b,f	---	---	--	---
871878-2	1	2b	--	---	---	--	---
883590-1	--	2b	--	Tr altered to talc	---	--	Poorly recrystallized. Areas of Tr not altered while some areas are, also areas of talc with no Tr.
896592-1	--	2a	--	4--Qtz dol = Tr Cc	---	--	Both reactions are in progress. Qtz-Dol surrounded by Tr (talc).
873894-1	--	2b	--	Tr Cc Qtz = Di	---	--	---
88894-1	--	2a	3a	4--Qtz dol = Tr Cc	---	--	Fibrous calcite.
888594-2	--	2a,b	--	Tr altered extensively to talc	---	--	---
837900-2	--	2b	--	4--Qtz dol = Tr Cc	---	--	Beautiful reaction texture. Qtz still polygonal aggregate.
901902-1	--	2a	--	Tr altered to talc	---	--	Carbonate interlayered with silicates. Coarse grained.
93915-1	--	2a,b	--	Tr altered to talc	---	--	Dolomite well recrystallized, calcite deformed.
844922-2	--	2a	3b	Tr altered to talc.	---	--	Good distinct Tr.
861931-2	--	2a	--	---	---	--	---
880935-1	--	2b	--	---	---	--	Carbonate dirty but well recrystallized; Tr contains talc Cc patches.
880935-2	--	2b	--	---	---	--	Carbonate generally cloudy and not well recrystallized.
854033-1	--	2a	--	Tr altered to talc Cc.	---	--	Unaltered Fo present.
893939-1	--	2a	--	Feldspar--scapolite	---	--	---
893939-3	--	2b	--	slight chlorite alteration	---	--	---
02947-2	--	2a	--	Fo altered to serp	---	--	---
840954-3	--	2a,b	--	Feldspar--scapolite	---	--	---
837953-3	--	2a	--	---	---	--	---

Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
637958-4	--	--	3a,f,e	---	---	--	All twins distorted.
837958-1	--	2a	---	---	---	--	Qtz dol thought to be in contact.
837958-5	--	2a	---	---	---	--	No primary calcite
637958-1	--	2b	3f	---	---	--	Qtz dol appear to be in contact.
010963-1	--	2b	---	---	---	--	Coarse grained.
932963-1	--	2b	---	---	---	--	Section dirty due to abundant graphite. 'Fe' staining common.
932963-2	--	2a	---	---	---	--	---
900964-1	--	2b	---	4--Tr Cc Qtz = Di	---	--	---
900964-1	--	2b	---	---	---	--	---
900964-1	--	2a,b	---	4--Tr Cc Qtz = Di	---	--	Qtz Tr rim Di.
900964-2	--	2a	---	---	---	--	Section displays good banding.
943975-1	1	--	---	---	---	5a?	Difficult to tell if texture 1 or 5
895974-2	--	--	3b,f	---	---	--	Qtz Dol probably in contact.
907979-1	--	2b	3b	4--reaction involving formation of mica but reactants too fine grained to I.D.	---	--	---
907979-2	--	2b,c	3b	---	---	--	---
891984-1	--	2b	---	---	---	--	Coarse grained.
012984-1	2b	2b	---	---	---	--	Individual grains of Tr and Di.
885986-1	--	2a,b	---	---	---	--	---
863986-2	1	2b,c	---	---	---	--	Rhomb of calcite still present.
954986-1	1	2b	---	---	---	--	---
042989-2	--	2e,c	---	Tr altered to talc	---	--	Di not altered as much as Tr.
834992-1	--	2a	---	---	---	--	---
834992-2	--	2b	---	---	---	--	---
912995-2	--	--	---	---	---	--	---
961995-1	--	2b	3b,f	---	---	--	---
035997-1	--	--	---	---	---	--	---
063997-2	--	2a,e	---	---	---	--	---
979998-1	--	2a,b	---	Tr altered to talc	---	--	Talc grows into calcite and along grain boundaries with no apparent Tr.
032000-1	--	2a,b	---	Tr altered to talc	---	--	Coarse grained.
029002-2	--	2b	---	Fo? altered to serp Cc talc. Possibly serp after Di.	---	--	No forsterite remains.
023004-1	--	2a,b	---	---	---	--	Poikiloblastic Tr.
023004-2	--	2b	3b	4--Qtz dol = Tr Cc	---	--	Only moderately well recrystallized.
023004-3	--	2a	---	4--Qtz dol = Tr Cc	---	--	Coarse grained.
923004-1	--	2b	---	Tr altered to talc Cc	---	--	Fine grained. Calcite rims dolomite and forms small round structures.

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Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
025008-1	--	2b	--		---	--	Some cloudy carbonate but generally clean.
024010-2	--	2b	--		---	5b	Serp after Fol
880012-2	--	2b	--		---	--	Carbonate stains bluish indicating 'Fe'.
876016-1	--	2b	--		---	--	Carbonate grains irregular but well twinned.
927018-1	--	2e	--		---	--	Tr massive.
036020-1	--	2b	--		4--Qtz dol = Cc Tr	--	Reaction patches contain fine grained reactants so that identification difficult.
036020-2	--	2b	--		4--reaction appears to involve talc. Can't determine if talc primary.	--	Talc present as areas with Cc centre and no Tr so that maybe primary.
835	--						
835023-2	--	2a	--		Serp alteration of Fol	--	
835025-1	--	2b	3b		4--Qtz dol = Tr Cc	--	Serp present as small irregular patches.
042026-4	--	--	--		Fo altered to serpf	5b	Idioblastic Tr.
895033-1	--	2b	--		---	--	Calcite cloudy and illformed but dolomite well recrystallized.
895033-2	1	2b	--		---	--	
920035-2	--	2b	--		---	--	
921037-1	--	2a	--		4--Qtz dol = Tr Cc	--	
921037-3	--	2a	--		---	--	
921037-4	--	2a	--		---	--	
963041-1	--	--	3f,b		---	--	Good clean texture. Qtz recrystallized.
976049-1	--	2a	--		---	--	Twins curved and bent in most grains.
861066-1	--	2a	--		---	--	Some Tr Qtz Cc in contact but no reaction Qtz-dol.
969068-1	--	2	--		---	--	
969068-1	--	2	--		---	--	Myrmekitic feldspar. Talc growing along grain boundaries.
969068-1	--	2	--		---	--	
009079-1	--	2a	--		4--Qtz dol = Tr Cc	--	Good reaction areas.
980081-2	--	2b	--		---	--	
984087-1	--	--	3b,f		---	--	
878141-1	--	--	--		---	--	

SPECIMEN NUMBER	CALCITE	DOLomite	QUARTZ	DIOPSIDE	TREMOLITE	SERPENTINE	FORSTERITE	TALC	TOURMALINE	APATITE	SPHENE	SPINEL	RUThLE	PLAGIOCLASE	KSPAR	CHROMITE	MUSCOVITE	EPIDOTE	CHROMODITE	SCAPOLITE	SERICITE
062283-2	60	05	15	--	--	--	--	--	03	--	--	--	--	--	10	--	--	--	--	--	--
068288-1	55	--	10	15	--	--	--	--	--	--	02	--	--	--	15	--	--	--	--	--	--
069289-2	90	--	02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
071290-1	85	--	05	10	01	--	--	--	--	--	01	--	--	03	01	--	--	--	--	--	--
071291-1	20	--	10	50	02	--	--	--	--	--	02	--	--	10	20	01	--	--	--	05	--
072292-1	05	--	15	--	--	--	--	--	--	--	01	--	--	20	25	--	--	--	--	30	--
072293-1	10	--	35	--	01	--	--	--	--	--	05	--	--	20	15	--	--	--	--	10	--
126314-3	10	--	02	05	10	--	--	--	--	--	05	--	--	--	40	--	--	--	--	10	--
033318-3	70	--	20	--	--	--	--	--	--	--	01	--	--	--	--	05	--	--	--	--	--
033318-1	80	--	10	--	--	--	--	--	02	--	--	--	--	--	--	02	--	--	--	--	--
113318-1	60	--	05	--	--	--	--	--	--	--	02	--	--	05	10	05	10	--	--	--	--
111318-8	70	--	10	--	--	--	--	--	--	--	01	--	--	--	15	02	05	--	--	--	--
125318-2	80	05	--	--	05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
111318.5-1	70	--	05	--	--	--	--	--	--	--	02	--	--	05	10	03	10	01	--	--	--
111319-1	03	75	05	--	--	--	--	--	--	--	02	--	--	--	05	10	--	--	--	--	--
116320-1	65	--	05	10	--	--	--	05	--	--	02	--	--	10	03	--	02	01	--	10	--
119320-1	15	60	--	--	05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
125320-1	70	--	15	--	--	--	--	--	--	--	01	--	--	02	--	01	03	01	--	--	--
033320-1	85	--	05	01	01	01	--	--	--	--	01	--	--	02	--	--	--	--	--	--	--
033320-1	80	--	10	--	02	--	--	--	--	--	01	--	--	01	02	01	--	--	--	--	--
123321-2	40	--	05	--	--	--	--	--	--	--	--	--	--	05	35	--	15	--	--	--	--
123321-1	40	35	05	--	--	--	--	--	--	--	--	--	--	05	05	03	03	--	--	--	--
021322-3	75	--	15	--	--	--	--	--	--	--	--	--	--	--	--	01	05	02	--	--	--
105322-2	60	--	03	10	--	--	--	--	--	--	03	--	--	20	05	03	--	--	--	--	--
105322-1	60	--	03	05	--	--	--	--	--	--	02	--	--	10	03	05	--	--	--	--	--
034323-1	70	--	10	05	--	--	--	--	--	--	02	--	--	05	03	05	--	--	--	03	--
020323-1	80	--	05	--	--	--	--	--	--	--	--	--	--	--	--	01	01	--	--	--	--
020323-3	75	--	10	--	02	--	--	--	--	--	01	--	--	10	05	05	01	--	--	02	--
020324-1	55	--	20	--	03	--	--	--	01	--	02	--	--	05	10	01	02	--	--	05	--
035325-2	85	--	05	01	--	05	--	--	--	--	01	--	--	01	02	--	--	--	--	--	--
038328-2	70	--	15	--	--	--	--	--	--	--	01	--	--	--	05	05	--	--	--	--	--
027330-1	90	--	02	--	--	--	--	--	--	--	--	--	--	--	02	--	01	--	--	--	--
023331-1	60	--	20	--	02	--	--	--	--	--	03	--	--	05	--	03	01	--	--	--	--
034332-3	85	--	10	--	02	--	--	--	--	--	02	--	--	--	--	02	--	--	--	--	--
028333-1	75	--	05	--	10	--	--	--	--	--	01	--	--	--	--	--	--	--	--	02	--
043336-1	40	30	15	--	--	--	--	--	01	--	01	--	--	--	03	05	--	--	--	--	--
074339-2	40	--	05	30	--	--	--	--	--	--	03	--	--	05	03	--	--	--	--	10	--
116347-1	03	60	15	--	--	--	--	--	--	--	--	--	--	--	15	1	05	--	--	--	--
116347-1	05	--	20	--	--	--	--	--	--	--	02	--	--	05	70	--	02	01	--	--	--
105348-2	30	--	35	20	--	--	--	--	--	--	02	--	--	02	02	--	--	--	--	--	--
081348-3	02	80	10	--	--	--	--	--	--	--	--	--	--	--	01	--	01	--	--	--	--
105348-3	50	--	10	15	--	--	--	--	--	--	08	--	--	05	--	02	--	--	--	10	--
084350-1	90	--	02	--	--	--	--	--	--	--	01	--	--	01	01	--	01	--	--	--	--
083350-1	75	--	10	--	--	--	--	--	--	--	01	--	--	--	--	05	02	--	--	--	--
105351-1	75	--	10	01	--	05	--	--	--	--	--	--	--	--	--	05	--	--	--	--	--
068353-1	80	--	05	02	05	--	--	--	--	--	02	--	--	--	05	--	02	--	--	05	--
105353-1	55	--	15	15	--	--	--	--	--	--	02	--	--	--	01	01	01	--	--	01	--
470354-2	75	--	15	02	--	--	--	--	--	--	03	--	--	02	01	01	01	--	--	01	--
086355-3	75	--	05	--	--	--	--	--	01	--	--	--	--	--	05	--	02	--	--	--	--
056355-1	05	75	05	--	--	--	--	--	--	--	--	--	--	--	05	--	--	--	--	--	--
069356-1	02	--	50	01	--	--	--	--	--	--	--	--	--	30	02	--	02	--	--	10	--
071360-2	02	90	05	--	--	--	--	--	--	--	--	--	--	--	--	01	01	--	--	--	01
088362-1	70	--	20	--	01	--	--	--	--	--	01	--	--	--	--	--	01	--	--	--	--
089363-2	40	--	15	20	--	--	--	--	--	--	02	--	--	02	10	--	01	--	--	10	--
073364-1	85	--	10	--	01	--	--	--	--	--	--	--	--	--	--	01	--	--	--	02	--
079364-1	65	--	05	05	--	--	--	--	--	--	02	--	--	--	--	05	--	--	--	15	--
097365-2	60	--	10	15	01	--	--	--	--	--	02	--	--	10	--	--	--	--	--	--	--
075365-1	40	--	05	40	--	--	--	--	--	--	03	--	--	02	05	--	01	--	--	05	--
095367-1	90	--	02	02	--	--	--	--	--	--	02	--	--	--	--	--	01	--	--	--	--
095367-2	60	--	15	10	03	--	--	--	--	--	02	--	--	--	03	--	02	--	--	--	02
075370-2	50	--	30	--	01	--	--	--	--	--	03	--	--	02	02	--	01	--	--	02	--
093370-2	65	--	15	10	02	--	--	--	--	02	02	--	--	02	01	01	02	--	--	05	--
075370-1	70	--	15	--	02	--	--	--	--	--	03	--	--	--	05	--	02	--	--	02	--
076371-1	70	--	25	--	--	--	--	--	--	--	01	--	--	05	03	05	02	--	--	--	--
076373-1	70	--	05	01	--	--	--	--	--	--	02	--	--	10	05	--	--	--	--	--	--
088375-2	65	--	20	--	--	--	--	--	--	--	--	--	--	10	--	--	--	--	--	--	--
078376-2	60	--	20	15	--	--	--	--	--	--	01	--	--	10	05	--	--	--	--	10	--
081376-1	60	--	02	25	--	--	--	--	--	--	03	--	--	02	02	02	01	--	--	10	--
097378-1	80	--	05	--	--	--	--	10	--	--	02	--	--	10	02	01	01	--	--	--	--

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SPECIMEN NUMBER	CALCITE	DOLomite	QUARTZ	DIOPSIDE	TREMOLITE	SERPENTINE	FORSTERITE	TALC	TOURMALINE	APATITE	SPHENE	SPINEL	ROUTLE	PLAGIOCLASE	KSPAR	CHLORITE	PHLOG.	MUSCOVITE	SERICITE	SCAPOLITE	CHONDRODITE	EPIDOTE
097381-1	65	—	10	—	03	—	—	—	—	—	01	—	—	10	10	—	03	—	—	15	—	—
089384-1	75	—	10	—	01	—	—	—	—	—	—	—	—	02	02	—	—	—	—	—	—	—
082385-1	50	—	25	10	—	—	—	—	—	—	03	—	—	03	—	01	—	—	—	05	—	—
089387-1	90	—	05	—	—	—	—	—	01	—	—	—	—	—	03	01	—	10	—	—	—	—
102396-2	40	—	25	—	—	—	—	—	01	—	02	—	—	20	15	03	02	—	—	—	—	—
102396-1	15	60	10	—	—	—	—	—	—	01	—	—	—	02	05	02	02	—	—	—	—	—
102397-1	35	50	10	—	—	—	—	—	—	—	—	—	—	—	—	03	—	—	—	03	—	—
101399-2	80	02	10	—	—	—	—	—	—	—	—	—	—	03	03	—	—	—	—	—	—	—
101399-1	80	01	10	—	—	—	—	—	01	—	—	—	—	—	05	—	01	01	—	—	—	—
101403-1	40	05	05	—	—	—	—	—	—	—	01	—	—	10	05	03	01	—	—	—	—	—
098404-1	05	70	—	—	—	25	—	05	—	—	—	—	—	—	—	—	—	—	—	—	—	—
098406-3	35	55	08	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
099411-1	60	—	25	—	—	—	—	—	—	—	02	—	—	—	05	05	—	—	—	—	—	—
095413-1	—	50	—	—	—	40	—	03	—	—	—	—	—	—	—	—	—	—	—	—	—	—
099413-1	60	—	05	—	—	—	—	—	—	—	02	—	—	—	05	10	—	—	—	—	—	—
099414-7	45	—	05	—	—	05	—	—	01	—	03	—	—	05	20	—	—	—	—	—	—	02
096415-2	10	60	—	—	—	30	—	—	—	—	—	—	—	—	—	—	01	—	—	—	—	—

Sample No.	Unrecrystallized		Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational				
062283-2	1	--	--		Plag altered to green chloritic mixture	--	-----
068288-1	--	2a,b	--		Feldspar -- Scapolite	--	Di fairly fresh.
069289-2	--	2a,b	--		-----	--	Fine grained. Not well recrystallized.
071290-1	--	2a	--		-----	--	Tr and Di indiv. grains.
071291-1	--	2b,c	--		-----	--	Mymerkitic feldspar.
072292-1	--	2b,e	--		-----	--	Wide range in grain size.
072293-1	--	2b,e	--		-----	--	Abundant opaques give section dirty appearance.
126314-3	--	2b,e	--		-----	--	Silicates dominate.
033318-3	--	2b	--		h--Tr Qtz Cc = Di	--	Mymerkitic feldspar.
033318-1	--	2b	--		Patches of chloritic alteration.	--	Polygonal Qtz.
113318-1	--	2b,c	--		Plag altered to green chloritic material.	--	Possible overgrowths
111318-8	1	--	--		Slight chlorite development	--	Qtz and feldspars aggregated.
125318-2	--	2a,b	--		-----	--	Mymerkitic feldspar.
111318-5-1	1	2b	--		-----	--	Coarse grained.
111319-1	1	2b	--		Plag extensively altered to green chloritic mass	--	Rhomb of carbonate still present.
116320-1	1	--	--		Di altered to chlorite	--	Aggregates of radiating Qtz.
119320-1	--	2a	3a		Plag altered to sauss.	--	Talc masses retrograde or prograde?
125320-1	--	2b	--		Plag altered to green chloritic mass.	--	Poorly recrystallized.
033320-1	--	2a,b	--		h--Tr Cc Qtz = Di	--	Februous calcite.
033320-1	--	2a,b	--		-----	--	Overgrowths?
123321-2	--	2a,c	--		-----	--	Mymerkitic feldspar.
123321-1	1	--	--		Greenish alteration areas	--	Rhomb of calcite still present.
021322-3	1	2b	--		Feldspar altered to green mixture of undetermined composition.	--	Qtz strained-radiating extinction.
105322-2	--	2b	3b		Di altered to epidote - chlorite mixture.	--	Plag and kspar fresh.
105322-1	--	2a	--		-----	--	Coarse grained.
034323-1	--	2a,b	--		Di altered to epidote - chlorite mixture.	--	Di fairly fresh.
020323-1	1	2b	--		-----	--	'Fe' staining.
020323-3	--	2a,b	--		Feldspar altered to sauss.	--	Staining indicates some Fe present.

Sample No.	Unrecrystallized			Recrystallized		Reaction	Hydrothermal	Remarks
	Sedimentary	Mosaic	Deformational					
020324-1		2a	--			---	--	Tr rimmed by Qtz. Phlog growing into feldspar area.
035325-2	--	--	3b,e,f			---	--	Good clean carbonate.
038328-2	--	2a	--			---	--	Coarse grained.
027330-1	--	2a	--			Plag altered to chlorite etc.	--	
023331-1	--	2a	--			Feldspar altered slightly	--	
034332-3	--	2a	--			Plag altered to sauss.	--	
053333-1	--	2a,b	--			---	--	Aggregates of polygonal Qtz.
043336-1	1	--	--			---	--	Coarse grained.
074339-2	4	2a,c,e	--			---	--	Radiating Qtz aggregates.
116347-2	2a	--	--			Plag altered to green chloritic mixture	--	Fine grained.
116347-1	1	--	--			---	--	Mymerkitic feldspar.
105348-2	--	2e	--			---	--	Overgrowths on feldspar.
081348-3	1	--	--			Plag altered to sericite and minor chlorite	--	Phlog growing into Qtz-kspars areas.
105348-3	--	2a,b	--			Feldspar--Scapolite	--	Poorly recrystallized.
084350-1	1	2b	--			Plag altered to sauss.	--	Clean well recrystallized carbonate.
083350-1	--	2b(to 1)	--			Plag altered to sauss.	--	Serp veins (chlorite).
105351-1	1	2b	--			---	--	Aggregates of polygonal Qtz.
068353-1	--	2a'	--			h--Tr -Cc Qtz = Di Di altered to Tr	--	Poorly recrystallized.
105353-1	--	2a,b	--			---	--	Aggregates of polygonal Qtz.
070354-2	--	2b	3b			Di altered to both Tr and chlorite mixture.	--	Poorly recrystallized.
063355-3	--	2a,b	--			---	--	Aggregates of polygonal Qtz.
056355-1	1	2b	--			Plag altered to sauss.	--	Rhombs present.
069356-1	--	2b,e	--			Plag -- Scapolite	--	Radiating Qtz.
071360-2	1	--	--			---	--	Di rimmed by Tr
083362-1	1	2b	--			---	--	Slight alteration only.
039363-2	--	2a,b	--			---	--	Some 'Fe' staining.
073364-1	--	2b	--			---	--	Overgrowths present.
079364-1	--	2b	--			---	--	Phlog growing into feldspar areas.
097365-2	--	2a,b	--			---	--	Silicates dominate.
						---	--	Vague recrystallization only.
						---	--	Poorly recrystallized.
						---	--	Mymerkitic feldspar. Kspars unaltered.
						---	--	Plag altered. (scap)
						---	--	Aggregates of polygonal Qtz.
						---	--	Di clean.

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Sample No.	Unrecrystallized Sedimentary	Recrystallized Mosaic	Deformational	Reaction	Hydrothermal	Remarks
075365-1	--	2b	--	Di and plaz altered to a brown-green product.	--	Carbonate very dirty.
095367-1	--	2a,b	--	4--Qtz Cc Tr = Di	--	-----
095367-2	--	2a,b	--	Plaz altered to sausa.	--	Mymerkitic feldspar.
075370-2	--	2a,b,c	--	4--Qtz Cc Tr = Di	--	-----
093370-2	--	2a	--	4--Qtz Dol = Tr Cc	--	-----
075370-1	--	2b	--	Plaz altered to green chloritic mixture.	--	-----
076371-1	--	--	3b,e,f	-----	--	-----
076373-1	--	2a,b	--	Feldspar -- Escapolite	--	Aggregates of Polygonal Qtz.
088375-2	--	2b	--	Plaz altered to sericite and sausa.	--	Mymerkitic feldspar.
078376-2	--	--	3b,d,f	-----	--	Poorly recrystallized.
061376-1	--	2a	--	-----	--	Poorly recrystallized.
097378-1	1	--	--	-----	--	Polygonal Qtz often strained.
097381-1	--	--	3b,f,d	-----	--	Clean Di.
089384-1	--	2a	--	-----	--	Qtz surrounded by talc. Phlog growing into feldspar area.
082385-1	--	2a,b	--	-----	--	Mymerkitic feldspar.
069387-1	--	2a,b	--	-----	--	-----
102396-2	--	2a	--	Plaz altered to sausa.	--	Coarse grained.
102396-1	1	2b	--	4--Kspar Dol = Phlog Cc	--	Polygonal Qtz. Carbonate well recrystallized.
102397-1	--	2b	--	-----	--	-----
101399-2	1	--	--	Plaz altered to sausa.	--	Radiating Qtz.
101399-1	1	--	--	-----	--	Rhombz vaguely present. Qtz-Dol in contact. Radiating Qtz.
101403-1	--	2a	--	Plaz altered slightly	--	Mymerkitic feldspar.
098404-1	--	--	--	-----	5b	Poorly recrystallized.
098406-3	1	2b	3b	Plaz extensively altered to green-brown product.	--	Strained Qtz aggregates.
099411-1	--	2a,b	--	-----	--	Zoned rhombz.
095413-1	--	--	--	Patches of chlorite alteration	5a	Plaz altered kspar clean.
099413-1	--	2b	--	Plaz altered to sericite	--	Serp sometimes crystal outline of pyroxene after Di
099414-7	--	2b	--	Patches of serp alteration	--	-----
096415-2	--	--	--	-----	5b	Rounded serp areas after Fo? Qtz has radiating extinction.
						Serp after Fo?

Table 1 (cont'd.)

Sample	Result	Sample	Result	Sample	Result
6650-1	Tourmaline	69152-1	Tourmaline	91353-1	Microcline Tremolite
6650-2	Tremolite	69152-2	Phenocryst	91353-2	Chlorite
6650-3	Quartz	69152-3	Phenocryst	91353-3	Serpentine
6650-4	Tourmaline	71353-1	Quartz	91353-4	Dioctite
6650-5	Quartz Phenocryst	71353-2	Actinolite Tremolite Quartz	91353-5	Serpentine Calcite
6650-6	Tremolite	71353-3	Actinolite	91353-6	Serpentine
6650-7	Tremolite	71353-4	Actinolite	91353-7	Serpentine
6650-8	Tremolite	71353-5	Serpentine of Chlorite	91353-8	Serpentine
6650-9	Tremolite	71353-6	Microcline Calcite	91353-9	Serpentine Actinolite
6650-10	Actinolite Tremolite	71353-7	Actinolite	91353-10	Serpentine
6650-11	Actinolite	71353-8	Actinolite	91353-11	Serpentine
6650-12	Quartz Phenocryst	71353-9	Actinolite	91353-12	Serpentine
6650-13	Tremolite	71353-10	Actinolite	91353-13	Serpentine
6650-14	Actinolite	71353-11	Actinolite	91353-14	Serpentine
6650-15	Quartz Phenocryst	71353-12	Actinolite	91353-15	Serpentine
6650-16	Tremolite	71353-13	Actinolite	91353-16	Serpentine
6650-17	Tremolite	71353-14	Actinolite	91353-17	Serpentine
6650-18	Tremolite	71353-15	Actinolite	91353-18	Serpentine
6650-19	Tremolite	71353-16	Actinolite	91353-19	Serpentine
6650-20	Tremolite	71353-17	Actinolite	91353-20	Serpentine
6650-21	Tremolite	71353-18	Actinolite	91353-21	Serpentine
6650-22	Tremolite	71353-19	Actinolite	91353-22	Serpentine
6650-23	Tremolite	71353-20	Actinolite	91353-23	Serpentine
6650-24	Tremolite	71353-21	Actinolite	91353-24	Serpentine
 

APPENDIX C DISTRIBUTION OF ISOREACTION-GRADS IN THE STUDY AREA

1) Isobaric Invariant Isoreaction-grad II

- a) Lyndhurst Pluton - Detailed Area
- b) Carleton Place Map-Area
- c) Perth Map-Area
- d) Westport Map-Area
- e) Tichborne Map-Area

2) Isobaric Univariant Isoreaction-grads

- a) Carleton Place Map-Area
- b) Carleton Place High-Grade Zones
- c) Perth Map-Area
- d) Westport Map-Area
- e) Tichborne Map-Area

Distribution of Isoreaction-grads in the Study Area1) Isobaric Invariant Isoreaction-grad IIA) Lyndhurst Pluton - Detailed Area

The trace of isobaric invariant point 2 (figure 7) in $P_f - t - X_{CO_2}$ space has been mapped surrounding the Lyndhurst pluton as isoreaction-grad II, representing the assemblage calcite - dolomite - quartz - tremolite - diopside. The isoreaction-grad conforms to the outline of the pluton over most of its length although it diverges somewhat from the pluton at its northern margin, possibly reflecting an extension of the pluton in this direction at depth. Mapping of isoreaction-grad II was accomplished mainly by bracketing it, in the manner suggested by Skippen (1974), between the numerous isobaric, univariant and divariant assemblages established in the area.

Immediately south of the pluton, one-quarter mile west of Grippen Lake, the isoreaction-grad II is constrained between a quartz dolomite assemblage at location 062283 and a group of closely spaced diopside bearing assemblages several hundred feet to the north at locations 068288, 069289, etc. The position of the isoreaction-grad to the west is uncertain as no data exist for the narrow region between the pluton and the edge of the map-area. East of the initial constraint the isoreaction-grad runs under Grippen Lake and is lost for $1\frac{1}{2}$ miles. East of Grippen Lake the isoreaction-grad passes unconstrained for $\frac{1}{2}$ mile to Singleton Lake where it is restricted on the north by a diopside - tremolite - calcite assemblage at location 107303. It is unconstrained to the south where only inconclusive tremolite assemblages are present. The isoreaction-grad is thought to swing eastward around the diopside assemblage at location 107303

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and head northward under Singleton Lake. Passing northward it is constrained to the west by a diopside - tremolite - calcite - quartz isobaric univariant assemblage at location 105311. It is not constrained on the east. Immediately north of the diopside isobaric univariant assemblage, the isoreaction-grad becomes constrained between this assemblage and a phlogopite - potassium feldspar - dolomite - calcite assemblage $\frac{1}{2}$ mile to the northeast at location 111319. The isoreaction-grad continues northward for $\frac{1}{2}$ mile where it swings to the east in order to pass north of a phlogopite - potassium feldspar - calcite - dolomite assemblage at location 111319 and between it and diopside assemblages several hundred feet to the northwest and northeast at locations 105322 and 116320. Immediately to the east the isoreaction-grad turns back to the north, being constrained between the phlogopite - potassium feldspar - calcite - dolomite isobaric univariant assemblage at location 118319 and the diopside assemblage at location 116320. North from this constraint it passes unrestricted for $1\frac{1}{2}$ miles until a tremolite - calcite - quartz - diopside isobaric univariant assemblage at location 120341 constrains it on the west. It travels northwest around this diopside assemblage passing between it and a potassium feldspar - dolomite - phlogopite - calcite isobaric univariant assemblage $\frac{1}{2}$ mile due north at locality 116347. Passing west of location 116347, the isoreaction-grad travels for several miles northward, being constrained to the east by a quartz - dolomite assemblage at location 118368 and to the southwest by the pluton. The isoreaction-grad is constrained on the north side of this quartz - dolomite assemblage by two diopside bearing assemblages $\frac{3}{4}$ mile to the northwest at locations 111381 and 111378. Continuing north of these constraining localities, isoreac-

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tion-grad II passes east of the two diopside locations and then swings north around them and passes west between them and quartz - dolomite assemblages one mile to the north at locations 102397 and 101399. It then passes under Lower Beverley Lake and is lost for several miles.

The isoreaction-grad can be detected again at the southwest corner of Lower Beverley Lake, $1\frac{1}{2}$ miles north of the town of Brier Hill. Here the isoreaction-grad is constrained between a quartz - dolomite assemblage at location 071360 and diopside - calcite - quartz assemblages to the northeast at location 075365 and to the south at location 069356. The isoreaction-grad runs under the lake north of this constraint but appears to swing to the west where it can be detected in a small area of marble $\frac{1}{2}$ mile west of the lake. In this marble area the isoreaction-grad is constrained between a diopside - tremolite - calcite - quartz isobaric univariant assemblage at location 061375 and a quartz - dolomite assemblage $1\frac{1}{4}$ miles to the south at location 056355. It is lost under the Paleozoic cover away from this constraint. South of the earlier constraint at the southwest corner of Lower Beverley Lake, the isoreaction-grad passes west of a group of diopside assemblages including a diopside - tremolite - calcite - quartz isobaric univariant assemblage at locality 068353. The isoreaction-grad must swing southeast around this univariant assemblage passing between it and a tremolite - calcite - quartz - dolomite assemblage 1 mile to the south at location 066337. Beyond this constraint the isoreaction-grad swings to the northeast, passing between the diopside assemblage at location 068353 and a quartz - dolomite assemblage at location 081348. It continues northeastward for about 1 mile at which point it is closely constrained by a diopside bearing assemblage (diopside observed in the

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field with tremolite - calcite - quartz observed in section. The location may in fact represent a diopside - tremolite - quartz - calcite isobaric univariant assemblage) at location 088362 and a quartz - dolomite assemblage 200 feet south at location 087360. The isoreaction-grad turns to the south and then to the southwest travelling for 2 miles, over which distance it is constrained by two quartz - dolomite assemblages to the northwest at locations 086355 and 081348 and by the pluton less than a mile to the southeast. At the north edge of Brier Hill the isoreaction-grad is closely constrained between two isobaric univariant assemblages - a tremolite - calcite - quartz - dolomite assemblage at location 061337 and a diopside - tremolite - calcite - quartz assemblage 100 feet to the southeast at location 068336. It continues for $1\frac{1}{2}$ miles to Morton where it passes between the pluton and a quartz dolomite assemblage $\frac{1}{3}$ mile to the north at location 048323. The isoreaction-grad passes to the northwest after leaving the Morton area, travelling between the quartz - dolomite assemblage at location 048323 and a diopside univariant assemblage $\frac{2}{3}$ mile to the northwest at location 038328. It travels north of this locality passing between it and another quartz - dolomite assemblage $\frac{1}{2}$ mile to the northeast at location 043336. The isoreaction-grad beyond this point is constrained only by assemblages on the high-grade side. Isoreaction-grad II is thought to pass close to these higher-grade assemblages keeping roughly parallel to the outline of the pluton. Certainly the trace of reaction (7) as defined by isobaric isoreaction-grad (7) follows the outline of the pluton and although this reaction is somewhat

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fluid composition dependent, it is not strongly so (Figure 7).

Isoreaction-grad II is expected to roughly follow this curve and similarly follow the outline of the pluton beyond the last well constrained location.

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B) Carleton Place Map-Area

The Carleton Place map sheet is characterized by a large central region of low-grade metamorphism along the margins of which are linear zones of higher metamorphic grade. The distribution of metamorphic grade in the region is directly reflected by isoreaction-grad II defining the trace of isobaric invariant point 2 (figure 7) in $P_f - T - X_{CO_2}$ space. This isoreaction-grad II represents isothermal conditions and, unlike the isoreaction-grads representing the isobaric univariant reaction curves, is independent of fluid composition. The position of this isoreaction-grad II in the field precisely indicates that distribution of metamorphic grade in the map-area, which appears directly related to several of the major intrusive bodies surrounding the region.

i) Eastern High-Grade Area

Along the eastern margin of the Carleton Place map-area is a high-grade area related to intrusive activity immediately to the west along the Mississippi River system. Isoreaction-grad II, defined by the isobaric invariant assemblage calcite - dolomite - quartz - diopside - tremolite, is best constrained in this region at its northern extremity, about 3 miles south of the town of Almonte. At this locality it is constrained between a serpentine (forsterite) - calcite - dolomite assemblage at location 042026 and a quartz - dolomite assemblage $\frac{1}{2}$ mile to the southwest at location 036020. The isoreaction-grad travels south of this quartz - dolomite assemblage passing between it and another serpentine (forsterite) assemblage 1 mile to the southwest at location 024010. Travelling southward around the west side of this serpentine assemblage the isoreaction-grad swings southward around it to the east where it passes between it and a tremolite - calcite - dolomite - quartz assemblage immediately to the

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southeast at location 025008. The isofeaction-grad then swings back to a southerly direction running east of a quartz - dolomite - tremolite - calcite assemblage at location 028004 and then between this assemblage and several diopside bearing assemblages $\frac{1}{2}$ mile to the southeast at locations 032000, 034998 and 035997. The isoreaction-grad travels $\frac{1}{2}$ mile farther south where it becomes constrained between a diopside - calcite - quartz - tremolite isobaric univariant assemblage at location 042989 and a quartz - dolomite assemblage $1\frac{1}{2}$ miles to the west at location 016994. It continues southward for 2 miles essentially unconstrained. After this distance it is loosely constrained between a forsterite (X-rayed) assemblage at location 025947 and a tremolite - calcite - dolomite - quartz assemblage (possibly having dolomite - quartz in contact, although the minerals were so fine grained that positive identification of the minerals in contact was difficult) $1\frac{1}{2}$ miles to the northwest at location 010963. The isoreaction-grad is unconstrained for the next several miles but is thought to pass to the west in order to swing around the west side of a forsterite-tremolite assemblage (X-rayed) at location 938908. Passing north and west of this locality the isoreaction-grad travels south for 4 miles to the edge of the Carleton Place map-area. Along this distance isoreaction-grad II is constrained on the west by several quartz-dolomite assemblages comprising the Lanark low-grade zone (915866, 903852, 899849), while to the east constraint is provided by the intrusion which is less than 2 miles east of the low-grade zone. South of the Carleton Place map sheet the isoreaction-grad can be identified in the Perth map-area and will be discussed under that area.

ii) Northern High-Grade Area

A high-grade area apparently related to the Almonte Pluton is present along the northern boundary of the Carleton Place map-area.

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Isoreaction-grad II is well constrained in only three localities within this zone. It is best constrained at locality 921037 where the assemblages tremolite - calcite - dolomite - quartz and tremolite - calcite - quartz - diopside are both present providing an upper and lower bracket on the isoreaction-grad. To the east of this constraint the isoreaction-grad travels generally northeastward conforming to the outline of the pluton. It is constrained in this direction by the numerous diopside assemblages to the north along the pluton margin (940068, 941065, 969068, 980080, etc.) and by one quartz - dolomite - tremolite - calcite univariant assemblage at location 976049, 1 mile southeast of the pluton. To the west of the initial constraint at location 921037 the isoreaction-grad is thought to travel generally westward, although the only constraint in this direction is provided by a quartz - dolomite - tremolite - calcite assemblage to the south at location 895033 and by the pluton 1 mile to the north. This isoreaction-grad may be continuous with the isoreaction-grad running north-south along the western margin but direct evidence of this is lacking at present.

iii) Western High-Grade Area

A high-grade zone runs north-south along the western margin of the Carleton Place map sheet. It is thought to be related to an intrusive complex situated along the western margin of the map-area. Isoreaction-grad II is not well constrained over much of this zone and is shown tentatively mainly to conform to the outline of the intrusive body. The isoreaction-grad is best constrained in the central region of this zone where it is restricted between two diopside - tremolite - calcite assemblages at locations 337958 and 840954 and two isobaric univariant tremolite - calcite - quartz - dolomite assemblages 1 mile to the southeast at locations 854938 and 855937. South of this central

constraint isoreaction-grad II swings immediately to the southeast in order to pass between the pluton and a quartz-dolomite assemblage several hundred feet to the northeast at location 861931. For the next 3 miles the isoreaction-grad travels unconstrained, following the general outline of the intrusive body. A quartz-dolomite assemblage at location 873894 provides the only constraint upon the isoreaction-grad over this distance. Beyond this constraint the position of the isoreaction-grad is not known.

Travelling north of the initial constraint in the central part of this zone, the isoreaction-grad passes to the northeast around the south end of a small part of the intrusive complex. It runs along the east side of this small body, passing between it and some quartz-dolomite assemblages further to the east and northeast at locations 895974 and 885986. The isoreaction-grad travels unconstrained for 2 miles northward until it becomes restricted between the intrusive body and quartz-dolomite assemblages immediately east of it at locations 875017 and 876016. A serpentine (forsterite) assemblage, 2 miles west of the quartz-dolomite assemblages, at location 835027 provides a more direct upper constraint upon the reaction at this point. The path of the isoreaction-grad north of this constraint is not known but it may be continuous with the same isoreaction-grad surrounding the Almonte Pluton to the north.

iv) Clyde River High-Grade Area

A small area of high-grade material extends south from the Clyde River about 2 miles west of Lanark. No direct heat source for this zone is obvious at the surface but may be present at a shallow depth. Isoreaction-grad II within the Carleton Place area of this zone is defined by 3 isobaric invariant assemblages. The isoreaction-grad runs to the southeast to form the eastern margin of this zone and to

the southwest to form the western margin of this zone, from the northernmost invariant point at location 896892. The eastern margin is constrained by a second invariant assemblage $2\frac{1}{2}$ miles to the south at location 891853, while the western margin is defined by a similar assemblage at location 882849. The eastern and western margins then proceed off the Carleton Place map sheet and onto the Perth map sheet. The western margin is essentially unconstrained in the Perth map-area although it is restricted on the higher grade side by several diopside assemblages which extend over 2 miles into the Perth area (880821, 873806 and 866794). Just how far to the west of these high-grade assemblages the isoreaction-grad passes is not known since only inconclusive tremolite assemblages are present to the west. The eastern margin is constrained 1 mile south into the Perth map-area by a quartz-dolomite-tremolite-calcite isobaric univariant assemblage, to the east at location 894814 and $\frac{1}{2}$ mile to the west by a diopside isobaric univariant assemblage at location 882817. One mile further south another tremolite-calcite-quartz-dolomite assemblage at location 887800 constrains the isoreaction-grad on the east while diopside assemblages at locations 873800 and 866794 constrain it to the west. The position of the isoreaction-grad beyond this point is not known and it is uncertain whether or not the two margins of this zone meet in this region. Although this is tentatively shown as being the case, it has been done principally to restrict this zone since there is not a definite heat source, and to prevent this zone from becoming confused with the Bennett Lake high-grade area immediately to the east. It should be noted that this zone could extend in a westerly direction since there is no data in this direction to refute such an arrangement.

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C) Perth Map-Area

The northern portions of the Perth map-area are characterized by the southerly extensions of the Clyde River high-grade area (previously discussed) and the eastern high-grade area of the Carleton Place map-area.

i) Bennett Lake High-Grade Area

Isoreaction-grad II, defining the trace of isobaric invariant point 2 (figure 7) in $P_f - T - X_{CO_2}$ space which was mapped along the eastern margin of the Carleton Place map-area, extends into the Perth area unconstrained for the first $1\frac{1}{2}$ miles. At this point it is constrained on the west by an isobaric univariant tremolite - quartz - dolomite - calcite assemblage at location 894814 and the pluton to the east. One mile south of this constraint it is restricted between another tremolite isobaric univariant assemblage at location 887800 and a serpentine (forsterite) assemblage $\frac{1}{2}$ mile to the east at location 894798. Isoreaction-grad II continues southwestward for 3 miles essentially unconstrained. Near the middle of Bennett Lake the isoreaction-grad is restricted to passing west of two diopside bearing isobaric univariant assemblages at locations 850754 and 838752. Passing west of these assemblages it continues to the south where it is restricted between these assemblages and a quartz - dolomite assemblage $1\frac{1}{2}$ miles to the southwest at location 820731. Beyond this constraint the isoreaction-grad passes off the map sheet and is lost.

On the east side of the Bennett Lake intrusion approximately $2\frac{1}{2}$ miles east of Bennett Lake, the isoreaction-grad is constrained only on the high-grade side. Two serpentine (forsterite) assemblages immediately along the edge of the intrusion at localities 892746 and

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877709 indicate that the isoreaction-grad, if present, lies farther to the east under the Paleozoic cover. Another intrusive body, the Perth pluton, situated 1 mile east of these serpentine (forsterite) assemblages, appears to have a considerable high-grade zone surrounding it. Considerable overlap of the high-grade zones from the two intrusions appears likely, suggesting that the whole area is higher grade than the isoreaction-grad and that the isoreaction-grad, therefore, is not defined in this region. However, two miles south of these high-grade assemblages the isoreaction-grad is defined. Two quartz-dolomite assemblages at locations 864693 and 859688 require that the isoreaction-grad passes between them and the pluton immediately to the west. The isoreaction-grad northward passes under the Paleozoic cover but is thought to intersect the isoreaction-grad surrounding the Perth pluton. This requires that it passes southward, under the Paleozoic cover, between the quartz-dolomite assemblages and the pluton $2\frac{1}{2}$ miles to the east. An isoreaction-grad envelope is thus created around the low-grade area, the western margin caused by the Bennett Lake intrusion and the eastern margin by the Perth pluton. The western margin, after being constrained between the intrusion and the quartz-dolomite assemblages at locations 864693 and 859688, passes southward for 1 mile where it is constrained between a quartz - dolomite assemblage at location 855675 and a diopside isobaric univariant assemblage $\frac{1}{2}$ mile west at location 839672. Immediately south it is further constrained on the high-grade side by a serpentine (forsterite) assemblage (isobaric univariant) at location 834662. It passes out of carbonate material further south and is lost.

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ii) Perth Pluton High-Grade Area

The eastern margin of the low-grade zone is initially defined by isoreaction-grad II which must pass under the Paleozoic cover, travelling between the quartz - dolomite assemblages at locations 864693, 859688 and 855675 and the Perth pluton, 2 miles to the east. The isoreaction-grad passes out from under the Paleozoic cover $1\frac{1}{2}$ miles north of Christie Lake and is constrained by a tremolite - calcite - quartz - dolomite assemblage at location 860653 and a group of diopside assemblages $1\frac{1}{4}$ miles south at locations 870635 and 867635. The isoreaction-grad is also constrained on the low-grade side by a quartz - dolomite assemblage at location 857634 immediately north of Christie Lake. Along the north shore of Christie Lake the isoreaction-grad swings to the east, passing south of the diopside assemblage at locations 867635 and 870635. It passes out of carbonate material to the east but can be located again 4 miles east, at the north end of Pike Lake, where it is constrained between a quartz - dolomite assemblage at location 948621 and a diopside isobaric univariant assemblage $\frac{1}{2}$ mile north at location 952629. It is lost once again to the east due to the lack of sufficient carbonate material but is tentatively shown as passing northeastward 3 miles to Otty Lake where it is constrained by two diopside assemblages along the west shore of Otty Lake at locations 026662 and 029669 and two quartz - dolomite bearing assemblages along the east shore at locations 061674 and 074675. It passes under Paleozoic cover to the north and is lost.

iii) Westport Plutonic Complex High-Grade Zone

The southern portion of the Perth map-area is characterized by isoreaction-grad II which surrounds the Westport plutonic complex

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immediately to the south. The isoreaction-grad at its western extremity is confined to passing under Christie Lake by a group of diopside and forsterite (serpentine) bearing assemblages south of Christie Lake at locations 824594, 830587, 856595 and 851589, and by a quartz - dolomite assemblage north of the lake at location 857634. The path of the isoreaction-grad cannot be traced beyond these constraints due to the lack of carbonate material in the immediate vicinity. East of Christie Lake (4 miles) near the north end of Pike Lake, the isoreaction-grad is constrained by diopside bearing assemblages on the south (942613, 937602, etc.) and by a quartz - dolomite assemblage on the north (948621). Three and one-half miles southeast of this constraint the isoreaction-grad is defined by an isobaric invariant assemblage at location 981563. The isoreaction-grad must pass northward from the assemblage as it is restricted to the south, west and east by higher grade diopside and forsterite assemblages. Immediately to the north of this invariant assemblage the isoreaction-grad is constrained by a group of diopside assemblages (981569, 982575, 984576, etc.) west and north of which the isoreaction-grad must pass. The path of the isoreaction-grad north of Black Lake is not known due mainly to the very minor amount of carbonate material in this area. It is thought to trend northeastward roughly parallel to the outline of the Rideau Lake pluton until it intersects the Rideau Lake fault system beyond which it is thought not to extend.

iv) Otter Lake High-Grade Area

A high-grade area situated along the eastern Paleozoic boundary is defined by the isoreaction-grad northwest and southeast of Otter Lake. Northwest of the lake the isoreaction-grad is

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constrained between serpentine (forsterite) and diopside assemblages at locations 079605 and 078613 and quartz - dolomite assemblages $\frac{1}{2}$ mile to the south at locations 076590, 089574, 099600, etc. Farther northwest the isoreaction-grad intersects the Rideau Lake fault system and is lost. To the northeast it runs under Otter Lake where it is thought to turn southward to the south end of the lake where it is constrained between a serpentine (forsterite) assemblage at location 114571 and a quartz - dolomite assemblage $\frac{1}{2}$ mile to the west at location 104563. The isoreaction-grad continues southward for $\frac{1}{4}$ mile running off the Perth map sheet and onto the Westport map sheet. In the Westport map-area the isoreaction-grad is initially constrained between a forsterite assemblage at location 104549 and the extensive quartz - dolomite area to the northwest. Beyond this constraint the path of the isoreaction-grad is not well known. It is thought to travel in a general southwest direction separating the quartz - dolomite area to the northwest from the serpentine (diopside?) assemblages at locations 070516, 110520 and 071523. The serpentine assemblages have not been well established due to the high degree of retrograde alteration in this region and, hence, the isoreaction-grad has not been considered very definite in this region.

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D) Westport Map-Area

The Westport map-area is characterized by high-grade zones surrounding the major intrusive bodies of the region (excepting the western portion of the area which is related to the metamorphic style in the Tichborne map-area immediately to the west). The metamorphic influence of the major plutons is best displayed by the Lyndhurst pluton which was studied in considerable detail. The distribution of grade within this region was outlined at the beginning of the section and serves to display the spatial relationships between the metamorphic grade and the intrusive mass.

The Westport plutonic complex is situated in the northern part of the Westport map-area and displays the most extensive metamorphic influence upon the surrounding material. The majority of the carbonate material surrounding this complex lies within the Perth map-area and the distribution of grade has been described under the Perth map-area. The distribution of metamorphic grade, as outlined by the trace of isoreaction-grad II in the remaining portion of the area, is as follows:

i) The Red Horse - Charleston Lake High-Grade Area

The small discontinuous low-grade zone north of Singleton Lake which gives rise to higher grade assemblages as the Lyndhurst pluton to the west is approached, also gives way to higher grade assemblages as one moves eastward into the Red Horse Lake - Charleston Lake area. Isoreaction-grad II in this region is best constrained at its northern extremity where it is restricted between a quartz - dolomite assemblage at location 123321 and a diopside bearing isobaric univariant assemblage several hundred feet to the east at location 125320. The path of isoreaction-grad II is uncon-

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strained farther north. To the south it travels $2\frac{1}{2}$ miles to the edge of the map sheet constrained by several diopside bearing isobaric univariant assemblages on the east (131288 and 123281) and low-grade potassium feldspar - dolomite - phlogopite - calcite assemblages to the northwest at locations 111319 and 118319. Two diopside bearing isobaric divariant assemblages at locations 126317 and 127310 also constrain the isoreaction-grad on the east over this distance. No control over the isoreaction-grad south of the Westport map-area has been established.

ii) Opinicon Lake High-Grade Area

A north-south trending high-grade area, apparently related to the Crow Lake pluton 2 miles to the east, is found along the west shore of Opinicon Lake. Isoreaction-grad II is best constrained at its northern extremity on the east shore of Benson Lake where it is restricted between a diopside assemblage at location 931383 and a quartz - dolomite - tremolite - calcite assemblage immediately to the south at location 931382. The isoreaction-grad passes under Benson Lake north of this constraint and has not been traced further. South of this constraint the isoreaction-grad travels west and south of a diopside assemblage at location 935380, passing between it and a quartz - dolomite assemblage $\frac{1}{2}$ mile to the south-east at location 940376. The isoreaction-grad passes north and then east of this quartz - dolomite assemblage and continues southward for $\frac{1}{2}$ mile where it becomes constrained by a quartz - dolomite assemblage and a diopside - tremolite - calcite - quartz isobaric univariant assemblage, both at the same locality 943369. Beyond this constraint isoreaction-grad II, for the 6 miles until it passes off the map sheet, is restricted only on its upgrade side, there

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being no quartz - dolomite assemblage to establish its western extent. The isoreaction-grad is tentatively shown as passing only slightly west of the diopside assemblages situated along the shore of Opinicon Lake but it is possible that the isoreaction-grad is considerably farther to the west. The diopside assemblages which restrict it along its eastern side are situated at the localities (from north to south) 944867, 942365, 928343, 931326, 908313 and 887293. The position of the isoreaction-grad south of the Westport map-area has not been established.

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E) Tichborne Map-Area

The Tichborne map-area, including the Devil Lake region of the Westport map-area, is characterized by a style of metamorphism which does not appear to be related to specific igneous intrusions. The entire area is of a high metamorphic grade, no remnant patches of unreacted quartz - dolomite being noted. In such an environment, isoreaction-grad II suffers from an overabundance of high-grade assemblages which can be used to bracket it on the high-grade side. In only three localities can it be constrained on the low-grade side.

Isoreaction-grad II is perhaps best constrained north of Devil Lake (Westport map-area) where it is restricted between a quartz - dolomite - calcite - tremolite isobaric univariant assemblage at location 844382 and ~~serpentine~~ (forsterite) assemblages $\frac{1}{2}$ mile to the north at location ~~824380~~ and $\frac{1}{2}$ miles to the west at locations 824380 and 821377. To the north the isoreaction-grad passes out of carbonate terrain and is lost. To the south it is lost under Devil Lake.

Isoreaction-grad II is also constrained $\frac{1}{2}$ mile west of the south end of Birch Lake where it is restricted between a tremolite - quartz - dolomite - calcite assemblage at location 752331 and a diopside - calcite - quartz - tremolite assemblage $\frac{1}{2}$ mile to the northeast at location 764337. Immediately to the south the isoreaction-grad is further constrained on the high-grade side by a forsterite - dolomite - calcite assemblage at location 748327. The isoreaction-grad is not constrained north or south of the above restrictions.

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The final constraint on isoreaction-grad II occurs at the southwestern edge of the map-area. The isoreaction-grad is constrained between a quartz - calcite - dolomite - tremolite isobaric univariant assemblage at location 665332 and a forsterite bearing assemblage $\frac{1}{2}$ mile to the north at location 667340 and 1 mile to the southeast at location 682326. Beyond these constraints the position of the isoreaction-grad is undetermined.

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2) Isobaric Univariant Isoreaction-grads

A) Carleton Place Map-Area

The Carleton Place map-area is characterized by an extensive "sea" of low-grade tremolite facies metamorphism. While tremolite bearing material dominates the region, lower grade unreacted quartz-dolomite zones are locally important. These low-grade quartz-dolomite zones are outlined by isoreaction-grad (3) which governs the first appearance of tremolite according to the reaction

Within the Carleton Place map-area three such zones of unreacted quartz - dolomite can be recognized.

1) Clyde River Low-Grade Zone

The Clyde River low-grade zone trends north-south across the west central part of the map-area, extending almost the full length of the map sheet. It is terminated on the north by high-grade east-west trending isoreaction-grads surrounding the Almonte pluton. To the south it is open ended running off the Carleton Place map sheet where control is lost.

The termination of this zone to the north is best displayed at the northwest corner of Clayton Lake where isoreaction-grad (3) outlining this zone intersects isoreaction-grad (7) outlining a diopside zone surrounding the Almonte Pluton. Location 921037 contains assemblages on isoreaction-grads (3) and (7) and displays conclusively the intersection of these two isoreaction-grads. Isoreaction-grad (3) can be traced, from this intersection location, both to the west where it must initially pass through the univariant assemblage at locality 895033 and to the south, along the eastern margin of this zone, where it is first constrained by having to pass

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between the two locations 920035 and 922026 comprising the assemblages of unreacted quartz - dolomite and tremolite - calcite - quartz respectively. Although the isoreaction-grad is initially well constrained to the south, its position for the next several miles in this direction is constrained only by tremolite bearing product assemblages to the east. For this reason the isoreaction-grad is tentatively shown as passing generally west of the seven (7) tremolite bearing localities located along the west shore of Clayton and Taylor Lakes. At the south end of Taylor Lake, location 912995, the isoreaction-grad becomes constrained for the next 2 miles by a series of closely spaced alternating reactant and product assemblages. Further south, as the isoreaction-grad approaches and passes along the Clyde River, the only constraint on its path is provided by several tremolite product assemblage locations (900964, 880935, 882909, etc.) west of which this isoreaction-grad must pass. Near the intersection of the Calabogie-Lanark highway and the Clyde River an invariant assemblage consisting of calcite - tremolite - quartz - dolomite - diopside requires that the isoreaction-grad pass through location 896892. The isoreaction-grad then proceeds $\frac{1}{2}$ mile to the west where it is constrained by a univariant assemblage at location 888894. (Southeast of the invariant location 896892 the isoreaction-grad (3) opens to enclose a separate entity, the Lanark low-grade zone.) From this univariant location (888894) southward until it passes off the Carleton Place map sheet, the isoreaction-grad is constrained between one locality of unreacted quartz-dolomite (867858) and several tremolite bearing localities about $\frac{3}{4}$ mile to the southeast (875849, 876848, etc.). There are no data points beyond the southern margin of the Carleton Place map-area and the position of the isoreaction-

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grad in this direction is unknown.

It may be recalled that at the northwest corner of Clayton Lake, isoreaction-grad (3), in addition to passing southward along the eastern margin of this zone as just described, also travelled to the west passing through a univariant assemblage at location 895033. Beyond this univariant position, isoreaction-grad (3) proceeds southward to define the western margin of this zone, being initially constrained between reactant and product assemblages at locations 885025 and 875017 respectively. Immediately south of this restriction the position of the isoreaction-grad is fixed by a univariant assemblage at location 880012. Two miles further south the isoreaction-grad is constrained by the fact that it must pass east of the tremolite product assemblage at 884992 and between the product and reactant assemblages at localities 891984 and 885986 respectively. For the next 3 miles south there is no control over the position of the isoreaction-grad except that it must travel generally southward in order to pass through two univariant assemblages south of the Clyde River at localities 854938 and 855937. South of these univariant positions, for the 6 miles to the edge of the map sheet, the position of the isoreaction-grad is loosely constrained by 8 product assemblages on the west (871878, 861866, etc.) and two reactant assemblages on the east (837894, 867858) spaced approximately 2 miles apart. The position of the isoreaction-grad further south is not known and the zone is open in this direction.

ii) Lanark Low-Grade Zone

A narrow, north-south trending low-grade zone, enclosed by isoreaction-grad (3), is centered immediately west of Lanark and extends for about 3 miles north and south. At its northwest corner

235 (896892) this zone is marked by the invariant assemblage quartz - dolomite - calcite - diopside - tremolite. Isoreaction-grad (3) from both the Clyde River and Lanark low-grade zones passes through this point. In addition, isoreaction-grad (7) marking the first appearance of diopside passes out of this location to outline a narrow high-grade zone to the south which separates the Clyde River and Lanark low-grade zones.

Isoreaction-grad (3) outlining the Lanark low-grade zone enters the invariant assemblage at location 896892 essentially unconstrained from the northeast and passes out of it to the south. Its position southward is constrained by another invariant assemblage 2 miles to the south at locality 891853, a position through which isoreaction-grad (7) also passes, underlining the close proximity of the low and high-grade zones in this region. Beyond this second invariant location the isoreaction-grad travels southward $\frac{1}{2}$ mile into the northern Perth map-area where it must pass through a narrow zone constrained both to the east and west by a series of tremolite product assemblage locations, in order to pass through a univariant assemblage at location 887800. The isoreaction-grad at this position is almost entirely enclosed by higher grade assemblages and the low-grade zone does not appear to travel any farther south. Instead, the isoreaction-grad is thought to return northward, travelling back through the narrow zone by which it entered. No low-grade unreacted quartz-dolomite assemblages are present in this southern section of the zone and it is possible that the univariant assemblage at locality 887800 represents an isolated occurrence so that the Lanark low-grade zone may not in fact extend this far south. Travelling northward from the Perth map-area into the Carleton Place map-area isoreaction-

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grad (3), now defining the eastern margin of this zone, is constrained between the quartz-dolomite assemblage at location 903852 and the tremolite assemblages $1\frac{1}{2}$ miles to the northeast at localities 925865, 923878 and 921879. The position of the isoreaction-grad north of these constraints is not known and the extent of this zone northward was not determined.

iii) Clayton Lake - Taylor Lake Low-Grade Zone

The Clayton Lake - Taylor Lake low-grade zone comprises a region of unreacted quartz-dolomite extending north-south along the east shore of Taylor and Clayton Lakes. At its northern boundary, along the Indian River, the zone appears to be elongated in a southeasterly direction in order to enclose a low-grade region 5 miles northwest of Carleton Place.

The low-grade nature of this zone is best displayed east of Taylor Lake where 3 localities of unreacted quartz-dolomite are present. Isoreaction-grad (3) is constrained in this area between these three reactant assemblage locations (963992, 955988, 954986) and a tremolite product assemblage at location 961955 immediately to the west. The southern termination of this zone is located $1\frac{1}{2}$ miles south of these constraints where isoreaction-grad (3) swings back to the north, passing around a quartz-dolomite assemblage at location 943975 and between it and tremolite bearing localities $\frac{2}{3}$ of a mile to the southwest (932963) and $1\frac{1}{2}$ miles to the southeast (947952). Returning northward the isoreaction-grad passes the first 2 miles unconstrained, after which it becomes restricted between a tremolite product assemblage at location 979998 and the quartz-dolomite assemblages along the east shore of Taylor Lake mentioned earlier. The path of the isoreaction-grad is unconstrained farther north but it

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is thought to pass only a short distance farther north where it swings to the southeast, passing south of a quartz-dolomite assemblage 3 miles to the southeast at location 016994. It is constrained south of this location by a tremolite bearing locality $1\frac{1}{2}$ miles to the southeast, to the north of which it must pass. Beyond this constraint the isoreaction-grad once more turns to the north passing between the quartz-dolomite location just mentioned and four diopside occurrences to the east at locations 042989, 035997, 034998 and 032000. Immediately north of this restriction the isoreaction-grad is constrained by two univariant assemblages at locations 028004 and 025008. Continuing north of these univariant locations, the isoreaction-grad passes west of a tremolite locality immediately to the north and swings around it to the northeast passing between it and a quartz-dolomite location (036020) 1 mile to the northeast. The isoreaction-grad then travels around the east side of this quartz-dolomite location turning to the northwest where it passes between it and a higher grade serpentine (forsterite) locality a further 2 miles to the northeast at location 042026. The path of the isoreaction-grad in this northwesterly direction is unconstrained for several miles but is present 4 miles to the northwest where it is constrained by a univariant assemblage at location 976049. Travelling through this univariant location the isoreaction-grad passes 1 mile to the south where it is constrained to the west by two tremolite product assemblages (968041, 963039) but is unconstrained to the east. The isoreaction-grad continues southward unrestricted until it becomes constrained by the original quartz-

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dolomite locations along the east shore of Taylor Lake. The iso-reaction-grad has returned to the original constraining position and the zone as described has been more or less completely defined.

239 B) Carleton Place Map-Area High-Grade Zones

The relatively low-grade plateau characteristic of the Carleton Place map-area is transected by four higher grade diopside and forsterite zones running along the margins of the map-area. The diopside zone is outlined by isoreaction-grad (7) representing the first appearance of diopside according to the reaction

The forsterite zone, which is not present in all of the high-grade areas, is outlined by isoreaction-grad (6) which represents the first appearance of forsterite by the reaction

In most instances the higher grade zones can be spatially related to one of the major plutonic masses present in the area.

The four high-grade zones are:

i) Eastern High-Grade Zone

A high-grade zone extends along the easternmost contact of the Grenville Supergroup and the Paleozoic cover. Isoreaction-grads (7) and (6), which define the first appearance of diopside and forsterite within this zone, are closely spaced and for most of their length roughly parallel. The isoreaction-grads appear to be related to intrusive material along the Mississippi River immediately to the east.

The first expression of the eastern high-grade zone to the northeast is found at a serpentine (forsterite) bearing locality (042026) 4 miles south of the town of Almonte. Isoreaction-grads (6) and (7) are constrained between this locality and a low-grade location (036020) 1 mile to the southwest, containing the assemblage quartz - dolomite - calcite. Isoreaction-grad (6) is not defined

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south of this constraint for several miles. It must pass to the east of a tremolite - dolomite product assemblage at location 032000, but exactly where to the east is not known. Isoreaction-grad (7), on the other hand, has some positive constraints in this initial northeast section of the zone. Passing southward from the initial constraint, the isoreaction-grad travels to the east of several low-grade locations in isoreaction-grad (3). It is constrained immediately south of these low-grade localities by having to pass between them and three diopside bearing locations $\frac{1}{2}$ mile to the southeast at positions 032000, 034998 and 035997. Isoreaction-grad (3) is next constrained a mile to the south at location 042989 which contains a tremolite - calcite - quartz - diopside univariant assemblage through which isoreaction-grad (7) must pass. Two miles farther south both isoreaction-grad (7) and (6) are constrained between a tremolite - calcite - quartz (dolomite) reactant assemblage for reaction (7) at locality 010963 and a forsterite product assemblage for reaction (6), $1\frac{1}{2}$ miles to the southeast at location 025947. For 5 miles south of this restriction neither isoreaction-grad is constrained. However, after this distance both isoreaction-grads are well constrained by a series of four locations aligned in a north-south direction. Isoreaction-grad (7) in this region is constrained between two tremolite reactant assemblages (as observed in the field) at locations 939915 and 934897 and a diopside assemblage (also observed in the field) at location 937904. Isoreaction-grad (6) is constrained to the north between a forsterite (X-rayed) locality (938908) and a tremolite-dolomite locality (939915) $\frac{1}{2}$ mile to the north. It is constrained to the south between the forsterite locality and a

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tremolite - calcite - quartz location (934897) $\frac{1}{2}$ mile due south.

A diopside bearing assemblage at location 937904 is situated midway between the southern constraining point for isoreaction-grad (6), but because it does not contain any tremolite it cannot be used to provide a constraint on isoreaction-grad (6). Both isoreaction-grads pass under the Paleozoic cover south of these localities.

ii) Northern High-Grade Zone

The Almonte pluton, situated at the northern edge of the Carleton Place map sheets has superimposed a diopside zone upon the generally low-grade tremolite bearing material of the surrounding terrain. This higher grade diopside zone is outlined by isoreaction-grad (7). Its position is best known from a univariant assemblage at locality 921037. This locality also contains a univariant assemblage on isoreaction-grad (3) which results in the intersection of the two isoreaction-grads. To the west of this location the position of the isoreaction-grad is uncertain. It is thought to roughly conform to the outline of the Almonte Pluton but no data points are given to substantiate this. The position of the isoreaction-grad eastward is almost as uncertain although there is some constraint upon it in this direction. Immediately to the northeast an assemblage of diopside bearing material is present at locality 931042 requiring the isoreaction-grad to pass south of this position. Just how far south of this point the isoreaction-grad travels is not known but material surrounding Clayton Lake is all tremolite bearing, suggesting a very limited diopside zone in this direction. North of 931042 isoreaction-grad (7) is lost for several miles (no carbonate material) but can be located again at location 969068 which from field evidence contains diopside. The isoreaction-grad is constrained

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between this point and a location 1 mile north (980081) which contains tremolite - calcite - quartz. No diopside material was observed north of this point.

iii) Western High-Grade Zone

The presence of diopside and forsterite bearing material along the western margin of the Carleton Place map sheet appears to be related to plutonic activity along the western margin of the map-area. Isoreaction-grads (7) and (6) are indicated as outlining the diopside and forsterite zones in this region.

Isoreaction-grad (7) outlining the diopside zone is known only from the southern portion of this high-grade area where it is constrained between diopside bearing product assemblages (tremolite - dolomite - diopside $\pm$ calcite) at locations 840954 and 837958 and a univariant tremolite - calcite - quartz - dolomite assemblage 1 mile to the southeast at location 854938. North and south of this constraint the position of the isoreaction-grad is unknown.

Forsterite (serpentine) bearing material in this zone is known only from one locality, 835023. Isoreaction-grad (6), marking the first appearance of forsterite, is constrained between this locality and a tremolite - dolomite bearing region $\frac{1}{2}$ mile to the northeast (842028, etc.). The path of the isoreaction-grad north and south of this constraint has not been determined.

iv) Lanark High-Grade Zone

The final high-grade zone noted within the Carleton Place map-area is a north-south trending zone, running parallel to the western margin of the Lanark low-grade zone, about 2 miles west of the town of Lanark.

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The northern termination of this zone is defined by an invariant assemblage at location 896892. Isoreaction-grad (7), enclosing this zone, passes southward from this location to define the eastern margin of the zone on one side and the western margin on the other. Along the eastern margin isoreaction-grad (7), after travelling through the north invariant location, passes southward where it is constrained 2 miles to the south by another invariant assemblage at location 891853. South of this invariant location, the isoreaction-grad passes out of the Carleton Place area and into the northern Perth map-area where it is initially constrained by a product assemblage at location 880821 requiring it to pass east of this locality. A quarter mile farther south at location 882817, a univariant assemblage precisely locates the isoreaction-grad. From here it continues southward bending between a cluster of product and reactant assemblages $\frac{1}{2}$ mile to the south of the univariant location. One mile farther south it becomes constrained to a $\frac{1}{2}$ mile wide zone between a diopside assemblage at location 866794 (field observations) and a tremolite - calcite - dolomite reactant assemblage at location 875795. The position of the isoreaction-grad farther south is not precisely known but the topology of the other isoreaction-grads in surrounding areas suggests that it swings around from the south to the northeast. In the northeastward direction the isoreaction-grad is constrained between a univariant assemblage on isoreaction-grad (3) at location 887800 and a forsterite assemblage $\frac{1}{2}$ mile to the east at location 894798. Farther north it is constrained on the west by a tremolite bearing assemblage, east of which it must pass, but is unconstrained on the east. The position of the isoreaction-grad farther north is

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unrestricted but it is thought that its generally northward trend may indicate that it is continuous with isoreaction-grad (7), passing southward into this area from the Carleton Place map sheet. However, direct evidence to support the continuous nature of these isoreaction-grads is lacking.

The western margin of this zone, it was noted earlier, terminated to the north at the invariant assemblage located at locality 896892. South of this position isoreaction-grad (7), along the western margin, is unconstrained for the first two miles after which it is constrained by a univariant assemblage at location 882849. It continues southward for 1 mile, passing east of tremolite reactant assemblages (876847, 873844, etc.) into the northern Perth map-area where it is initially constrained by a product assemblage at location 868808 and a reactant assemblage $\frac{1}{2}$ mile to the west at location 873806. A further $1\frac{1}{2}$ miles to the south the isoreaction-grad is once again constrained by a pair of product and reactant assemblages. It is at this point that the western and eastern margins of this zone, which until now have been roughly parallel, swing away from each other, greatly enlarging the high-grade region. This expanded region of diopside bearing material is referred to as the Bennett Lake zone but is, in fact, continuous with the Lanark high-grade zone of the Carleton Place area.

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C) Perth Map-Area

The Perth map-area is characterized by substantial high-grade plutonic influence on a generally low-grade metamorphic terrain. Extensive higher grade zones enveloping the major plutonic masses have restricted lower grade zones to areas remote from the intrusive bodies. Such low-grade areas are generally discontinuous zones separating regions of higher metamorphic grade. The distribution of isoreaction-grads is closely related to the plutonic masses in the area, usually forming close, parallel zones around such bodies. The following metamorphic zones can be recognized:

i) Bennett Lake High-Grade Zone - Northern Perth Area

The northern Perth area, as outlined previously, is essentially a continuation of the southern Carleton Place map-area. The narrow Lanark high-grade zone extending south into the northern Perth area was noted as widening at the north end of Bennett Lake into the Bennett Lake high-grade zone. This zone is elongated along the western side of Bennett Lake. It is defined along its western margin by isoreaction-grad (7) which separates diopside bearing assemblages to the east from lower grade tremolite bearing material to the west. Isoreaction-grad (7), having passed into the Perth area from the north, was constrained for the first 3 miles by a series of product and reactant assemblages. South of these constraints (866794 to 862791) the isoreaction-grad travels towards Bennett Lake, passing west of a product assemblage at locality 864769 and through a univariant assemblage at location 850754 about 5 miles south of the Carleton Place - Perth boundary. It is constrained farther south along Bennett Lake by a reactant assemblage on the west at location 845753 and by another univariant assemblage

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immediately to the south at location 838752. The isoreaction-grad then travels south for $\frac{1}{2}$ mile passing east of a tremolite assemblage at location 837747. Constraints on the isoreaction-grad from this point south are lacking but it is thought to continue southward keeping to the east of tremolite assemblages about a mile west of Bennett Lake.

At the northeast end of Bennett Lake, within a thin marble band 2 miles to the east of the lake, a forsterite isoreaction-grad is indicated. Isoreaction-grad (6) defining the first appearance of forsterite is initially constrained between a forsterite product assemblage at location 894798 and a lower grade univariant assemblage (isoreaction-grad (3)) $\frac{1}{2}$ mile to the west at location 887807. North of this constraint the isoreaction-grad is restricted only to the west where lower grade zones are present. Although no direct evidence is present, the generally northeast trend of the isoreaction-grad at this point suggests that it may be continuous with a similar isoreaction-grad (6) in the southern Carleton Place area.

South of the initial constraint the isoreaction-grad swings to the southeast in order to pass west of, or possibly through, locality 906788. The evidence is rather confusing at this locality since three separate thin sections yield different mineral assemblages. Sample -1 contains the assemblage tremolite - dolomite - calcite - serpentine (forsterite) indicating a univariant assemblage. Sample -2 contains only dolomite - calcite - serpentine (forsterite), a product assemblage of reaction (6), while sample -4 contains unreacted quartz-dolomite. The conflicting assemblages can be reconciled if extremely CO₂ rich conditions prevailed during peak metamorphism, allowing unreacted quartz-dolomite to exist under

temperature conditions similar to those necessary for reaction (6) to occur. Calcite-dolomite geothermometry indicated a suitably high temperature for this location confirming the CO₂ rich conditions suggested. It appears that the univariant assemblage indicated by Sample -1 may be valid under such conditions and the isoreaction-grad is therefore shown as passing through this location. South of this univariant location the isoreaction-grad is lost for 3 miles, due mainly to the lack of sufficient carbonate material, but may be located again after this distance in a thin band of marble several miles east of Bennett Lake. Location 892746 at the north end of this marble band contains possible forsterite (based on field observations), thus restricting the isoreaction-grad between it and a reactant assemblage 1½ miles to the south at location 877716. Further constraint is placed on the isoreaction-grad immediately to the south where it must pass between this reactant assemblage and two forsterite bearing assemblages ½ of a mile to the southeast at localities 886709 and 887709. The isoreaction-grad runs out of the marble band at this point and cannot be traced farther south.

ii) Bennett Lake Low-Grade Zone

A low-grade quartz-dolomite bearing zone is present just north of highway 7, 1½ miles southeast of Bennett Lake. This zone is outlined by isoreaction-grad (3) which encloses four localities (863694, 864693, 859688, 855675) of unreacted quartz-dolomite. The isoreaction-grad, while enclosing these localities, is constrained between them and higher grade assemblages 1½ miles to the northeast (886709), 1½ miles to the south (860653), 1 mile to the southwest (842662) and ½ mile to the west (839672). Constraint upon the isoreaction-grad is not possible to the west, east and north due to

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the lack of carbonate material in these directions.

iii) Tay River - Otty Lake High-Grade Zone

A high-grade zone apparently related to plutonic activity southwest of Perth trends west to east from the south Tay River area to Otty Lake. At the western extreme of this zone both isoreaction-grads (7) and (6) are present although they are not very extensive. Only isoreaction-grad (7) defines this zone in other portions of the region.

Isoreaction-grad (6) in this zone is constrained by a forsterite bearing univariant assemblage at location 834662. Away from this locality the position of the isoreaction-grad is not known. Isoreaction-grad (7) at the western margin of this zone is defined by a univariant assemblage at location 839672. Its path away from this locality is ill-defined, although on the east side at least it must pass between the Bennett Lake low-grade zone to the northeast and the diopside bearing assemblage 1 mile to the southeast at locality 842662. Isoreaction-grad (7) can be located again several miles to the southeast near the north end of Christie Lake where it is constrained between a quartz-dolomite assemblage at locality 857634 and diopside assemblages at localities 867635 and 670635, 1/2 mile to the east. East of Christie Lake the position of the isoreaction-grad cannot be traced for many miles due to a lack of carbonate material. However, it can be picked up again 4 miles east of Christie Lake in a thin seam of marble just north of Pike Lake, where a univariant assemblage is present at locality 952629. The lack of carbonate material immediately to the east once again prevents tracing of the isoreaction-grad any farther. The next occurrence of pertinent carbonate material is along the

west shore of Otty Lake. Here two diopside bearing assemblages at localities 026662 and 029669 constrain the isoreaction-grad on the west while a low-grade quartz-dolomite assemblage 2 miles across the lake constrains it on the east. The Paleozoic cover quickly prevents tracing of the isoreaction-grad farther north.

iv) Christie Lake - Otty Lake Low-Grade Zones

A low-grade zone extends intermittently from north of Christie Lake eastward to Otty Lake. This zone, outlined by isoreaction-grad (3), roughly parallels the higher grade Tay River - Otty Lake zone from which it is separated by a $\frac{1}{4}$ to $\frac{1}{2}$ mile wide tremolite region.

At its western edge the zone is first defined by a univariant assemblage $1\frac{1}{2}$ miles north of Christie Lake at locality 860653. Isoreaction-grad (3), defining the northern margin of the zone at this point (the southern margin not being defined), travels southward from this univariant locality to the north end of Christie Lake where it is constrained by a quartz-dolomite assemblage at locality 857634 and a diopside assemblage $\frac{1}{2}$ of a mile to the northeast at locality 867635. As was the case with isoreaction-grad (7) of the high-grade zone to the north, isoreaction-grad (3) cannot be traced immediately to the east due to a lack of carbonate material. It can, however, be located again north of Pike Lake 5 miles to the east. North of Pike Lake the isoreaction-grad is constrained by a quartz-dolomite assemblage at location 948621, north and south of which are higher grade tremolite and diopside assemblages respectively. This low-grade zone cannot be traced eastward from this constraint with any confidence. Isoreaction-grad (3) is present 6 miles to the northeast along the east shore of Otty Lake, but

whether the isoreaction-grad at this point is a continuation of the Pike Lake isoreaction-grad is not certain. The isoreaction-grad at Otty Lake is constrained by a univariant assemblage 1 mile east of Otty Lake at locality 074675 and by a reactant assemblage $\frac{1}{2}$ mile to the west, the isoreaction-grad having to pass between this reactant assemblage and diopside assemblages 2 miles across the lake to the west. The Paleozoic cover prevents tracing of the isoreaction-grad beyond this locality.

v) Westport High-Grade Zone

Immediately south of the Christie Lake - Otty Lake low-grade zone a rapid rise in metamorphic grade is indicated. Isoreaction-grads (7) and (6), which define this zone, appear spatially related to the Westport plutonic complex to the south.

Isoreaction-grads (7) and (6) are present at the western edge of this zone just south of Christie Lake. Isoreaction-grad (7) is defined initially by a univariant assemblage at location 824594. (Based on field evidence an assemblage of tremolite - quartz - calcite - diopside is present at this location.) It is further constrained immediately to the southeast by a product assemblage at locality 817590 and a reactant assemblage at locality 825592. The isoreaction-grad is constrained a further $\frac{1}{2}$ mile to the southeast by another univariant assemblage at location 830587 (assemblage based on field and X-ray data). It then swings northeast to pass north of an assemblage containing diopside and forsterite at locality 856595. For the next 5 miles, until Pike Lake, no carbonate material is present and control over the isoreaction-grad is lost. Along Pike Lake a series of product and reactant assemblages constrain isoreaction-grad (7) over a distance of about $2\frac{1}{2}$ miles.

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East of Pike Lake control over the isoreaction-grad is essentially lost although it is thought to travel in a general east to south-east direction terminating at the Rideau Lake fault. East of Black Lake a group of localities containing diopside place some restriction upon the isoreaction-grad in this direction in that it must pass somewhere to the north of these locations. The path of the isoreaction-grad in this region has been placed as shown, principally to conform to the outline of the plutons to the south.

Isoreaction-grad (6), as was noted previously, is present south of Christie Lake. It is initially constrained to the north by univariant assemblages on isoreaction-grad (7) at localities 824594 and 830587. It is further constrained by these univariant assemblages, being restricted between them and a diopside - forsterite (X-ray) - calcite assemblage $1\frac{1}{2}$ miles to the northeast at location 856595. The isoreaction-grad passes north around location 856595, but its path beyond this point is lost until the southern Pike Lake area 4 miles to the southeast. At the south end of Pike Lake the isoreaction-grad is constrained between a reactant assemblage at location 916578 and a forsterite bearing assemblage (diopside has been observed in the field at both of these localities) $\frac{1}{2}$ mile to the south at location 907571. The path of the isoreaction-grad has not been determined farther east primarily because of a lack of sufficient carbonate material in this direction.

An area of marble immediately southeast of Black Lake extends between and slightly north of the Westport and Rideau Lake plutons. Both isoreaction-grads (7) and (6) define zones in this region. Isoreaction-grad (7) is present south of the Westport pluton, running closely along the shore of the Upper Rideau Lake.

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It passes through a univariant assemblage at locality 943493 but must pass under the lake to the west as only diopside bearing assemblages are present between the pluton and the lake. Towards the northeast the isoreaction-grad is constrained by passing east of a diopside assemblage at 947497 (possibly runs under the lake) but west of a tremolite reactant assemblage almost 1 mile due north. The isoreaction-grad north of this locality is not constrained by any further data points. The area to the north appears to have been subjected to the high temperature influence of both the Westport and Rideau Lake Plutons. It is of consistently high grade, containing assemblages above isoreaction-grad (7). It does not appear that the isoreaction-grad extends into this area but probably swings north around the tremolite reactant assemblage at locality 955510 and heads south parallel to the Rideau Lake Pluton until terminated by the Rideau Lake fault system.

Isoreaction-grad (6) in this region is known only around the western edge of the Rideau Lake Pluton. It is best defined at the north edge of the Westport map sheet where it passes through a univariant assemblage (forsterite - tremolite - dolomite - calcite) at locality 974546. South of this univariant location the isoreaction-grad is constrained to the west by a tremolite - dolomite reactant assemblage at location 970543 and then between this assemblage and a forsterite (serpentine) assemblage $\frac{1}{2}$ mile to the southwest at location 962537. Passing to the west of this forsterite locality the isoreaction-grad continues southward where it is shown as passing between the locations 958525 and 958521 and the Rideau Lake Pluton $\frac{1}{2}$ mile to the east. The assemblages at these locations are not well documented but are thought to be of lower grade than

isoreaction-grad (6). The assemblage at location 958525 consists of tremolite - calcite and possibly quartz in this section while dolomite and possibly diopside (chlorite - serpentine) are thought to be present in the field. This would place the assemblage close to isoreaction-grad (7) and before isoreaction-grad (6) if tremolite - dolomite are in fact present. The assemblage at location 958521 consists of calcite - quartz and possibly tremolite in this section while diopside (chlorite - X-rayed) appears to be present in the field. Such an assemblage would appear to be slightly above or possibly on isoreaction-grad (7), although the lack of tremolite - dolomite could allow the assemblage to exist at a higher grade than isoreaction-grad (6). The isoreaction-grad is tentatively shown as passing between these localities and the pluton, but more precise mineralogical data should be obtained for these locations. One mile farther south the isoreaction-grad is constrained between a reactant assemblage for isoreaction-grad (7) (tremolite (talc) - calcite - quartz) and the pluton $\frac{1}{2}$ mile to the east. Beyond this position the isoreaction-grad passes under Upper Rideau Lake and is lost.

North of the initial univariant assemblage at location 974546 the isoreaction-grad is constrained by a product assemblage at location 975550 to the west of which it must pass. The assemblage at location 975549 (tremolite - calcite - phlogopite) is inconclusive and the position of the isoreaction-grad with respect to this location is not certain. A further $\frac{1}{2}$ mile north the isoreaction-grad enters the southern Perth map-area where constraints upon the isoreaction-grad are based mainly on field observations. The locality 981563, immediately north of the Westport - Perth boundary, contains quartz-dolomite in section but was observed to contain tremolite

(X-rayed) and serpentine in the field as was the location 981569, $\frac{1}{2}$ mile to the north. A group of four localities $\frac{1}{2}$ mile to the northeast also contains serpentine (X-rayed at locality 992576), but with coexisting diopside from which it appears to be derived. If the serpentine is regarded as being derived from diopside in this area, then isoreaction-grad (6) must pass southeast of the above points, running between them and the Rideau Lake Pluton. (Isoreaction-grad (7) must pass northwest of these localities as mentioned previously.) The isoreaction-grad is further constrained by this group of diopside assemblages in that it must pass to the northeast between them and two localities (008576, 015580) a half mile to the east where forsterite was observed in the field. The isoreaction-grad passes unconstrained about a mile northeast of the above restriction until it intersects the Rideau Lake fault and is lost.

vi) Otter Lake Zone

A large group of scattered data stations west of Otter Lake form a rather extensive low-grade, unreacted quartz-dolomite region. Unreacted quartz-dolomite has been observed at such localities as 073558, 104563, 094567, 072571, 089574, 099600, etc. To the west this zone is terminated by the Rideau Lake fault. Northward the zone is lost under the Paleozoic cover, although two localities, 079604 and 078613, at the edge of the cover, contain abundant serpentine and diopside (field observation) suggesting a high-grade zone in this direction. Isoreaction-grad (7) outlining this higher grade region is constrained between these two locations and the host of lower grade assemblages farther to the south.

To the east, a high-grade zone runs along the edge of the Paleozoic cover, being separated from the low-grade zone by isoreaction

grad (6). This isoreaction-grad, passing out from under the Paleozoic cover at the northeast corner of Otter Lake, is quickly constrained between a low-grade quartz-dolomite assemblage at location 104563 and a serpentine (forsterite) bearing assemblage, 1/2 mile to the northeast, at location 114571. It continues southward into the northern Westport area where it is constrained between a forsterite (X-rayed) assemblage at location 104549 and the low-grade material to the northwest. It quickly passes under the Paleozoic cover just to the south and is lost. Serpentine and possibly diopside may be present at localities a little to the southwest about 2 miles north of Portland, indicating that the isoreaction-grad may pass in this direction. However, these assemblages are not well documented and the exact position of the isoreaction-grad in this region is not certain.

D) Westport Map-Area

The Westport map-area, like the Perth area to the north, is characterized by numerous high-grade metamorphic zones spatially related to the major plutonic masses in the region. A few discontinuous lower-grade metamorphic zones are present but are restricted to isolated localities removed from the influence of the intrusive activity.

The northern portion of the Westport map-area is dominated by the Westport Pluton complex. The high-grade zones surrounding these plutons occur mainly within marbles of the southern Perth area and have been described under that section. Isoreaction-grads outlining the low-grade area on the northeast corner of the Westport region are similarly related to the southern Perth map-area and have also been described under that section. The remaining metamorphic zones within the Westport map-area are related to two major plutons, the Lyndhurst and Crow Lake Plutons, in the southern portion of the district. Isoreaction-grads within the western portion of the area (Devil Lake area) have been considered extensions of zones within the Tichborne map-area and have been described under that section.

a) Lyndhurst Pluton Region

The carbonate material enclosing the Lyndhurst pluton was investigated in considerably more detail (1" = 2000') than the rest of the study area, allowing more precise positioning of the isoreaction-grads in this region.

Despite the presence of a high-grade envelope around the Lyndhurst pluton, there remain at least three low-grade remnant

zones only slightly removed from the pluton.

i) Morton Creek Low-Grade Zone

The most extensive low-grade zone occurs to the northwest of the pluton along Morton Creek. This low-grade zone of unreacted quartz-dolomite is enclosed by isoreaction-grad (3). The isoreaction-grad is best defined along the northwest margin of the pluton where it is constrained by two univariant assemblages, one at the junction of highway 15 and Morton Creek (048323) and the other $1\frac{1}{2}$ miles to the northeast along Morton Creek at locality 066337. Northeast of this last univariant assemblage the isoreaction-grad is restricted between a quartz-dolomite assemblage at location 081348 and the pluton $\frac{1}{2}$ mile to the south. Immediately to the northeast the isoreaction-grad is thought to pass east of several locations (084350, 083350, 086355) containing the assemblage phlogopite - calcite - quartz $\pm$ potassium feldspar. While the assemblage phlogopite - calcite - quartz (reacts to form tremolite - potassium feldspar by reaction 5) is stable beyond the conditions necessary for the formation of tremolite by reaction (3) such an assemblage does preclude the formation of diopside or forsterite by reactions (7) or (6). It is possible, therefore, that these phlogopite bearing localities are situated on the upgrade side of isoreaction-grad (3) (but not isoreaction-grads (6) or (7)). These localities, however, display very low-grade textures and have correspondingly been placed on the low-grade side of isoreaction-grad (3), a position not in conflict with the phlogopite assemblages. Travelling east of these locations the isoreaction-grad swings to the west passing between a phlogopite - calcite - quartz - potassium feldspar assemblage (thought to be low-grade texturally and possibly containing quartz-

dolomite in the field) at location 087360 and a tremolite product assemblage immediately to the north at location 088362. The isoreaction-grad is not well constrained for the next several miles but is tentatively shown as running roughly parallel to the somewhat better constrained isoreaction-grad (7). Despite the fact that large intervals of the isoreaction-grad are unconstrained in this area several important constraints are present. A quartz - dolomite assemblage at location 071360 constrains the isoreaction-grad between it and diopside bearing assemblages to the southwest at location 069356 and to the northeast at location 073364. A half-mile to the north of this constraint a pair of tremolite bearing product assemblages restrict the isoreaction-grad on its east side. It is near these localities that isoreaction-grad (3) is thought, based on the general topology, to swing around to the southwest, travelling in this direction to define the western margin of the zone. Midway down this margin the isoreaction-grad is constrained by a quartz - dolomite assemblage at location 056355, to the west of which the isoreaction-grad must pass. The nearest upgrade product assemblage is $2\frac{1}{2}$ miles to the northwest, not providing a very close constraint. A better constraint is placed upon it about $1\frac{1}{2}$ miles south at locality 043336 where the isoreaction-grad passes southeast around this locality, travelling between it and a univariant diopside assemblage $\frac{1}{2}$ mile to the south at location 038328. The isoreaction-grad then passes a mile to the southeast running through the univariant assemblage at the junction of highway 15 and Morton Creek, thus completely enclosing this zone.

ii) The North Singleton Lake Low-Grade Zone

A low-grade zone immediately north of Singleton Lake is defined by isoreaction-grads (1) and (3). Isoreaction-grad (1), governing the first appearance of phlogopite, outlines a small east-west trending zone of unreacted potassium feldspar and dolomite. Two univariant assemblages at locations 118319 (very little dolomite in thin section but dolomite horizons are present in the field) and 111319 mark the western and eastern extent of this zone respectively. The isoreaction-grad runs east-west between these locations to outline the northern and southern margins of the zone. Along the northern margin the isoreaction-grad is constrained between each of the univariant localities and an assemblage of diopside bearing material several hundred feet to the north at location 116320. Similarly, the isoreaction-grad along the southern margin is constrained between the two univariant assemblages and quartz-dolomite assemblages immediately to the south at localities 111318 and 113318. Isoreaction-grad (3) encloses a zone of unreacted quartz-dolomite which surrounds the small area of potassium feldspar - dolomite stability. This quartz-dolomite zone is roughly north-south trending and is open ended in both these directions. Along the eastern margin of this zone isoreaction-grad (3) to the south is initially constrained between the potassium feldspar - dolomite univariant assemblage at location 118319 and a tremolite bearing product assemblage at locality 119320. It then swings eastward passing between a tremolite product assemblage at location 123320 and a reactant assemblage to the north at location 123321. North of this position the isoreaction-grad is unconstrained and its exact location unknown.

The western margin of this zone is likewise ill-defined to the north and south. Passing northward from the south, where it is unconstrained, isoreaction-grad (3) passes to the west of a reactant assemblage at locality 111318 and a potassium feldspar - dolomite univariant assemblage at location 111319. It is constrained to the west by isoreaction-grad (7) which passes within 1500 feet of these low-grade locations. North of these constraints the isoreaction-grad swings to the east between isoreaction-grad (1) to the south and the diopside assemblage to the north at locality 116320. The isoreaction-grad continues to the north passing east of the diopside bearing locality, and between it and isoreaction-grad (3) defining the eastern margin of this zone. It is unrestricted for about $1\frac{1}{2}$ miles north until it becomes constrained between a tremolite assemblage at location 122342 (tremolite X-rayed) and a potassium feldspar - dolomite - phlogopite - calcite univariant assemblage, through which isoreaction-grad (1) passes, $\frac{1}{2}$ mile to the northwest at location 116347. It must swing to the northwest around this locality in order to pass between it and the pluton. The isoreaction-grad is unconstrained north of this constraint but is tentatively shown as passing northward joining with isoreaction-grad (3) of the Delta low-grade zone. Isoreaction-grad (1) is defined at a univariant assemblage locality (116347) about 1 mile northeast of Lyndhurst but is undefined north and south of this point and may just be a small isolated patch of unreacted potassium feldspar - dolomite.

iii) Delta Low-Grade Zone

Several localities of unreacted quartz - dolomite and one locality of potassium feldspar - dolomite define a low-grade zone about $\frac{1}{2}$ mile west of Delta along the east shore of Lower Beverley

Lake. Isoreaction-grad (1) is constrained by a univariant assemblage at locality 102396. To the north and south its position has not been determined. A more extensive low-grade, unreacted quartz - dolomite zone is outlined by isoreaction-grad (3). This zone is elongated north-south and defined only along its western margin. Isoreaction-grad (3) is essentially unrestricted north of Lower Beverley Lake but is constrained at the north end of the lake by a group of serpentine bearing localities which require it to pass somewhere farther east. A half mile farther south the isoreaction-grad is constrained by a quartz - dolomite assemblage located on Black Jack Island (098406) and by serpentine material immediately to the north (099411) and south (098404). The isoreaction-grad then travels south, passing from Black Jack Island on to the mainland where it runs east of the tremolite bearing locality 101403. It then bends southward around this locality passing between it and a quartz - dolomite locality 1 mile to the south (101399). The isoreaction-grad is lost immediately to the south as it runs under the lake in order to pass to the west of isoreaction-grad (1) then travelling along the shore at this point. It returns to the mainland farther south passing south of isoreaction-grad (1) and between it and a tremolite product assemblage 1 mile to the south at locality 110387. The isoreaction-grad travels east of this tremolite locality heading south where it is restricted to the west side of a quartz - dolomite assemblage at locality 118368. The path of the isoreaction-grad farther south is not defined.

iv) Grippen Lake Low-Grade Zone

One occurrence of unreacted quartz-dolomite at location 062283 just west of Grippen Lake indicates a possible low-grade zone

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south of the pluton. Isoreaction-grad (3) runs between this locality and higher grade diopside material $\frac{1}{2}$ mile to the north. No other low-grade material was sampled and the extent of this zone in other directions is not known.

v) Lyndhurst High-Grade Zone

High-grade diopside and tremolite bearing zones closely envelop the Lyndhurst pluton. Isoreaction-grad (7) governing the first appearance of diopside separates these two zones. It can be traced more or less continuously around the pluton from the southeast to the southwest corners.

Southeast of the pluton, immediately west of Grippen Lake, a group of seven closely spaced diopside bearing assemblages constrain isoreaction-grad (7) on the north, while a low-grade quartz - dolomite assemblage constrains it $\frac{1}{2}$ mile to the south at location 062283. Travelling northeast across Grippen Lake, the isoreaction-grad runs unconstrained for about $2\frac{1}{2}$ miles until Singleton Lake where it is restricted by a tremolite reactant assemblage to the south at location 107299 and by a diopside bearing assemblage to the north at location 107303. It then turns to the north running along Singleton Lake where it is constrained on the east by the Singleton Lake low-grade zone and on the west by a diopside product assemblage at location 105322. It continues northeast of Singleton Lake for about $1\frac{1}{2}$ miles to location 120341 where it is constrained by a univariant assemblage. Leaving this constraint the isoreaction-grad swings slightly to the northwest, travelling west of the low-grade assemblages at localities 115347 and 116347 and east of the pluton a quarter mile to the west. It travels north, essentially unconstrained for the next 2 miles, at which point it turns to the

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west passing between a diopside product assemblage at location 111381 and a tremolite - calcite - quartz (observed in the field) assemblage several hundred feet to the north at location 110387. The isoreaction-grad then travels southwest across Lower Beverley Lake passing south of two low-grade assemblages at localities 097378 and 097381. It continues to pass southwestward running through a univariant diopside assemblage at location 090374. The isoreaction-grad turns sharply to the northwest, travelling 1 mile farther to become constrained between a reactant assemblage on the east and a product assemblage on the west. After passing between these localities the isoreaction-grad turns once again to the southwest for $1\frac{1}{2}$ miles at which point it is constrained by a univariant assemblage (061375). Running through this univariant assemblage location it travels one mile to the southeast where another univariant assemblage is present. South of this point the isoreaction-grad is constrained on the east by a tremolite reactant assemblage at location 075370 and then between another tremolite reactant assemblage (075370) and a diopside product assemblage $\frac{1}{2}$ mile to the south at location 075365. Continuing southwest from this constraint it quickly passes between a series of product and reactant assemblages extending for about 1 mile. It then swings in a tight curve through a univariant assemblage at location 068353 and heads northeast. After running for about $1\frac{1}{2}$ miles to the northeast, the isoreaction-grad becomes constrained by a reactant assemblage (088362) on the south and by a product assemblage (089363) about 600 feet north. Continuing northward for $\frac{1}{2}$ mile it is restricted by a univariant assemblage at locality 093370. The isoreaction-grad passes through this assemblage and turns sharply to the south and within $\frac{1}{2}$ mile is constrained by another univariant

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assemblage (095367). It continues southward passing west of a product assemblage at location 097365, $\frac{1}{2}$ mile south of the univariant location. For the next 2 miles until Brier Hill, it continues to the south and southwest being constrained by the Morton Creek low-grade zone on the north and by the pluton on the south. Immediately north of Brier Hill the isoreaction-grad is constrained, not only by the low-grade zone to the north and the pluton to the south, but also by a univariant assemblage at location 068336. It continues southwest past Brier Hill for another 2 miles to the village of Morton on highway 15, being constrained over this distance by the Morton Creek low-grade zone to the north and the Lyndhurst Pluton to the south, which in this region are about $\frac{1}{2}$ mile to 1 mile apart. Travelling south of Morton the isoreaction-grad swings to the northwest, passing north of a group of diopside bearing assemblages and through a univariant assemblage at location 038328 one mile northwest of Morton. It proceeds westerly $1\frac{1}{2}$ miles to Jones Falls, being constrained over this distance by three reactant assemblages to the north and two product assemblages to the south. At Jones Falls the isoreaction-grad turns southward to follow the western margin of the pluton. One-half mile south of Jones Falls the isoreaction-grad is constrained to the east side of two reactant assemblages (020324, 020323) and between these assemblages and a group of diopside bearing localities $\frac{1}{2}$ mile to the east. Continuing southward the isoreaction-grad is unconstrained for the next $1\frac{1}{2}$ miles until reaching two univariant locations, 021300 and 021298 which constrain it over the next $\frac{1}{2}$ mile. These univariant locations are within 1 mile of the southern edge of the Westport map-area and the isoreaction-grad travels this distance unconstrained. The iso-

reaction-grad at this point, having been traced from the southeast edge of the pluton, has virtually encircled the body, leaving only a $2\frac{1}{2}$ mile stretch along the southern edge of the pluton unenclosed. Over this distance the isoreaction-grad has, except for a broadening of the pattern to the north, essentially conformed to the outline of the pluton and its spatial relationship at least is obvious.

vi) Lower Beverley Lake Serpentine Zone

Several serpentine bearing localities about 8 miles north of the pluton have been distinguished from the surrounding diopside and tremolite bearing localities. The reaction responsible for the formation of the serpentine is not known but it appears that the serpentine may be derived from diopside. The unnumbered isograd outlining this zone is best constrained in the vicinity of Black Jack Island about $\frac{1}{2}$ mile west of the village of Delta. The isograd in this area is constrained between a serpentine locality on the south end of Black Jack Island (098404) and a tremolite bearing locality on the mainland $\frac{1}{2}$ mile to the east (101403). The isograd south of this restriction passes under the lake and is lost. To the north it is constrained between the serpentine locality and a quartz - dolomite location (098406) in the middle of Black Jack Island $\frac{1}{2}$ mile to the north. Passing from between these localities the isograd swings west around the quartz - dolomite locality and heads northeast onto the mainland where it is restricted to the east side of a group of three serpentine assemblages at locations 099411, 099413, 099414. North of these localities the isograd is unconstrained and its position not determined.

While the eastern margin of this zone is more or less constrained the western margin is undefined lying somewhere west of

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Lower Beverley Lake so that the zone includes those serpentine bearing localities on the northwest shore of the lake. The zone would appear to be terminated to the south where the isograd must pass between the serpentine localities at the north end of the lake and the tremolite material found along the more southerly portions. The exact relationship of these zones, however, is not known in this region and it is possible for the serpentine zone to extend considerably southward.

vii) Red Horse - Charleston Lake High-Grade Zone

The metamorphic grade east of the Lyndhurst pluton decreases rapidly towards the Singleton Lake low-grade area. Further eastward, approaching Red Horse and Charleston Lakes, the grade once again increases. Isoreaction-grad (7) marking the first appearance of diopside in this region separates the tremolite and quartz-dolomite bearing material of the Singleton Lake zone from the diopside bearing assemblages in the Red Horse - Charleston Lake area.

The isoreaction-grad runs essentially north-south from the southern edge of the map-area to just north of Red Horse Lake. At its southern extremity the isoreaction-grad is defined by a univariant assemblage at locality 123281. A tremolite reactant assemblage is present about $\frac{1}{2}$ mile to the west. Travelling north from this univariant locality, the isoreaction-grad is restricted by another univariant assemblage $\frac{1}{2}$ mile to the north at locality 131288. It continues northward for about 2 miles passing through another univariant assemblage at location 126314 and just to the west of a diopside assemblage at location 127310. A further $\frac{1}{2}$ mile north the isoreaction-grad is constrained by another univariant assemblage at location 125320. Immediately prior to this univariant assemblage

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the isoreaction-grad is thought to be constrained between a tremolite - calcite - dolomite assemblage* at location 125318 and a diopside assemblage* several hundred feet to the southeast at location 126317.

[*The tremolite - calcite - dolomite assemblage at location 125318 as determined from thin section contains no quartz. However, tremolite - quartz was observed in the field and it is thought that the location does provide a constraint upon the low-grade side of the isoreaction-grad. The diopside assemblage at location 126317 is also confused; diopside was observed in the field but not in thin section which contained only quartz - dolomite. It is possible that the diopside formed under locally CO₂ rich conditions by reaction (12) and that this locality does not properly constrain isoreaction-grad (7).] North of the univariant assemblage constraining the isoreaction-grad at location 125320, constraints upon the isoreaction-grad are lacking and its position not known.

b) Opinicon Lake Region

A band of marble trending north-south along the west shore of Opinicon Lake contains isoreaction-grads possibly related to the Crow Lake Pluton 2 to 3 miles to the east. The isoreaction-grads trend northeast-southwest roughly parallel to the outline of the pluton, and outline successive zones of diopside and tremolite. Isoreaction-grads (7) and (3) separate the diopside and tremolite zones respectively.

i) High-Grade Zone

Isoreaction-grad (7) enclosing the diopside zone can be traced for 6 miles from the south end of Newboro Lake to the south end of Opinicon Lake. At its northern extremity isoreaction-grad (7) is constrained between a tremolite - calcite - quartz - dolomite assemblage at location 931382 and diopside assemblages immediately to the north and south at locations 931383 and 935380. The isoreaction-grad is thought to pass close to the assemblage at location 931382 (univariant assemblage on isoreaction-grad (3)) as diopside was tentatively identified in the field and this locality may in fact represent an invariant assemblage. The isoreaction-grad continues south of the initial constraint passing west of two localities observed in the field to contain quartz - dolomite - calcite - diopside (935380, 936377). It proceeds to the southeast between these two localities and a quartz - dolomite assemblage $\frac{1}{2}$ of a mile to the southeast at location 940376. (Diopside and tremolite were tentatively identified in the field at location 940376 and it may represent an invariant assemblage, in which case both isoreaction-grads (7) and (3) will be constrained by it.) The isoreaction-grad continues south for another $\frac{1}{2}$ mile where it is constrained by a

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 diopside univariant assemblage (943369). This location also contains a tremolite - quartz - dolomite - calcite univariant assemblage on isoreaction-grad (3) but a five mineral invariant assemblage was not observed. The isoreaction-grad is constrained $\frac{1}{2}$ mile to the south at location 942365 by another univariant assemblage. It then travels southwest for $1\frac{1}{2}$ miles passing east of a reactant assemblage at location 932347 and through a univariant assemblage at location 928343. The isoreaction-grad is constrained over the next $1\frac{1}{2}$ miles by a diopside assemblage at location 913326 and tremolite reactant assemblages to the north (919333) and south (914324). Beyond these constraints the isoreaction-grad is not well defined. It passes west of a diopside assemblage at location 908313 but its position farther south is not really known except that it must pass somewhere west of the diopside assemblage at location 887293, 2 miles south of Opinicon Lake.

ii) Sand Lake High-Grade Zone

Isoreaction-grad (7) is present northeast of Sand Lake where it is defined by a univariant assemblage at location 011368. Its path away from this point is not known nor is there sufficient marble to trace it any distance in this area.

iii) Low-Grade Zone

Isoreaction-grad (3) defines a narrow tremolite zone running roughly parallel to the diopside zone immediately to the east. At its northernmost position isoreaction-grad (3) is defined by a univariant assemblage at location 931382. It proceeds southeast of this locality for $\frac{1}{2}$ mile where it is constrained between a quartz-dolomite assemblage at location 940376 and diopside localities to the north (936377) and south (941372). After passing between these

constraints the isoreaction-grad runs a quarter mile to the south where it is constrained by a univariant assemblage at location 943369. The isoreaction-grad continues southward for 2½ miles to the south end of Opinicon Lake, being constrained only by several isolated tremolite bearing assemblages to the east (936359, 932347). At the south end of Opinicon Lake the isoreaction-grad is thought to travel west of the locations 917333 and 911330. Both these localities contain sphene which under most moderate CO₂ - H₂O conditions is stable at temperatures beyond that required for the formation of tremolite by reaction (3). Farther south the isoreaction-grad is unconstrained and its position not certain.

E) Tichborne Map-Area

The Tichborne map-area, including the western section of the Westport map-area (Devil Lake region), is characterized by extensive zones of high-grade regional metamorphism apparently unrelated to specific intrusive bodies. A large forsterite zone outlined by isoreaction-grad (6) runs northeast to southwest across the central portion of the area. It is flanked by successive zones of diopside and tremolite.

i) Devil Lake High-Grade Zone

The Devil Lake region situated in the western portion of the Westport map-area contains a high-grade zone which appears to be the eastward extension of a similar zone in the Tichborne area. A forsterite (serpentine) zone enclosed by isoreaction-grad (6) and a tremolite zone enclosed by isoreaction-grad (3) are present. A diopside isoreaction-grad was not observed but if present would probably be confined to the very narrow zone between isoreaction-grads (6) and (3).

Isoreaction-grad (6) is best defined at the north edge of Devil Lake where it is constrained between two serpentine (forsterite) assemblages at localities 847388 and 849390 and a tremolite - calcite - quartz - dolomite univariant assemblage (isoreaction-grad (3) 1 mile to the south at locality 844382. To the north of this constraint the isoreaction-grad passes into granulitic gneisses and its position is indeterminable. Southward, however, constraint upon the isoreaction-grad is provided by serpentine (forsterite) assemblages along the west shore of the lake (841377, etc.) and by tremolite assemblages a mile to the east at locations 843380 and 844382. The isoreaction-grad is unrestricted beyond this constraint but is thought to travel

generally southwestward becoming continuous with an isoreaction-grad (6) travelling towards Devil Lake from the Tichborne sheet.

Isoreaction-grad (3) is best constrained by a univariant assemblage on the north shore of Devil Lake at locality 844382. North of this location the isoreaction-grad passes to the southeast of two serpentine localities and becomes lost in the granulite gneisses farther north. To the south the isoreaction-grad is restricted to the east side of a tremolite - dolomite (observed only in the field) assemblage immediately southeast of the initial univariant assemblage. It then passes under Devil Lake and is lost.

ii) Canoe Lake - Desert Lake Central Forsterite Zone

An extensive central forsterite (serpentine) zone centered on the Canoe Lake - Desert Lake water system is outlined by isoreaction-grad (6). This zone trending northeast - southwest is enclosed along the northwest and southeast edges but is open ended to the northeast and southwest.

Isoreaction-grad (6) along the southeast margin is constrained at its northern extremity by a univariant assemblage $\frac{1}{2}$ mile southeast of Canoe Lake at location 785381. North of this location the isoreaction-grad is unrestricted but is thought to trend generally eastward to join with the isoreaction-grad in the Devil Lake area to the east. South of this univariant assemblage the isoreaction-grad passes west of a tremolite - diopside - quartz - calcite univariant assemblage (X-rayed) at location 780376 and through a serpentine (forsterite) univariant assemblage at location 764359 2 miles to the south. Continuing southeastward for $1\frac{1}{2}$ miles the isoreaction-grad is constrained between a serpentine - calcite - tremolite - quartz assemblage at locality 969345 and a tremolite

reactant assemblage to the north (770358) and a univariant diopside assemblage to the south (764337). The isoreaction-grad is unconstrained for the next $1\frac{1}{2}$ miles, but must travel generally to the southwest in order to pass between a univariant assemblage on isoreaction-grad (3) at location 752331 and a univariant assemblage on isoreaction-grad (9) $\frac{1}{2}$ mile to the southwest at location 748327. Beyond this constraint isoreaction-grad (6) is unconstrained and the zone is open in this direction.

Isoreaction-grad (6) defining the northwest margin of this zone is constrained at the southwest extremity by a serpentine (forsterite) univariant assemblage at location 667340. The isoreaction-grad runs a mile southeast of this locality, passing between a univariant assemblage on isoreaction-grad (3) at location 665332 and a serpentine (forsterite) locality (682326) farther to the southeast. Beyond this constraint the isoreaction-grad is unconstrained. On the northeast side of the initial univariant assemblage (667340) the isoreaction-grad travels unrestricted for $1\frac{1}{2}$ miles until it becomes constrained between a forsterite product assemblage at location 697352 and a tremolite - calcite - quartz assemblage $\frac{1}{2}$ mile to the northeast at location 702352. It then proceeds northeast for about 1 mile, being constrained between tremolite zone assemblages to the northwest (706357, 702353) and forsterite zone assemblages to the southeast (716344, 722344, 709343). Control over the isoreaction-grad is lost beyond these localities for several miles due mainly to a lack of carbonate material. It can, however, be located again 7 miles to the northeast at the south end of Wolfe Lake where it is constrained between a tremolite - dolomite (X-rayed) assemblage (798442) to the south and a tremolite - calcite - serpentine assem-

blage to the north. Assemblages at locations 799455 and 798454 between these two constraining points are diopside bearing but evidence (the presence of tremolite - dolomite or forsterite) as to whether forsterite has yet formed is inconclusive. The isoreaction-grad is tentatively shown as passing south of these locations although it may pass to the north of one or both of them. A mile to the northwest the isoreaction-grad travels between a tremolite - dolomite - calcite - diopside assemblage at location 789460 and a calcite - dolomite - serpentine assemblage $\frac{1}{2}$ mile north at location 793464. It then proceeds northward for $\frac{1}{2}$ mile where it is constrained between a tremolite - dolomite reactant assemblage at location 798467 and the serpentine assemblage at location 793464. North of the tremolite - dolomite assemblage it is constrained by another product assemblage at location 801468. The isoreaction-grad is not constrained beyond this point and the forsterite zone is open in this direction.

iv) Birch Lake High-Grade Zone

Surrounding the Desert Lake - Canoe Lake forsterite zone are narrow zones of diopside, the first appearance of which is marked by isoreaction-grad (7). These diopside zones run along the northwestern and southeastern margins of the forsterite zone and, similarly, are open to the northeast and southwest.

Isoreaction-grad (7) outlining the southeastern or "Birch Lake" zone is best defined at its northeastern limit where it is constrained by a tremolite - diopside - calcite - quartz univariant assemblage at location 780376 (the isoreaction-grad has not been traced north of this point). One mile southwest of this locality the isoreaction-grad is constrained between a quartz - calcite - tremolite reactant assemblage at locality 770358 and a univariant

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tremolite - calcite - dolomite - serpentine (forsterite) assemblage at locality 764359 $\frac{1}{2}$ mile to the west. Southwest $1\frac{1}{2}$ miles, the isoreaction-grad, after having passed to the east of the serpentine product assemblage at location 769345, is once again constrained by a univariant assemblage at location 764337. One mile to the southeast the isoreaction-grad becomes constrained between univariant assemblages on isoreaction-grads (3) (752331) and (9) (748327) as did isoreaction-grad (6). There is insufficient data to map isoreaction-grad (7) beyond these two constraining localities.

Isoreaction-grad (3), indicating the presence of a definable tremolite zone, has been constrained by only one assemblage - a univariant assemblage at location 752331. The isoreaction-grad cannot be traced beyond this point although the tremolite zone does exist farther to the northeast as indicated by a tremolite - calcite - quartz product assemblage at location 770358.

v) Ross Lake High-Grade Zone

A univariant diopside - tremolite - calcite - quartz assemblage at locality 669345 defines isoreaction-grad (7) at the southwest corner of the northwestern "Ross Lake" zone. Southwest of this locality the isoreaction-grad is not precisely defined but it is thought to circle around to the southeast, within a short distance, enabling it to pass between the univariant assemblages on isoreaction-grad (6) (667340) and (3) (665332) located immediately to the south.

On the northeast side of the initial univariant assemblage (669345), the isoreaction-grad passes unconstrained for 2 miles until it becomes restricted between a forsterite product assemblage at location 697352 and a tremolite - calcite - quartz reactant assemblage at location 702352. Continuing northeastward the iso-

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reaction-grad is essentially unconstrained for the next 4 miles until it passes through a diopside univariant assemblage at location 754415. Over this distance a loose constraint was placed on the isoreaction-grad by tremolite - quartz - calcite reactant assemblages to the northwest at locations 732395 and 741403. Northeast of this last univariant location, the isoreaction-grad proceeds for 2½ miles, passing to the west of several diopside product assemblages, until it is constrained by a diopside univariant assemblage at location 763455. Immediately to the north the isoreaction-grad is constrained to a narrow zone between a tremolite - calcite - quartz assemblage at location 764459 and a diopside - calcite - dolomite product assemblage at location 766459. One mile northeast of this constraint another univariant diopside bearing assemblage restricts the isoreaction-grad to location 783469. The isoreaction-grad is not mappable for 2 miles farther north due to a lack of sufficient carbonate material. After this distance it is constrained for 2 miles by two reactant assemblages (793514, 795520) and two product assemblages (795517, 795524). North of these assemblages the position of the isoreaction-grad is not known.

Isoreaction-grad (3) is defined within the Ross Lake zone by a univariant assemblage at locality 665332. The isoreaction-grad has not been traced beyond this location although several tremolite bearing product assemblages are present to the northeast, indicating that the tremolite zone does extend in this direction.

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II

6

3

042026

030020

010

030004

032020

034908

035997

7

II

042989

78

446°C
478°C

016944

406

Glen Isle

Y Q

LEGEND

508

PALEOZOIC

ORDOVICIAN

MIDDLE ORDOVICIAN

UTRAWA FORMATION: sandy shale, fine-grained grey limestone, sandy limestone

LOWER ORDOVICIAN

OXFORD AND MARCH FORMATIONS: dolomite and limestone, sandy dolomite

LOWER ORDOVICIAN OR CAMBRIAN

NEPEAN FORMATION: sandstone and conglomerate, 16a, arkose and conglomeratic arkose

PRECAMBRIAN

Diabase 15a, porphyritic andesite

Red pegmatite

Coarse grained leucocratic red monzonite, syenite, quartz monzonite, granodiorite, 13a, Ridge Lake monzonite pluton, 13b, Lyndhurst quartz monzonite pluton, 13c, Crow Lake quartz monzonite pluton

White pegmatite, always associated with crystalline limestone (4), 12a, white leucocratic granite and syenite

Pearly foliated migmatite and intermixed granitic and metamorphic rocks, associated fine-grained biotite schist

Diorite, quartz diorite, 10a, Donaldson Bay quartz diorite

Gabbro, gabbroic anorthosite

Fine to medium grained, massive, quartz-feldspathic granulite, granite in part

GRENVILLE METAMORPHIC SERIES (NOT IN STRATIGRAPHIC SEQUENCE)

Pyroxene gneiss, pyroxene-biotite gneiss, 7a, amphibolite

Stratiform quartz-biotite feldspar gneiss, commonly with cordierite and sillimanite, 6a, granite and charnockitic quartz-feldspar gneiss

Garnet-sillimanite gneiss, garnet-hypersthene gneiss, garnet cordierite gneiss, garnet lit-par-lit gneiss

Crystalline limestone and dolomite, siliceous limestone skarn, includes fragments of white pegmatite (12), rusty gneiss (2) and diorite (10)

Interbedded quartzite and siliceous crystalline limestone, usually

608

③ 80012

x8200

②

884992

885986

891984

007982

4907679

008975

899968

00964

837958

1840954

③

3

854938

855 937

1931

887935

893939

844922

638914

③

882909

384913

88790d

1961902

373894

933890

56892

823-888

9/28/86

Glen
Isle

Carleton
Place

906

Fine to medium grained, massive, quartz-feldspathic granulite, granite in part

GREENVILLE METAMORPHIC SERIES
(NOT IN STRATIGRAPHIC SEQUENCE)

Pyroxene gneiss, pyroxene-biotite gneiss, 7a, amphibolite

Stratiform quartz-biotite-feldspar gneiss, commonly with cordierite and sillimanite, 6a, graphite and charnockitic quartz-feldspar gneiss

Garnet-sillimanite gneiss, garnet-hypersthene gneiss, garnet cordierite gneiss, garnet lit-par-lit gneiss

Crystalline limestone and dolomite, siliceous limestone skarn, includes fragments of white pegmatite (12), rusty gneiss (2) and diorite (10)

Interlayered quartzite and siliceous crystalline limestone, usually finely laminated, calc-silicate rocks

Rusty paragneiss, contains quartz, pyroxene, phlogopite, graphite and pyrite

White to buff quartzite

1000

Symbols for Assemblages

(1)	potassium feldspar - dolomite - phlogopite - calcite	— ▼
	quartz - dolomite (unreacted)	--- ▲
(3)	quartz - dolomite - tremolite - calcite	— ▲
	tremolite - calcite - dolomite	--- ▲
	tremolite - calcite - quartz	
(7)	tremolite - calcite - quartz - diopside	— ●
	diopside - calcite - tremolite	--- ●
	diopside - calcite - quartz	
	diopside - quartz - tremolite	
(6)	tremolite - dolomite - forsterite - calcite	— ★
	forsterite - calcite - tremolite	--- ★
	forsterite - calcite - dolomite	
(11)	tremolite - diopside - calcite - dolomite - quartz	— ☆
	lower bracket	
	quartz - dolomite	--- ▲
	tremolite - quartz - dolomite - calcite	--- ▲
	upper bracket	
	diopside - dolomite - calcite - tremolite	--- ●

Lanark

1106

CARLETON PL
ONTARIO
MILES

1206

010963

ONTARIO PLACE Map A

MILES

1306

15
29

1700

1406

Symbols for Assemblages

(1)	potassium feldspar - dolomite - phlogopite - calcite	—	▼
	quartz - dolomite (unreacted)	---	▲
(3)	quartz - dolomite - tremolite - calcite	—	▲
	tremolite - calcite - dolomite	---	▲
	tremolite - calcite - quartz	---	▲
(7)	tremolite - calcite - quartz - diopside	—	●
	diopside - calcite - tremolite	---	●
	diopside - calcite - quartz	---	●
	diopside - quartz - tremolite	---	●
(6)	tremolite - dolomite - forsterite - calcite	—	★
	forsterite - calcite - tremolite	---	★
	forsterite - calcite - dolomite	---	★
(11)	tremolite - diopside - calcite - dolomite - quartz	—	☆
	<u>lower bracket</u>		
	quartz - dolomite	---	▲
	tremolite - quartz - dolomite - calcite	---	▲
	<u>upper bracket</u>		
	diopside - dolomite - calcite - tremolite	---	●
	diopside - calcite - quartz - tremolite	---	●
	diopside - calcite - quartz	---	●
	diopside - calcite - tremolite	---	●
	diopside - quartz - tremolite	---	●
	forsterite - calcite - tremolite - dolomite	---	★
	forsterite - calcite - tremolite	---	★
	forsterite - calcite - dolomite	---	★
	serpentine - calcite - quartz	---	☆
	serpentine - calcite - dolomite	---	☆

Isoreaction-grads

Definite

Assumed

Probable

Intrusions

Granitic

Dioritic

150815

206

308

406

5d

LEGEND

PALEOZOIC	ORDOVICIAN	
	MIDDLE ORDOVICIAN
	OTTAWA FORMATION sandy shale, fine-grained grey limestone, sandy limestone
	LOWER ORDOVICIAN
	OXFORD AND MARCH FORMATIONS dolomite and limestone, sandy dolomite
	LOWER ORDOVICIAN OR CAMBRIAN
	NEPEAN FORMATION sandstone and conglomerate, 150, arkose and conglomeratic arkose
PRECAMBRIAN		Diabase 150, porphyritic andesite
	Red pegmatite
	Coarse grained leucocratic red monzonite, syenite, quartz monzonite, granodiorite, 13a, Rideau Lakes monzonite pluton, 13b, Lyndhurst quartz monzonite pluton, 13c, Crow Lake quartz monzonite pluton
	White pegmatite, always associated with crystalline limestone (4) 12a, white leucocratic granite and syenite
	Poorly foliated migmatite and intermixed granitic and metamorphic rocks, associated fine-grained plagioclase schist
	Diorite, quartz diorite, 10a, Donaldson Bay quartz diorite
	Gabbro, gabbroic anorthosite
	Fine to medium grained, massive, quartz-feldspathic granulite, granite in part
	GRENVILLE METAMORPHIC SERIES (NOT IN STRATIGRAPHIC SEQUENCE)
	Pyroxene gneiss, pyroxene-biotite gneiss, 7a, amphibolite
	Stratiform quartz-biotite feldspar gneiss, commonly with cordierite and sillimanite, 6a, granite and charnockitic quartz-feldspar gneiss
	Garner-sillimanite gneiss, garnet-hypersthene gneiss, garnet cordierite gneiss, garnet-lil-por-lil gneiss

SMITHS FALLS

Pech
Pluton

RIVER

- ⑦ 52629
- ② 52624
- ③ 52627
- ② 258
- ⑦ 52625
- ⑦ 52626
- ⑦ 52627

537602

706

PERTH

LOWER RIDEAU
LAKE

001074
235°C

7

024669

026652

RIDEAU

BASS
LAKE

LAKE

11

079605

908

SMITHS
FALLS

ER. RIDEAU
LAKE

906

FALLS

PRECAMB

gneiss in part

GRENVILLE METAMORPHIC SERIES
NOT IN STRATIGRAPHIC SEQUENCE

Pyroxene gneiss, pyroxene-biotite gneiss, To, amphibolite

Stratiform quartz-biotite feldspar gneiss, commonly with cordierite and sillimanite, Ga, granite and charnockitic quartz-feldspar gneiss

Garnet-sillimanite gneiss, garnet-hypersthene gneiss, garnet cordierite gneiss, garnet lit-par-lit gneiss

4

Crystalline limestone and dolomite, siliceous limestone skarn, includes fragments of white pegmatite (12), rusty gneiss (2) and diorite (10)

interlayered quartzite and siliceous crystalline limestone, usually finely laminated, calc-silicate rocks

Rusty paragneiss, contains quartz, pyroxene, phlogopite, graphite and pyrite

White to buff quartzite

Symbols for Assemblages

1000

(1) potassium feldspar - dolomite - phlogopite - calcite

quartz - dolomite (unreacted)

(3) quartz - dolomite - tremolite - calcite

tremolite - calcite - dolomite

tremolite - calcite - quartz

(7) tremolite - calcite - quartz - diopside

diopside - calcite - tremolite

diopside - calcite - quartz

diopside - quartz - tremolite

(6) tremolite - dolomite - forsterite - calcite

forsterite - calcite - tremolite

forsterite - calcite - dolomite

(11) tremolite - diopside - calcite - dolomite - quartz

lower bracket

quartz - dolomite

tremolite - quartz - dolomite - calcite

upper bracket

diopside - dolomite - calcite - tremolite

diopside - calcite - quartz - tremolite

diopside - calcite - quartz

diopside - calcite - tremolite

12 of

PERTH
ONTARIO
MILES

H
10
S

Map B

130h

RIDEAU

TE

Y014

3

18

29

1406

Symbols for Assemblages

(1)	potassium feldspar - dolomite - phlogopite - calcite		
	quartz - dolomite (unreacted)		
(3)	quartz - dolomite - tremolite - calcite		
	tremolite - calcite - dolomite		
	tremolite - calcite - quartz		
(7)	tremolite - calcite - quartz - diopside		
	diopside - calcite - tremolite		
	diopside - calcite - quartz		
	diopside - quartz - tremolite		
(6)	tremolite - dolomite - forsterite - calcite		
	forsterite - calcite - tremolite		
	forsterite - calcite - dolomite		
(11)	tremolite - diopside - calcite - dolomite - quartz		
	lower bracket		
	quartz - dolomite		
	tremolite - quartz - dolomite - calcite		
	upper bracket		
	diopside - dolomite - calcite - tremolite		
	diopside - calcite - quartz - tremolite		
	diopside - calcite - quartz		
	diopside - calcite - tremolite		
	diopside - quartz - tremolite		
	forsterite - calcite - tremolite - dolomite		
	forsterite - calcite - tremolite		
	forsterite - calcite - dolomite		
	serpentine - calcite - quartz		
	serpentine - calcite - dolomite		

Isoreaction-grades

Definite

Assumed

Probable

Intrusions

Granitic

Dioritic

150815

1108

LEGEND

PALEOZOIC	ORDOVICIAN	
	MIDDLE ORDOVICIAN	
	OTTAWA FORMATION: sandy shale, fine-grained grey limestone, sandy limestone	
	LOWER ORDOVICIAN	
	OXFORD AND MARCH FORMATIONS: dolomite and limestone, sandy dolomite	
	LOWER ORDOVICIAN OR CAMBRIAN	
	NEPEAN FORMATION: sandstone and conglomerate, 16a, arkose and conglomeratic arkose	
PRECAMBRIAN		Diabase: 15a, porphyritic andesite
		Red pegmatite
		Coarse grained leucocratic red monzonite, syenite, quartz monzonite, granodiorite, 13a, Rideau Lakes monzonite pluton, 13b, Lyndhurst quartz monzonite pluton, 13c, How Lake quartz monzonite pluton
		White pegmatite, always associated with crystalline limestone (4-12a), white eulocratic granite and syenite
		Partly foliated migmatite and intermixed granitic and metamorphic rocks, associated fine-grained mafic schist
		Diorite, quartz diorite, 10a, Donaldson Bay quartz diorite
		Gabbro, gabbroic anorthosite
		Fine to medium grained, massive, quartz-feldspathic granulite, granite in part
	GRENVILLE METAMORPHIC SERIES (NOT IN STRATIGRAPHIC SEQUENCE)	
		Pyroxene gneiss, pyroxene-biotite gneiss, 7a, amphibolite
		Stratiform quartz-biotite feldspar gneiss, commonly with cordierite and sillimanite, 6a, garnet and chamoekitic quartz-feldspar gneiss
		Garnet-sillimanite gneiss, garnet-hypersthene gneiss, garnet cordierite gneiss, garnet lit-par-lit gneiss

208

1941

406

50b

GRENVILLE METAMORPHIC SERIES
[NOT IN STRATIGRAPHIC SEQUENCE]

Pyroxene gneiss, pyroxene-biotite gneiss, 7a, amphibolite

Stratiform quartz-biotite feldspar gneiss, commonly with cordierite and sillimanite, 6a, granite and charnockitic quartz-feldspar gneiss

Garnet-sillimanite gneiss, garnet-hypersthene gneiss, garnet cordierite gneiss, garnet il-por-il gneiss

Crystalline limestone and dolomite, siliceous limestone skarn, includes fragments of white pegmatite (12), rusty gneiss (2) and diorite (10)

Interlayered quartzite and siliceous crystalline limestone, usually finely laminated, calc-silicate rocks

Rusty paragneiss, contains quartz, pyroxene, phlogopite, graphite and pyrite

White to buff quartzite

Symbols for Assemblages

(1) potassium feldspar - dolomite - phlogopite - calcite
quartz - dolomite (unreacted)

(3) quartz - dolomite - tremolite - calcite
tremolite - calcite - dolomite
tremolite - calcite - quartz

(7) tremolite - calcite - quartz - diopside
diopside - calcite - tremolite
diopside - calcite - quartz
diopside - quartz - tremolite

(6) tremolite - dolomite - forsterite - calcite
forsterite - calcite - tremolite
forsterite - calcite - dolomite

(14) tremolite - diopside - calcite - dolomite - quartz

lower bracket

quartz - dolomite

tremolite - quartz - dolomite - calcite

upper bracket

diopside - dolomite - calcite - tremolite

diopside - calcite - quartz - tremolite

diopside - calcite - quartz

diopside - calcite - tremolite

diopside - quartz - tremolite

forsterite - calcite - tremolite - dolomite

forsterite - calcite - tremolite

608

49390
7358

DEVIL LAKE

708

3

928461
928458

NEWBORO LAKE

806

505
575

9376

93363
944767
942766

93369

92347

92343

PINELON

93334
93333

93323
94724

93318

01637
01630

SAND LAKE

42

906

4

3

5

10

023375

016370 018371
011368

061375

090374

089366

087360

083350

11

15

1KE

024330 034332

034332

048332

048332

Symbols for Assemblages

(1) potassium feldspar - dolomite - phlogopite - calcite		
quartz - dolomite (unreacted)	---	
(3) quartz - dolomite - tremolite - calcite		
tremolite - calcite - dolomite	---	
tremolite - calcite - quartz		
(7) tremolite - calcite - quartz - diopside		
diopside - calcite - tremolite	---	
diopside - calcite - quartz		
diopside - quartz - tremolite		
(6) tremolite - dolomite - forsterite - calcite		
forsterite - calcite - tremolite	---	
forsterite - calcite - dolomite		
(11) tremolite - diopside - calcite - dolomite - quartz		
lower bracket		
quartz - dolomite	---	
tremolite - quartz - dolomite - calcite	---	
upper bracket		
diopside - dolomite - calcite - tremolite	---	
diopside - calcite - quartz - tremolite	---	
diopside - calcite - quartz		
diopside - calcite - tremolite	---	
diopside - quartz - tremolite		
forsterite - calcite - tremolite - dolomite	---	
forsterite - calcite - tremolite	---	
forsterite - calcite - dolomite		
serpentine - calcite - quartz	---	
serpentine - calcite - dolomite		

Isoreaction-grads

Definite

Assumed

Probable

Intrusions

Granitic

Dioritic

1206

13 of

WESTPORT
ONTARIO
MILES

4
dykes of white granite (100) and diorite (101)

150815

LEGEND

44°45'

308

406

Fine to medium grained, massive, quartzite - dolomite
granite in part

GRENVILLE METAMORPHIC SERIES
NOT IN STRATIGRAPHIC SEQUENCE

Pyroxene gneiss, pyroxene-biotite gneiss, Zr amphibolite

Stratiform quartz-biotite feldspar gneiss, commonly with cordierite and sillimanite, Gc, granule and charnockitic quartz-feldspar gneiss

Garnet-sillimanite gneiss, garnet-hypersthene gneiss, garnet-cordierite gneiss, garnet-qtz-por-ph gneiss

4 Crystalline limestone and dolomite, siliceous limestone shorn, includes fragments of white pegmatite (2), rusty gneiss (2) and diorite (10)

Interlayered quartzite and siliceous crystalline limestone, usually finely laminated, calc-silicate rocks

Rusty pegmatite, contains quartz, pyroxene, phlogopite, greenschist and quartz

White to buff quartzite

Symbols for Assemblages

(1)	potassium feldspar - dolomite - phlogopite - calcite	---	▼
	quartz - dolomite (unreacted)	---	▲
(3)	quartz - dolomite - tremolite - calcite	---	▲
	tremolite - calcite - dolomite	---	▲
	tremolite - calcite - quartz	---	▲
(7)	tremolite - calcite - quartz - diopside	---	●
	diopside - calcite - tremolite	---	●
	diopside - calcite - quartz	---	●
	diopside - quartz - tremolite	---	●
(6)	tremolite - dolomite - forsterite - calcite	---	★
	forsterite - calcite - tremolite	---	★
	forsterite - calcite - dolomite	---	★
(11)	tremolite - diopside - calcite - dolomite - quartz	---	☆
	lower bracket	---	▲
	quartz - dolomite	---	▲
	tremolite - quartz - dolomite - calcite	---	▲
	upper bracket	---	●
	diopside - dolomite - calcite - tremolite	---	●
	diopside - calcite - quartz - tremolite	---	●
	diopside - calcite - quartz	---	●
	diopside - calcite - tremolite	---	●

608

35

708

906

1000

Rusty porphyries, contains quartz, pyroxene, phlogopite, graphite and pyrite

MINERAL DUFF QUARTZITE

Symbols for Assemblages

(1) potassium feldspar - dolomite - phlogopite - calcite ---

quartz - dolomite (unreacted) ---

(3) quartz - dolomite - tremolite - calcite ---

tremolite - calcite - dolomite ---

tremolite - calcite - quartz ---

(7) tremolite - calcite - quartz - diopside ---

diopside - calcite - tremolite ---

diopside - calcite - quartz ---

diopside - quartz - tremolite ---

(6) tremolite - dolomite - forsterite - calcite ---

forsterite - calcite - tremolite ---

forsterite - calcite - dolomite ---

(11) tremolite - diopside - calcite - dolomite - quartz ---

lower bracket ---

quartz - dolomite ---

tremolite - quartz - dolomite - calcite ---

upper bracket ---

diopside - dolomite - calcite - tremolite ---

diopside - calcite - quartz - tremolite ---

diopside - calcite - quartz ---

diopside - calcite - tremolite ---

diopside - quartz - tremolite ---

forsterite - calcite - tremolite - dolomite ---

forsterite - calcite - tremolite ---

forsterite - calcite - dolomite ---

serpentine - calcite - quartz ---

serpentine - calcite - dolomite ---

Isoreaction-grads

Definite ---

Assumed ---

Probable ---

Intrusions

Granitic ---

Dioritic ---

11/05

35'

77.00

1306

TICHBORNE
ONTARIO
MILES

Map D

1406

150815

108

205

Philipville

Mud Lake

LOWER

095412
096415
099414
099413
099411
098406
098404
101403
101399
102397
102396

308

LEGEND

PALEOZOIC

ORDOVICIAN
MIDDLE ORDOVICIAN

OTTAWA FORMATION: sandy shale, grey limestone, sandy limestone

LOWER ORDOVICIAN

OXFORD AND MARCH FORMATIONS: limestone, sandy dolomite

LOWER ORDOVICIAN OR CAMBRIAN

NEPEAN FORMATION: sandstone, 16a, arkose and conglomeratic arkose

PRECAMBRIAN

Diabase: 15a, porphyritic andesite

Red pegmatite

Coarse grained leucocratic red monzonite, 13a, Rideau Lakes monzonite pluton, 13c, Crow Lake quartz

White pegmatite, always associated with 12a, white leucocratic granite and 12c

Poorly foliated monzonite and related rocks, associated fine-grained biotite

Diabase, quartz diorite, 12a, Donaldson

Gabbro, diabase, anorthosite

Fine to medium grained massive, quartzite in part

GRENVILLE METAMORPHIC (NOT IN STRATIGRAPHIC SEQUENCE)

Pyroxene gneiss, pyroxene-biotite gneiss

Stratiform quartz-biotite feldspar gneiss, 6a, 6b, 6c, 6d, 6e, 6f, 6g, 6h, 6i, 6j, 6k, 6l, 6m, 6n, 6o, 6p, 6q, 6r, 6s, 6t, 6u, 6v, 6w, 6x, 6y, 6z

LEGEND

Map E

PALEOZOIC

ORDOVICIAN
MIDDLE ORDOVICIAN

OTTAWA FORMATION: sandy shale, fine-grained grey limestone, sandy limestone

LOWER ORDOVICIAN

OXFORD AND MARCH FORMATIONS: dolomite and limestone, sandy dolomite

LOWER ORDOVICIAN OR CAMBRIAN

NEPEAN FORMATION: sandstone and conglomerate, 16a, arkose and conglomeratic arkose

Diabase, 13a, porphyritic andesite

Red pegmatite

Coarse grained leucocratic red monzonite, syenite, quartz monzonite, granodiorite, 13a, Rideau Lakes monzonite pluton, 13b, Lyndhurst quartz monzonite pluton, 13c, Crow Lake quartz monzonite pluton

White pegmatite, always associated with crystalline limestone (4), 12a, white leucocratic granite and syenite

Poorly foliated migmatite and intermixed granitic and metamorphic rocks, associated fine-grained biotite schist

Diabase, quartz diorite, 12a, Donaldson Bay quartz diorite

Gabbro, diabasic anorthosite

Fine to medium grained, massive, quartz-feldspathic granulite, gneiss in part

PRECAMBRIAN

GRENVILLE METAMORPHIC SERIES
(NOT IN STRATIGRAPHIC SEQUENCE)

Pyroxene gneiss, pyroxene-biotite gneiss, 7a, amphibolite

Stratiform quartz-biotite, feldspar gneiss, commonly with cordierite and sillimanite, 6a, granitic and characteristic quartz-feldspar gneiss

608

018371

056355

048336

028333

024331

034332

102396
LOWER

BEVERLEY

LAKE

Brier Hill

Lyndhurst

706

806

- 4 fragments of white pegmatite (12), rusty gneiss (2) and diorite (10)
- interlayered quartzite and siliceous crystalline limestone, usually finely laminated, calc-silicate rocks
- Rusty porphyry, contains quartz, forsterite, phlogopite, pyroxene and calcite
- white to buff quartzite

Symbols for Assemblages

- (1) potassium feldspar - dolomite - phlogopite - calcite —
- quartz - dolomite (unreacted) —
- (3) quartz - dolomite - tremolite - calcite —
- tremolite - calcite - dolomite —
- tremolite - calcite - quartz —
- (7) tremolite - calcite - quartz - diopside —
- diopside - calcite - tremolite —
- diopside - calcite - quartz —
- diopside - quartz - tremolite —
- (6) tremolite - dolomite - forsterite - calcite —
- forsterite - calcite - tremolite —
- forsterite - calcite - dolomite —
- (11) tremolite - diopside - calcite - dolomite - quartz —
- lower bracket —
- quartz - dolomite —
- tremolite - quartz - dolomite - calcite —
- upper bracket —
- diopside - dolomite - calcite - tremolite —
- diopside - calcite - quartz - tremolite —
- diopside - calcite - quartz —
- diopside - calcite - tremolite —
- diopside - quartz - tremolite —
- forsterite - calcite - tremolite - dolomite —
- forsterite - calcite - tremolite —
- forsterite - calcite - dolomite —
- serpentine - calcite - quartz —
- serpentine - calcite - dolomite —

Isoreaction-grades

Definite

Assumed

Probable

906

083350 X X 084350

081348

Brier Hill

066337

068336/5

074335

Morton

Sweet Corners

1106

07 293

072292

071291

071290

069289

X 069288

068288

Grippe

(6) tremolite - dolomite - forsterite - calcite
forsterite - calcite - tremolite
forsterite - calcite - dolomite

(11) tremolite - diopside - calcite - dolomite - quartz

lower bracket

quartz - dolomite

tremolite - quartz - dolomite - calcite

upper bracket

diopside - dolomite - calcite - tremolite

diopside - calcite - quartz - tremolite

diopside - calcite - quartz

diopside - calcite - tremolite

diopside - quartz - tremolite

forsterite - calcite - tremolite - dolomite

forsterite - calcite - tremolite

forsterite - calcite - dolomite

serpentine - calcite - quartz

serpentine - calcite - dolomite

Isoreaction-grads

Definite

Assumed

Probable

Intrusions

Granitic

Dioritic

1306

II

Jones Falls

▲ 020524
▲ 020823
X 021322

Hog I.

Dean Island

Morron

1400

III

06828

022

Brier Hill

Lynchburg

Sweet Corners

Singlro Lake

1506

066337
068336/5
074239

07 293
072292
071291
071296
069289
068288
X 069288

105322
111322
116320
144318

105311
107303

107299

107291

Grippe

Lake

Pressure = 1 bar

Temp °K

1200

1150

1100

1050

1000

950

900

850

800

750

206

■ Goldsmith, J.R., and Newton, R.C. 1969

● Graf, D.L. and Goldsmith, J.R. 1958

Temp °K

1000

950

900

850

800

750

700

650

600

550

500

300

Mole %

- Goldsmith, J.R., and Newton R.C. 1969.
- Graf, D.L., and Goldsmith, J.R. 1958
- ▲ Harker, R.I., and Tuttle, O.F. 1955
- Goldsmith, J.R. and Heard, H.C. 1961
- Goldsmith, J.R. and Heard, H.C. 1961 calcite only

14 16 18 20 22 24 26 28 30

gCO₃ in Calcite (XMgCO₃)

4065

Pressure = 5 kbars

Temp °K

1200
1150
1100
1050
1000
950
900
850
800

206

Temp °k

950
900
850
800
750
700
650
600
550
500

0

2

4

6

8

10

12

14

16

18

20

22

24

26

28

30

32

34

36

38

40

42

44

46

48

50

52

54

56

58

60

62

64

Mole % Mg

300

■ Goldsmith, J.R., and Newton, R.C. 1969

● Graf, D.L., and Goldsmith, J.R. 1958

▲ Harker, R.I., and Tuttle, O.F. 1955

□ Goldsmith, J.R. and Heard, H.C. 1961

14 16 18 20 22 24 26 28 30

wt% MgO in calcite (XMgCO_3)

4.065

108.

205

9

8

7

6

5

308

5

OF/DE

5

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

406

508

FIGURE 7.1

2b

2a

2

0.3 0.4 0.5 0.6

608

X_{CO2}

$P_{CO_2} + P_{H_2O} = 5000 \text{ bars.}$

0.6

0.7

0.8

0.9

1.0

706

T °C

— 500°

— 450°

— 400°

— 350°

— 300°

1.0

Figure 7.1

8008

END

07 11 77

FIN