The Use of Maps and Map Metaphors for Integration in Geography:

A Case Study in Mapping Indicators of Sustainability and Wellbeing.

Brian G. Eddy

Thesis submitted in partial fulfillment
of the requirements for
the degree

Doctor of Philosophy
Department of Geography and Environmental Studies
Carleton University,
Ottawa, Canada.

September, 2006

Your file Votre référence
ISBN: 978-0-494-18216-1
Our file Notre référence
ISBN: 978-0-494-18216-1

Abstract

This thesis explores the use of maps and map metaphors for *integration* in the field of Geography and Environmental Studies (GES). One challenge in this type of integration is how to interface knowledge and methods derived from the physical and social sciences, and the arts and humanities, as they are used in various sub-disciplines in GES. Four papers are presented wherein contributions from three published papers are integrated in a more comprehensive fourth paper to illustrate the integrative utility of maps and map metaphors for this purpose. The approach taken examines frameworks for integration from a perspective of *geoinformation processing* (GIP). Maps and map metaphors provide a means of visualizing different types of knowledge and data. Examples of their use are developed in an application that explores the comprehensive subject of *sustainability* and *wellbeing* by mapping indicators of these referents at multiple geographical scales. Results of this analysis yield a series of illustrative arguments as to *why geography matters*. This develops a concept of *geo-ontological contingency* which highlights the necessity for integration when dealing with comprehensive geographical issues. An additional map metaphor is presented to help navigate geo-ontological contingency and provides a framework for integration. This map, known as an *AQAL map*, is based on a body of work called *Integral Theory* developed by the American scientist and philosopher Ken Wilber. Several derivatives of the AQAL map are applied to illustrate its potential for multiple disciplines and methodologies to take part in an integrative collaborative environment in GES. It is from this analysis that several conclusions about the use of maps and map metaphors for integration in GES are derived.

Acknowledgements

I would like to acknowledge the support of the following individuals and organizations in the research and production of this thesis. First, and most immediate, I would like to thank the members of my advisory committee, Dr. D.R. Fraser Taylor, Dr. Ken Torrance, and Dr. Iain Wallace for supporting my research interests, and their guidance and wisdom. As is the case with many Ph.D. projects, there is often a tendency for the student to wander, and they ensured that I stayed on course.

I also like to acknowledge other faculty and graduate students in the Department of Geography and Environmental Studies at Carleton: in particular, Fran Klodawsky, Simon Dalby, Dale Armstrong, Andrew Baldwin, and Jamie Linton. Our many formal and informal debates and discussions greatly informed my learning experience. The administrative staff in the department are greatly acknowledged for their impeccable support: Hazel Anderson, Elsie Clement, Judy Donaldson and Judy Eddy. .

Financial support for this thesis was provided by a Social Sciences and Humanities Research Council (SSHRC) Doctoral Fellowship (Award No. 752-2003-1827). Additional support was provided through a research assistantship under Dr. Taylor's Cybercartography and the New Economy (CANE) project, which was funded by the SSHRC Initiative on the New Economy (INE) program.

I would like to thank and acknowledge the many students, professors, and administrative staff who I worked with on the CANE project, in particular the members of the Geomatics and Cartographic Research Centre (GCRC): Sebastien Caquard, JP Fiset, Barbara George, Amos Hayes, Yam Hean Kong, Tracey Lauriault, and Peter Pulsifer; as well as the many Masters students who flowed through the lab in the past three years. Three prominent cartographers, Michael Peterson, William Cartwright, and Georg Gartner are greatly acknowledged. Learning about the many directions cartography is taking in this 'age of the internet' through their pioneering work was very inspiring for my own intellectual development. I also like to thank students and professors from the Human-Oriented Technology Lab (HOTLab), Cognitive Science, the Institute for Contemporary Studies in Literature, Art and Culture (ISLAC), and the Norman Patterson School of International Affairs (NPSIA). Working with people from our own lab and these other schools provided me the opportunity to learn what collaborative research truly entails.

As readers will find, this thesis explores an integrative philosophy and theoretical framework called Integral Theory, which was developed by the American scientist and philosopher Ken Wilber. I would like to thank Ken and several of his collaborators whom I have worked with over the past four years: Sean Esbjörn-Hargens, Forest Jackson, Barrett Brown, Don Beck, and Marilyn Hamilton. Ken kindly funded international conference calls to enable students of his work to discuss theoretical and practical issues, and to foster an environment for collaboration among graduate students and other students of his work. Meeting and working with these wonderful people reinforced my enthusiasm for integral research.

I acknowledge Dr. Graeme Bonham-Carter and Dr. Charlie Jefferson at the Geological Survey of Canada who were instrumental in cultivating my early intellectual development in geomatics and its practical application. I also like to acknowledge Dr. Jeff Harris, who has worked around the clock in editing the special volume of a

Geological Association of Canada paper in GIS applications in the Earth Sciences, to which myself, Graeme and Charlie have made a contribution.

I thank Wendy Ripmeester at Natural Resources Canada for introducing me to Robert-Prescott Allen and his Wellbeing Assessment work. Robert kindly provided me the data from his Wellbeing of Nations report, and this is greatly acknowledged; otherwise the thesis might have had to take a completely different direction. I would also like to thank the staff at Carleton's MADGIC centre, in particular, Heather MacAdam and Wendy Watkins for their help in navigating Statistics Canada's data sources.

I would not have embarked upon a Ph.D. program nor completed this thesis without the encouragement and support of my family and friends. They truly are the most important people in a researcher's life: my Mom, Dad and family and for their endless inspiration, support and encouragement; my friends Abby, Linsday, Sophie, Mike, Berkeley, Paul, Erick, and Lloyd for their emotional and intellectual support, and especially for keeping me grounded. I would especially like to thank Catherine for always being there and for keeping my focus on the things that matter most.

Most significantly, I dedicate this thesis to my good friend George Hawkins. During the week that I was accepted into the Ph.D. program at Carleton, I had to make an emergency trip to Halifax, Nova Scotia to attend George's funeral. George died at the too young age of 38 from a six year battle with brain cancer. Why some lives are cut so short, while others are allowed to continue is part of the great mystery of life. Ironically, it is this mystery that George always dived into without fear. George was the kind of guy who saw no challenge as a barrier; he often set goals for himself, and worked hard at achieving them. As kids, he would often give me a kick in the rear whenever I showed some lack of confidence or self-doubt, and pushed me to realize my own potential. George was a dedicated person; becoming a well known and respected RCMP officer in Halifax, and dearly loved his wife and two young girls. He had a very humourous and sarcastic personality. His trademark attitude, in which most of my friends would agree, was whenever we got caught up in an argument that wandered aimlessly, he was always quick to jump in and ask: “So what’s your point?”. His presence was felt as I struggled with arriving at my thesis statement. “Thanks Buddy! Here’s my point!”

TABLE OF CONTENTS

LIST OF FIGURES

Figures for the Introduction

Figures for PAPER A

Figures for PAPER B

Figures for PAPER C

Figures for PAPER D

LIST OF TABLES

Tables for the Introduction

Tables for PAPER A

Tables for PAPER B

Tables for PAPER D

Ah for just one time
I would take the Northwest Passage,
to find the hand of Franklin
reaching for the Beaufort Sea.

Tracing one warm line
through a land so wide and savage,
and make a Northwest Passage to the sea.

Stan Rogers
Northwest Passage

Introduction

About this Thesis

The above chorus from Stan Rogers' song *Northwest Passage* also appears at the beginning of my MSc thesis (Eddy, 1996) which presented a method for working with 'sparse data' in 'sparse lands'; essentially an exploration into unknown territories. The study area of my MSc thesis was the Parry Islands that lie north of the Northwest Passage in the Canadian Arctic; so the lyric seemed appropriate. In this thesis, I find the metaphor applies in a different context. Taylor (2003) argues that *maps will be as important in the information era as they were to the era of exploration.* These newer territories within which we find ourselves navigating, exploring and discovering are increasingly becoming the inner territories of human knowledge, thought and contemplation; and looking at how we as humans think about the world manifests in our increasingly globalizing impact on the planet. This thesis is one contribution toward the use of maps in this context.

The territory explored in this thesis is metaphorically similar to the *land so wide and savage* navigated by the early explorers like Franklin. The territory of geography and environmental studies, as an integrative discipline of physical sciences, social sciences, and the humanities; and with the use of advanced information technology in geomatics, can be taxing on an individual's intellectual and emotional capacity. It certainly is a wide territory. 'Savage' might be too strong a metaphor in this case; although the word 'contentious' seems reasonable. I have sensed that scholars, students and practitioners of geography must be careful where they step as they navigate their way through this field.

There has been a war going on in this territory for several decades (at least) concerning how to approach the study of the world in an integrative manner. Part of what constitutes the approach that I offer is based on the work of American scientist and philosopher Ken Wilber. His view contextualizes the intellectual climate as emanating from a *philosophical cold war* between modernity and post-modernity. Navigating this territory and finding reconciliation is certainly a challenge. In a sense, this thesis is an account of one student's journey; and I view it as a trace of *one warm line* through this territory (Figure I-1). I do feel I have reached a *Sea of Possibilities* for integration, however, it is doubtful that others might follow the same path that I have traveled, or that they might venture into the territory with the same motivation. In any case, this thesis documents a journey through this territory wherein I provide a record of my findings and discoveries as a contribution to the field.

The *one warm line* can be seen as tracing a number of discoveries along this journey that are captured in a collection of four papers (Table I-1). In 2005, the Department of Geography and Environmental Studies (GES) at Carleton University implemented a new thesis option for Ph.D. students who have been actively publishing their research during the course of their program. Under this option, students can submit a thesis that is comprised of a collection of their published works, with the addition of an enveloping text that combines their contributions in either an integrative context, or an application of various aspects of their published material.

Table I-1. The four papers contained in this thesis.

PAPER A	Eddy, B.G., Bonham-Carter, G.F., and Jefferson, C.W. 2006. *Mineral Potential Mapped and Analyzed at Multiple Scales: A Modified Fuzzy Logic Method Using Digital Geology.* In: Harris, J.R., Editor, GIS Applications in the Earth Sciences: Geological Association of Canada, Special Paper 44, pp. 143-163.
PAPER B	Eddy, B. and Taylor D.R.F. 2005b. *Exploring the Concept of Cybercartography Using The Holonic Tenets of Integral Theory.* In: D. R. F. Taylor (2005). (ed.), Cybercartography: Theory and Practice, Amsterdam: Elsevier. pp. 35-61.
PAPER C	Eddy, B.G. 2005. *Integral Geography: Space, Place and Perspective.* World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp. 151-163.
PAPER D	Eddy, B.G. 2006. *The Use of Maps and Map Metaphors for Integration in Geography : A Case Study in Mapping Indicators of Sustainability and Wellbeing.* (Unpublished, this thesis)

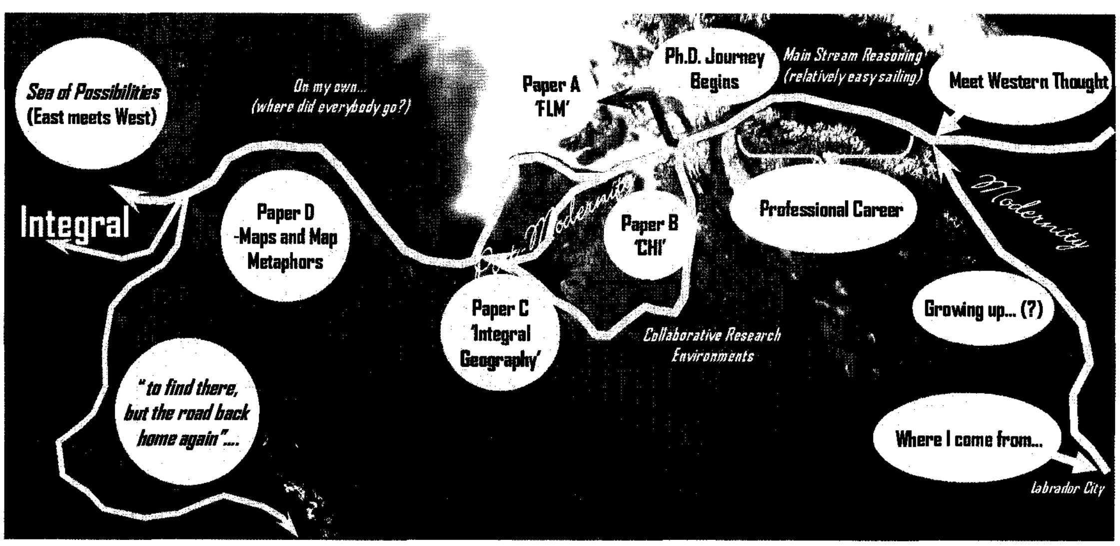


Figure I-1. Map metaphor of this thesis as a journey likened to early explorations through the Northwest Passage. (Image source: http://en.wikipedia.org/wiki/Northwest_Passage; last accessed July 5th, 2006)

Given that I have been actively publishing throughout my program, mostly as a result of opportunities associated with a number of collaborative research activities, I have chosen to take this option. Three of the papers are published works; two in peer-reviewed journals (Papers A and C), and one is a book chapter (Paper B). Paper D is an integrative application of the three published papers. The relations of the key contributions among all papers are described in more detail below; in particular, how results from the three published papers were integrated in the fourth.

Bringing these works together presented several challenges, most of which involved arriving at an overall *thesis statement.* Metaphorically, I have thought of the challenge of arriving at a thesis statement as a point along the journey wherein I was much more on my own, and needed to find some means for integrating and making sense of what the material in these three papers might represent as a whole. The thesis statement resulted from a serendipitous discovery process, and this aspect is elaborated in the following sections.

This introduction provides a road-map for readers to navigate the enclosed papers, and also provides an overarching context for the potential significance and use of the results, and how I arrived the thesis statement. First, I begin by providing some background and context that describes my principal research interests, and why I think they are important to the discipline of GES, as well as for practical application in society. Second, as the title indicates, this thesis concerns the use of maps and map metaphors for integration in GES, and a significant portion of the fourth paper is dedicated to this theme. Feedback from early reviews by my thesis committee suggested that a brief introduction to this theme up front may help readers navigate the thesis with greater ease.

I have therefore included an introduction to why I believe maps and map metaphors are important for integration, and I frame this argument in terms of a construct that I refer to as *geo-ontological contingency*, and briefly describe what I mean by this term.

Third, I provide a roadmap that guides readers through what I have identified to be the key intellectual contributions from each of the three published papers, and how they were applied in the fourth paper that explores geo-ontological contingency, and the use of maps and map metaphors for integration in GES.

Background and Context

It is worth mentioning at the outset, that I primarily affiliate myself within the *Geographical Information Processing* (GIP) stream within the discipline as a whole. However, I maintain strong research interests in many areas in both human and physical geography, and environmental studies. My interests stem from more than fifteen years of professional experience working in a broad range of applications of geomatics technology, GIS and computer-based cartography. My intent in highlighting this experience is to set a context for some of the key research interests I maintain, and plan to carry into the future. I also believe it is relevant for readers to appreciate what experiences might motivate a researcher to approach a particular problem in a particular way, or why one might see something as a research problem to begin with.

The areas of application in which I have worked include mapping bedrock geology, mineral potential mapping and exploration, resource management, marine geophysics and oceanography; hydrographic, sea-ice and meteorological studies; land-use, biodiversity and protected areas; socio-economic and demographic statistics, and mapping indicators of sustainability, development, and wellbeing. A common element in all of these projects is that there was always a practical or societal context within which they took place. That is, there was a demand for these various types of geoinformation to support some current issue, project or purpose; and its practical need set a number of constraints on what information was collected, and how it was processed and presented.

These areas of application are often conventionally regarded as *uni-thematic* issues. The focus has often been only on subjects such as geology, or oceanography, or biodiversity, or socio-economics. In recent years, I have discovered that many organizations are interested in how they can be inter-related; usually under the realization that 'everything is connected to everything else' within the current milieu of sustainability and globalization. Exploring how everything is inter-connected presents an immense challenge in that there does not seem to be any consensus on how to approach comprehensive issues in an integrative manner. Many of the barriers involve technological and scientific issues, but the most significant ones are political, organizational, and I believe above all, conceptual.

In working in the geomatics field on both technical/scientific and management levels, and through such a broad range of application areas, I have become increasingly interested in not only technological and scientific issues of geoinformation, but more so in the diversity of its use in society. I am particularly interested in sensitivities geoinformation often carries with respect to some of the more pressing contemporary issues of our time; such as the environment, climate change, globalization and geopolitics, to name a few. As a GIP theorist and practitioner, I believe it is important to develop a sensitivity to needs of people and organizations as much as possible. It is often necessary to learn as much as one can about the intangibles in the use of geoinformation; such as the political climate, what policies or issues are driving the need, the organizations and personalities involved, and even more so – what *purposes* the information will serve.

Bringing these considerations into a *geoinformation processing* context required me to develop and sensitize my own mental map with respect to many contemporary issues that are debated in GES and the world as a whole. Part of this challenge involves dealing with a paradoxical situation. Individual human beings cannot be experts in all areas of specialization; yet at the same time, in this information age, there is a significant increase in cross-specialization, or what many refer to as a shift in academia, business, government and other organizations towards multi-disciplinary, inter-disciplinary, and more recently trans-disciplinary collaborative activities. So how does one purport to participate in such a collaborative environment while simultaneously maintain some grounding in their own respective area of specialization?

While I remain primarily affiliated with GIP, my main research interests involve how GIP interfaces with contemporary issues of our time. We might view the debates within the field of GES about *integration* primarily directed towards reconciling methodological and ideological differences between human and physical geography; arguably surfacing partly in response to external pressures to provide more comprehensive frameworks to address contemporary issues. It is to this broad issue that I contribute an approach as a principal contribution in this thesis; but I emphasize that what I do offer here, is simply just that – an *offering.* It is one student's perspective on this issue. Testing its usefulness will require significantly more collaborative work than what can be attained in a Ph.D. thesis. But it is an offering that I believe is worthy of consideration.

The manner in which I approach this issue is to regard the subject of integration in GES from a perspective of *geoinformation processing*. One contribution in this thesis is an argument that what we conventionally regard as *geoinformation* has been rather narrowly defined; usually pertaining to remote sensing, GIS, GPS, and map-based data. I regard these types of information as constituting a core, however, what we regard as geoinformation should not preclude other types and formats; such as narratives, videos, works of art, geographical stories, books and journal papers, or real-time news items. In essence, if we as human beings are 'thinking geographically' in any sense, either formally or informally, then we are processing geoinformation in some respect. Comprehensive issues such as sustainability, globalization, or climate change inevitably involve some mix of human and physical geographical information, as well as their interface in environmental studies. (Figure I-2).

Under a broadened definition of geoinformation, a GIP practitioner is faced with the task of how to integrate information emanating from various fields of specialization. One of my doctoral student colleagues, Peter Pulsifer, suggests GIP practitioners are increasingly serving a role as *mediator* of information flow (Pulsifer and Taylor, 2005); and he identifies two types of mediation in GIP: 1) *geographical mediation*, and 2) *cartographic mediation.* I have drawn parallels with his analysis in that the relation between geography and cartography can be framed in terms of pertaining to *what we* *have to say about the world* (geography) and *how we might say it* (cartography); wherein, both geographical and cartographical aspects may draw from numerous types of geographical information (Eddy and Taylor, 2005). Although we do not restrict the types of information to explicitly geospatial data (conventional GIP); I believe it is necessary to maintain *spatiality* as a core component of geoinformation, highlighting the discipline's common focus on all things spatially related.

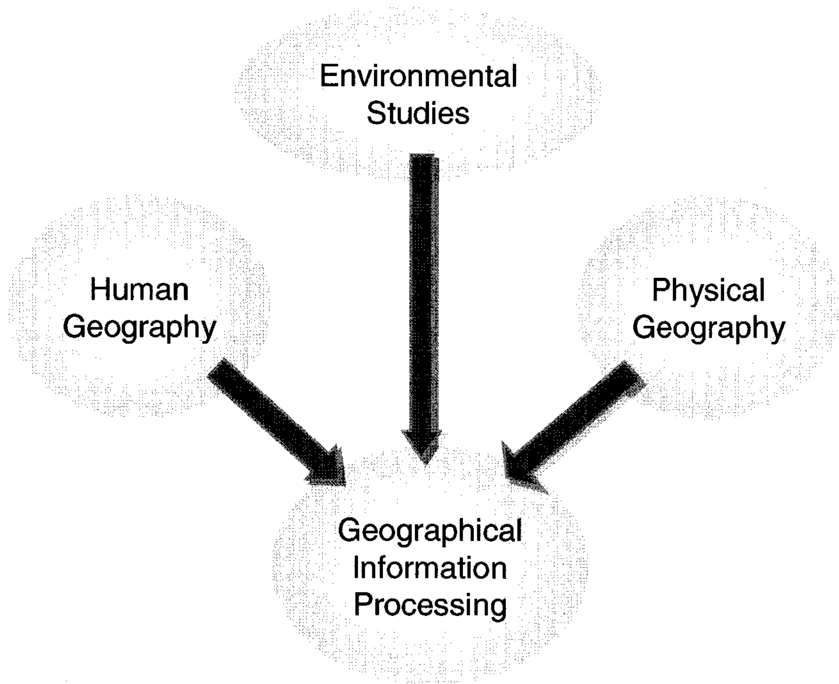


Figure I-2. Schematic illustrating Geographical Information Processing as serving an integrative function among the main disciplines in Geography and Environmental Studies.

It is from this vantage point that I take the opportunity to examine conceptual issues on how integration may proceed in GES; at least, from the perspective of a GIP theorist and practitioner who sees himself as ultimately serving a role as a *mediator* for integrating a wide array of information created in the field. I believe a GIP mediator must learn the languages of many sub-disciplines within GES, at least to a level where he or she can facilitate meaningful information flow and exchange. As with any kind of mediation process, the challenge often involves some degree of translation among the many languages used from various areas of specialization, and where possible, offering up suggestions for integration, and where there might be conflict, suggestions for reconciliation.

It is not surprising then, that developing this scholastic or professional capacity inevitably interfaces with some of the key debates in the discipline pertaining to how to more effectively integrate across the human and physical divide. Scholars in the field are well aware of numerous contentious debates over the past several decades, and I feel I do not need to review any here. In recent years the debates have taken on a different tone of reconciliation, and have garnered a number of important insights. These are highlighted by several recent collaborative efforts (e.g. Trudgill and Roy, 2005; Castree, et. al., 2005), and have been a focal point in recent presidential addresses (e.g. Gober, 2000; Wallace, 2002; Murphy, 2006).

A common theme among these latter perspectives concerns not only how to approach integration within discipline, but to also consider geography's role and visibility in broader societal issues. One approach may be framed in terms of presenting, in some way, an effective and illustrative argument as to *why geography matters* (what we have to say) that communicates clearly some of key insights provided by geographical enquiry in terms that people outside the discipline can understand (how we say it). A main contribution of this thesis is to suggest the argument can be made in terms of highlighting *geo-ontological contingency* in human knowledge, and I briefly introduce what I mean by this concept.

Why Geography Matters

A central concept examined in this thesis focuses on *ontology*; and more specifically, the idea of *geo-ontology*. The approach taken here builds upon a perspective offered by the post-modern French philosopher Gilles Deleuze. As described by May (2005), Deleuze's perspective on ontology departs from some of his French predecessors; notably, Jacques Derrida and Michel Foucault. He argues that Derrida and Foucault have abandoned ontology on the grounds that it is a hegemonic social construct that is imposed upon society with regard to how things 'should be' in relation to a particular ideological position of those with power. Deleuze agrees with his predecessors on this issue, but emphasizes that instead of abandoning ontology altogether, or locking ontological studies into notions of how things *should be*, he approaches ontology from the perspective of how things *might be*; within the context of a broader philosophical and practical question of '*How might one live?*'.

I simplify these aspects of an *integrative ontology* as interfacing two schools of thought on ontology that are associated with the analytical school in discerning '*what there is*' in reality (however it may be perceived by humans), and the continental school that is focused on discerning '*how things might be*' (based on what humans may value in any given circumstance). Here, I describe this approach to ontology as *common* *ontology*, wherein one does not explicitly define what aspects of reality or the world at large an ontology pertains. I build upon this approach by making explicit what aspects of the world to which an ontology pertains, considering two types of geographical boundary conditions (Figure I-3).

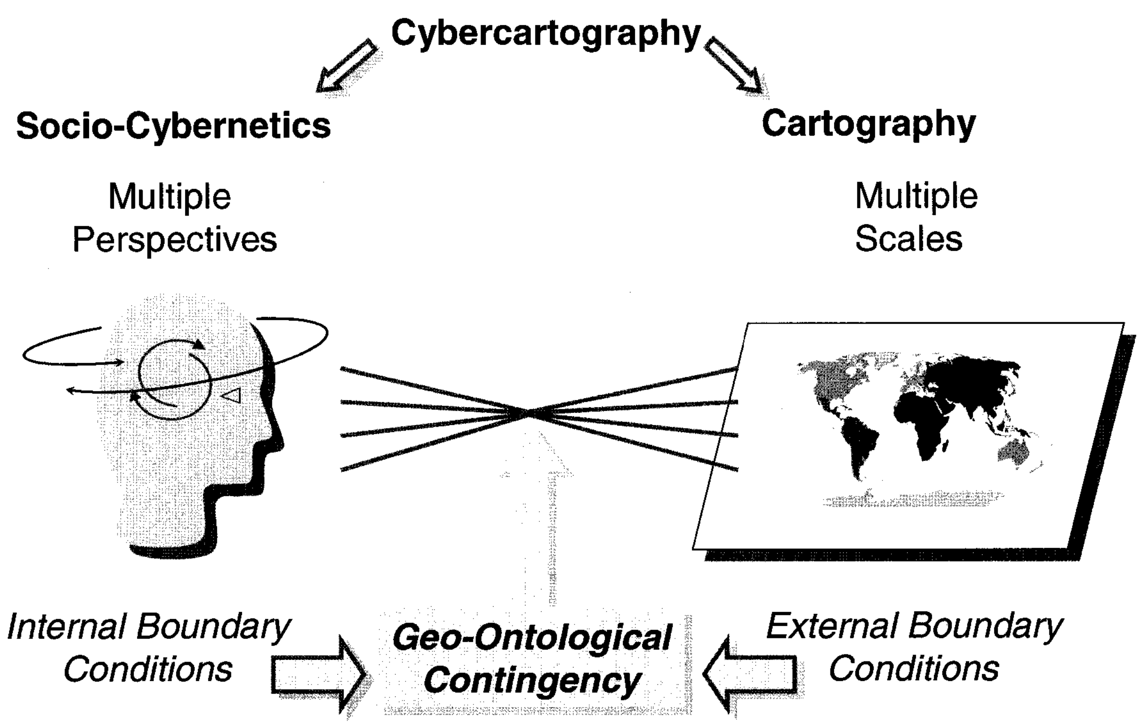


Figure I-3. Graphical illustration of key elements involved in *geo-ontological contingency*: internal boundary conditions perpetrating multiple perspectives, and external boundary conditions projected at multiple geographical scales.

The two ways consider 'internal' and 'external' boundary conditions; wherein internal boundary conditions pertain to human mental processing (thought, reasoning, contemplative and emotional processing, self-identity, etc.), and external boundary conditions that pertain to physical geographical boundaries within which we perceive things to be. Contingency in human thought and knowledge lies in the realization that the same geographical phenomena can be looked at from multiple perspectives, at multiple scales (or *distances* embedded in representation), and be simultaneously *valued differently* according to differences in *circumstance.* Both the world and human perspectives are in constant flux; and my argument here is that *scale* and *spatiality* constitute a fundamental aspect in this contingency in human knowledge; and especially in its influence on *processes of actualization* (being in the world).

In this information era, much of human mental processing is either directly or indirectly influenced by electronic and mass communication media; or what information theorists describe as *cybernetics.* Building upon Taylor's (2003) original definition of *cybercartography*, Martinez and Reyes (2005), and Reyes, et. al. (2006) describe cybercartography as an integration of studies of cartography and socio-cybernetics (Figure I-3). I follow this approach in situating the theory and practice of *cybercartography* in relation to *geographical information science* (GI Science). I affiliate much of the work being conducted in GI Science as proximal with the analytical ontology school with its interest in modelling geographical phenomena in various representational schema; the *what there is* aspect of an integrative ontology. Cybercartography 'transcends and includes' GI Science and systems (Taylor, 2005) by mediating and facilitating our discernment in *how things might be*, with a particular focus on not only providing people with a means to *visualize* and *communicate* geoinformation, but also enabling processes of *realization* and *actualization* (or being in the world). This principal aspect of cybercartography situates GIP more directly at the cyber-human interface, maintaining a focus on the affects that various types of geoinformation have on people and society.

In summary, maps and map metaphors are used in combination to cover these two aspects of an integrative ontology, wherein both internal and external boundary conditions are simultaneously examined in relation to geo-ontological contingency. The approach presented here situates maps and map metaphors in relation to principal domains of GES in two ways as an invitation for integrative studies (Figure I-3):

1. by providing collaborative researchers a space to utilize maps and map metaphors as a means for exploring geo-ontological contingency in research and applications, and

2. by providing an additional map metaphor wherein multiple knowledge domains, disciplines, and areas of specialization may interface in navigating geo-ontological contingency in human thought.

The map metaphor that I bring into this framework is based on the integrative research and writings of Ken Wilber (1995, 1996, 2000, 2002). Wilber's body of work spans several decades (1970s to the present), and is known as *Integral Theory*. Integral Theory is described in several areas among the papers contained in this thesis, and I explore it as one means for situating integrative studies in GES. The base template of Integral Theory is a map metaphor called an *AQAL map*; which is an acronym for *All Quadrants, All Levels*. There are four *quadrants* to the AQAL map (Figure I-4), and I discern three main levels in the model that pertain to Anthropospheric, Biospheric, and Cosmospheric phenomena; which can all be looked at from 1st person, 2nd person, and 3rd person perspectives and associated methodologies.

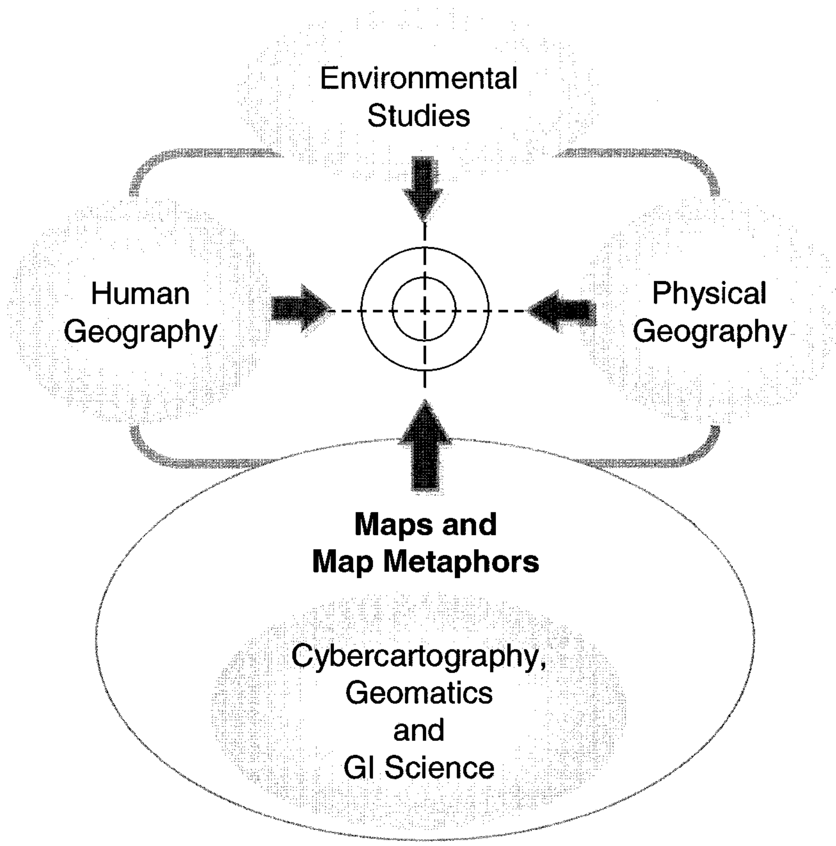


Figure I-4. Situating maps and map metaphors in relation to some of the main domains of Geography and Environmental Studies.

For Wilber, the quadrants represent four basic dimensions of reality from which anything can be studied, and my analysis of his model suggests various methods and sub-disciplines in GES can be situated within this model. I summarize this approach as an A-B-C/1-2-3 approach to integrative and collaborative studies. Integral Theory, the AQAL map, Wilber's philosophy, and my own adaptation of his work is described more fully throughout this thesis. The key elements emphasized in this introduction include a focus on how maps and map metaphors can be used in a GI Science and Cybercartographic context to examine geo-ontological contingency, and also to provide a map metaphor that has ample room for multiple knowledge domains and perspectives to explore and navigate this contingency. The following section provides a road-map through the key contributions made in the four papers contained in this thesis, and a lineage of how I arrived at this framework for integration.

Thesis Outline and Key Contributions

As described above in metaphor (Figure I-1), the relations among specific contributions among the four papers contained in this thesis are the result of a combination of collaborative research activities and my own research and synthesis. The choice of language used in each of the published papers considered different readers; or knowledge communities. Readers will find that the three papers are somewhat different in this regard, yet there are some common elements among them. Part of my aim in Paper D is to illustrate how the key contributions of the three published papers can be: 1) integrated, and 2) communicate a message in a language and style that is accessible to geographers and people outside the discipline. A map of the inter-relations among the key contributions is presented in Figure I-5 and described in Table I-2.

Paper A is the result of several years of research on a GIS-based method for mapping knowledge; in this case, the application involves mapping some aspects of how geologists think about mineral potential when looking at a geological map, and applying their knowledge of mineral potential criteria. In developing this method, and building upon the research of my predecessor Dr. Graeme Bonham-Carter, I felt it was necessary to elucidate a distinction between 'data-driven' (statistical/probabilistic based) methods, from those that are more 'knowledge-driven' (conceptual/deterministic based) methods. As my analysis reveals, in practice, the two are not so easily discernable. I relate them to a non-linear and non-dualistic view of how *induction* and *deduction* are inter-related (A-1). This signifies a shift in thought from a logic of *either-or* reasoning to *both-and* reasoning. A utility of *both-and* reasoning is that it can accommodate *either-or* logic, but restricts its use to situations that are appropriate and discernable. Wilber describes this shift in reasoning as the beginning of a *trans-rational* cognitive structure that he calls *vision-logic*; and he regards this as a presently emerging stage of cognition in humans (but not yet fully formed). One of its principal affects is a shift human thought from relegating answers to questions to distinct crisp bins of *either-or* categorizations; such as yes or no, true or false, body or mind, qualitative or quantitative, or human or environment, etc.

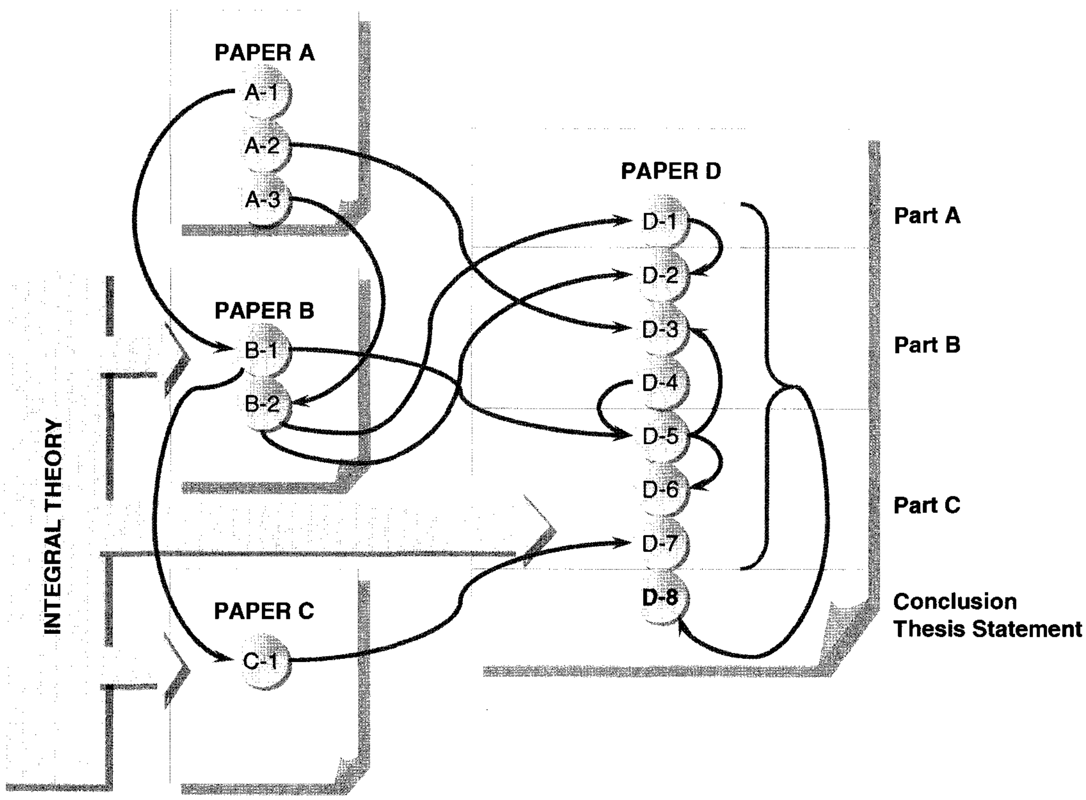


Figure I-5. Lineage chart showing the connections and flow of key contributions in this thesis.

Table I-2. Index and descriptions of key contributions.

Index	Description
	PAPER A
A-1	An argument for the non-linearity and non-duality of induction and deduction in relation to data and knowledge in geoinformation processing.
A-2	Development of a Modified Fuzzy Logic method (FLM) for mapping knowledge and uncertainty at multiple geographical scales.
A-3	An application of the FLM and illustration of the influences of 'societal/user context' and 'geographical boundaries' on geoinformation processing.
	PAPER B
B-1	An analysis and interface between Integral Theory and Information Theory as may be applied to geoinformation and cartography.
B-2	A multi-disciplinary analysis and synthesis in a Cybercartographic Human Interface (CHI) model.
	PAPER C
C-1	Analysis and application of Integral Theory to geography in the concept of Integral Geography.
	PAPER D
D-1	An application and expansion of a triadic model of cartographic theory for use with map metaphors.
D-2	An application of a map metaphor to mapping indicators of wellbeing using the Wellbeing of Nations data and knowledge base.
D-3	Using maps and map metaphors to illustrate how qualitative statements about some aspect of the world are 'geo-ontologically contingent'.
D-4	The design and development of a new cartographic technique for displaying multi-level variation in statistical data called a 'Domino Map'.
D-5	An application of the Holonic Tenets of Integral Theory as a tool for constructive critical analysis using the map metaphor of the Wellbeing of Nations data.
D-6	An application of a map metaphor to the concept of wellbeing called an "Integral Topology of Being".
D-7	A simplified 'A-B-C/1-2-3' conceptual model for Integral Geography.
D-8	Thesis Statement on the use of maps and map metaphors for integration in geography.

In essence, it means we begin to frame difficult questions in a different context. With respect to processes of induction versus deduction, we do not define them as '*induction is the process by which...., .and deduction is a process by which...*'; rather, we ask "*what aspect of any thought process is the deductive element, and what aspect is the inductive element?*" The two are seen not as binary opposites, but as mutually inclusive and inter-twining in any reasoning process. I highlight this contribution because it lays a foundation for a common theme that permeates all following contributions. It is a framework for approaching a *non-dual* frame of mind. It is important to emphasize again, that a paradox of non-dual thinking is that it can include dualistic thinking where necessary, but does not relegate answers to questions into dualistic bins. Most questions and issues in GES require moving beyond dualistic notions, and I believe this is one approach.

Contribution A-2 is a modified fuzzy-logic method that provides a capacity to situate human knowledge along a spectrum of knowledge that includes both dualistic (crisp) categories, and greater room for inclusivity, uncertainty and ambiguity. It is demonstrated by an application for mapping mineral resource potential, and can be applied to mapping knowledge of any geographical phenomena (for which there is mapped data). Contribution A-3 highlights the importance of social or political 'context' within which geoinformation is constructed or constrained. In particular, are issues of *scale* and sometimes arbitrary *geographical boundary conditions* that are imposed upon the process. These three contributions are carried forward in the other three papers in different ways.

Paper B is the result of an opportunity to publish a chapter in Dr. Fraser Taylor's first book on early research results in cybercartography. This work presents the results of my research into a general theory of *information* that takes a different approach than what I have found in most texts on the subject. What I have found is that most theories of information tend to be overly reductionistic in their approach (i.e. highly mathematical), or overly generalistic in that the very word *information* is simply taken for granted. It is at this point where I explore Ken Wilber's *Integral Theory*, in particular, his application of the concept of *holons* (whole-part relationships) and *holarchy* as they may apply to information theory. Contribution B-1 builds upon A-1 by adding and including a third and more significant element to data and knowledge, that of *meaning*. This model suggests that all *information* contains some combination of *data, knowledge,* and *meaning;* and their inter-relations involve non-linear interactions of inductive and deductive reasoning processes at different levels of cognitive and existential functioning. The application of Integral Theory proves to be a useful framework in this regard, as I demonstrate how different views and theories of information emanating from various disciplines can be integrated and synthesized. This synthesis is presented in a 'Cybercartographic-Human Interface' (CHI) model (B-2) that captures what I believe are a minimum number of elements that need to be considered in an information theory model; and in particular, one that applies to geoinformation. The analysis of the influence of societal context presented in A-3 is carried forward in the model presented in B-2.

I treat Paper C as a single contribution (C-1) which is a brief introduction of a framework for *Integral Geography*. Essentially, it presents an approach that integrates essential elements from both physical and human geography, as well as the use of mapping. This paper was published as part of a special issue on *Integral Ecology* in Ervin Laszlo's *World Futures: Journal of General Evolution.* Its readers are general evolutionary theorists, ecologists, and trans-disciplinary practitioners; and Laszlo requested this special issue to provide findings on applications of Wilber's Integral Theory to ecology. The guest editor of this volume is Sean Esbjörn-Hargens (2005); who, along with Micheal Zimmerman (2005), has been researching and developing a knowledge-base and framework for integral ecology. He frames the context of integral ecology in terms of asking 'who, what, and how' of environmental phenomena. These are three principal elements that must be taken into account with humans studying themselves in relation to nature. Their claim is that our knowledge and experience of ecological processes and environmental phenomena depend upon *who* is doing the looking/research, *what* aspects of ecology or the environment are they investigating, and *how* are they probing reality (what methods are being used). His introductory paper to this issue is comprehensive as it covers an introduction to Wilber's AQAL map and framework, and sets a foundation for other contributions in the issue.

The approach that I took in introducing *Integral Geography* was to add questions of *where* and *when* to Esbjörn-Hargens' framework. Considering the target audience, my intent was to outline not only how Integral Theory might be applied to geography (its use *within* the discipline), but to also communicate to others outside the discipline a potential role for geography to their respective fields. Some of the ideas presented in this paper are not new to geographers; perhaps, they barely begin to summarize our vast territory, but it is an attempt to communicate some essential ideas. However, some of these ideas might be considered new to geographers as well, such as a model that I developed that situates various fields of knowledge in relation to three broad realms of geographical enquiry that I identify as Anthropospheric, Biospheric, and Cosmospheric, and their unique inter-relationships when brought together in an integral framework that highlights the unique conditions of *place*. Because Esbjörn-Hargens provides an introduction to Integral Theory in his paper, it is presumed that readers have some basic understanding of it when reading my paper. It is for this reason that I have placed this paper after Paper B in this thesis, which includes an introduction to Integral Theory (B-1), and is sufficient for readers to follow through in Paper C.

Paper D is an integration of the above contributions. It explores the use of maps and map metaphors for integration in GES, using a case study in mapping indicators of wellbeing derived from Prescott-Allen's work in the Wellbeing of Nations (Prescott-Allen, 2001). This is a more comprehensive and integrative paper than papers A-C, and it has three parts: 1) Theory, 2) Application and 3) Praxis. As a theoretical contribution, I build upon the CHI model developed in Paper B (B-2) and situate the use of map metaphors by expanding upon MacEachren's (1995) triadic cartographic model (which in turn is based upon Charles Pierce's theory of semiotic relations). I introduce the concept and utility of a map metaphor using a children's literary classic *The Phantom Tollbooth*, which I hope readers will find as amusing and playful as I have.

In application, I develop a map metaphor for mapping indicators of sustainability and wellbeing using Prescott-Allen's report and data (D-2) by applying the CHI model (B-2) as a basis for the metaphor. The map metaphor is presented as a visual tool for critical analysis, and raises questions about the logic and uncertainties in human thought when exploring comprehensive subjects such as wellbeing. In response to the critical analysis, I build upon Prescott-Allen's assessment framework by offering an alternative qualitative assessment index (D-3) derived from the modified fuzzy logic method developed in Paper A (A-2). The experiments included in that section illustrate more clearly some of the *internal boundary* conditions intrinsic in human thought, and sets a cornerstone for exploring geo-ontological contingency. External boundary conditions are explored by mapping the same indicators at different geographical scales using different spatial data frameworks. Some of the maps presented are conventional choropleth maps, and another is a surface model, which are not new to the GIP community. However, I do present an original type of map that I refer to as a *Domino Map*, and consider it a new contribution (D-4).

The elements of geo-ontological contingency are not new for geographers; what is new here, is making these arguments *explicit* and *visual* with the use of maps and map metaphors as a tool for critical analysis, and as a means for communicating visually why geography matters. It is reasonable to anticipate questions about what to do with geo-ontological contingency; that is, how might people work with it, and what does it mean in real-world applications? One serendipitous discovery I made along this journey was the idea that Wilber's AQAL map can be used as a metaphor for navigating geo-ontological contingency. What it offers is a map-based framework within which there is an intrinsic *vision-logic* language that is intrinsically *spatial* and *topological.* This provides a different context for re-introducing integral theory in Part C, than how it was described in Papers B and C.

There is some repetition of material in Paper D that is covered in Papers A, B, and C. This is intentional, because my aim is to use Paper D as a stand-alone paper, wherein the contributions I bring into it from the other papers are more generally described in the context if its own analysis. My intent is to make all of this material available as an on-line cybercartographic atlas. Content for Paper D would be the main interface, and provide linkages to the elements of the other papers where readers may explore these elements in more detail. This is an example of a hyper-textual non-linear structure for which its main interface will be a map metaphor for navigating the text.

To illustrate another application of the AQAL map, I provide an additional map metaphor that I call *An Integral Topology of Being*. Its main elements are essentially a synthesis of core elements of the AQAL map. I apply the vision-logic in this map to briefly explore a number of contemporary issues in GES; including how we think about the relation between humans and the rest of nature from a physical standpoint, the relation between individuals and collectives in a geo-political context, and questions of identity; and explore some issues in GI Science concerning the use of ontologies in spatial data modelling. I finish by interfacing this discussion with several recent works among other geographers whom I believe are heading in a similar direction in geographical thought. It is from this analysis that I arrive at a concise thesis statement concerning the use of maps and map metaphors for integration in GES.

A long time ago, a man on a track,
Walking thirty miles with a sack on his back,
He put down his load, where he thought it was the best,
Made a home in the wilderness.

He built a cabin and a winter store,
And plowed up the ground by the cold lake shore,
The other travelers came walking down the track,
They never went further, they never went back.

Mark Knopfler,
Telegraph Road.

PAPER A

Mineral Potential Analyzed and Mapped at Multiple Scales: A Modified Fuzzy Logic Method Using Digital Geology

Eddy, B.G[1]. Bonham-Carter, G.F.[2] and Jefferson, C.W.[2]

[1] Geomatics and Cartographic Research Centre (GCRC),
Dept. of Geography and Environmental Studies,
Carleton University, Ottawa, Ontario,
CANADA K1S 2L2
bgeddy@connect.careleton.ca

[2] Geological Survey of Canada,
601 Booth St., Ottawa, Ontario
CANADA K1A 0E8
bonham-carter@nrcan.gc.ca
cjeffers@nrcan.gc.ca

Abstract

Data-driven statistical methods used in Mineral Potential Mapping (MPM), such as weights-of-evidence (WofE), are usually constrained to study areas where there is a sufficient number of known mineral occurrences, complemented by multi-thematic geoscience data sets. However, vast geographical areas remain deficient of this quality and quantity of data; areas for which MPMs are required for regional economic and land-use planning, and mineral exploration. In Canada, such areas of data deficiency constitute over 70 % of the land area, including the Canadian High Arctic and other less explored frontier regions. Requirements often call for MPM at multiple scales, and for different commodities and deposit types. Resource geologists are constrained by data deficiency, and further challenged to adequately accommodate 'uncertainty' in the presentation of results, with a presentation style that is consistent across scales, and concisely informative for multi-disciplinary audiences.

A knowledge-driven, 'modified' fuzzy logic method is presented for MPM at multiple scales using only geological maps (as data) and mineral deposit criteria (as knowledge). Previous applications of fuzzy logic use a 'base 0' approach that restricts application to multi-scale mapping, and conflates areas with rankings of low potential with areas of missing data. This modified method uses a 'base 0.5' approach as an uncertainty 'hinge line' upon which Fuzzy Membership Values may diverge toward the pure end members (where 0=No, and 1=Yes) with increasing certainty depending on the data and knowledge available in a variety of geographical scales. A mock WofE example is used to demonstrate how this 'possibilistic' knowledge-driven method is empirically

consistent with the 'probabilistic' data-driven approach. The method is demonstrated using an application mapping MVT Pb-Zn potential on Bathurst Island, Nunavut, and surrounding areas, at four scales of representation, using four different geological maps. This illustrates the use of fuzzy logic to create MPM in an objective manner that also permits review and iterative modification of the logical steps taken, using different model criteria and assumptions.

Introduction

GIS-based analysis for mineral exploration and research has increased significantly in the past decade. A variety of methods have been developed for preparing mineral potential maps (MPM) with digital geoscience data sets (An, et.al, 1991: Agterberg, et. al, 1993; Bonham-Carter, 1994; Cheng, 1994; Chung and Fabbri, 1993; Constanza and Hale, 2001; Eddy, 1996; Harris, et. al., 2001; Mihalasky, 2001; Wright, 1996). The choice of method often depends on the data available, the scale and scope of the requirements, the commodities or deposit types being modelled, and the type of mineral potential information required. The location and geographical extent of the study area will often influence the choice of method due to the limitations of the data available. It is now known that some methods are generally more successful for more localized study areas for which multi-thematic data are available, and for which modelling the potential for a specific deposit type is the primary objective.

MPMs are also needed for larger regions, such as for reconnaissance exploration, research or land-use planning. In contrast to localized studies, regional geologists are often confronted with sparse, disparate, or fragmented data as well as a paucity of known mineral occurrences from which any consistently inductive analysis might be based. Regional studies may need to assess multiple deposit types or commodities, such as is required in the Mineral and Energy Resource Assessment (MERA) process (Scoates, et. al., 1986).

Exploring and analyzing mineral potential at regional scales requires reconciling constraints imposed by limitations in data and knowledge available for these scales. The ability to conduct detailed field studies and generate new data is often not possible. One means of overcoming these constraints is a modified fuzzy logic approach that can be applied at many scales, to one or many commodities and with as little input data as a single geological map used in combination with deposit model criteria. This approach is introduced in comparison with the weights-of-evidence (WofE) method.

A comprehensive vocabulary describes the two approaches compared herein. The fuzzy logic approach is variously described as knowledge-driven or based (KD); deductive, possibilistic, hermeneutic, and theoretical. The WofE approach is described as data-driven or based (DD); inductive, statistical, heuristic, and probabilistic. Both are effectively rendered in GIS. Throughout this paper, the terms KD and fuzzy logic are used interchangeably, as are DD and WofE.

Outline

This paper is presented in three sections. In the first section, a general context and approach is presented to exemplify some of the more common constraints in producing mineral potential information on regional levels, especially for frontier regions such as in the Canadian High Arctic. We explore general relationships of data to knowledge, and DD to KD MPM as originally outlined by Bonham-Carter (1994). Geographical scale, as well as logistic, political, and other constraints are also explored. The second section presents the basis for a modified fuzzy logic approach using a comparative analysis with a mock WofE example. This comparison demonstrates the principles by which the modified fuzzy logic method is internally consistent with DD approaches. The third section presents a case study that applies the modified fuzzy logic method to mapping MVT Pb-Zn potential in the Canadian High Arctic, using four different geological maps at four different geographical scales, with the same set of deposit criteria. We conclude by discussing potential further development and application of this method.

Context and Constraints in Mineral Potential Mapping

The Use of Geoscientific Information in MPM

In many mineral potential studies the context is critical. The choice of method is often constrained not only by technical or scientific factors relating to data and scale, but also by politics, economics and logistics (Figure A-1). Inter-relationships among these factors vary considerably, and it may be necessary to reconcile conflicting or contradictory information. The differentiation of data and knowledge is not always apparent. This has important bearing on the overall methodology, especially in GIS, so that the choice of method best suits the study requirements. It is therefore necessary to examine more closely how the terms 'data' and 'knowledge' are implied in some GIS-based MPM.

Data-Driven (DD) and Knowledge-Driven (KD) Methods

Bonham-Carter (1994) discussed distinctions between DD and KD approaches to GIS modelling. In the context of MPM, DD approaches make use of known deposits and occurrences within the study area as training sites. KD methods utilize the opinions or judgment of experts who assign weights to various model input factors, and also control the model construction and processing. DD methods are often regarded as more heuristic, objective, or empirical, whereas KD methods are regarded as more theoretical, or subjective. Hybrid methods are those that combine some element of both DD and KD elements, such as when an expert assigns the relative weights based on the results of a weights-of-evidence analysis (Bonham-Carter, 1994).

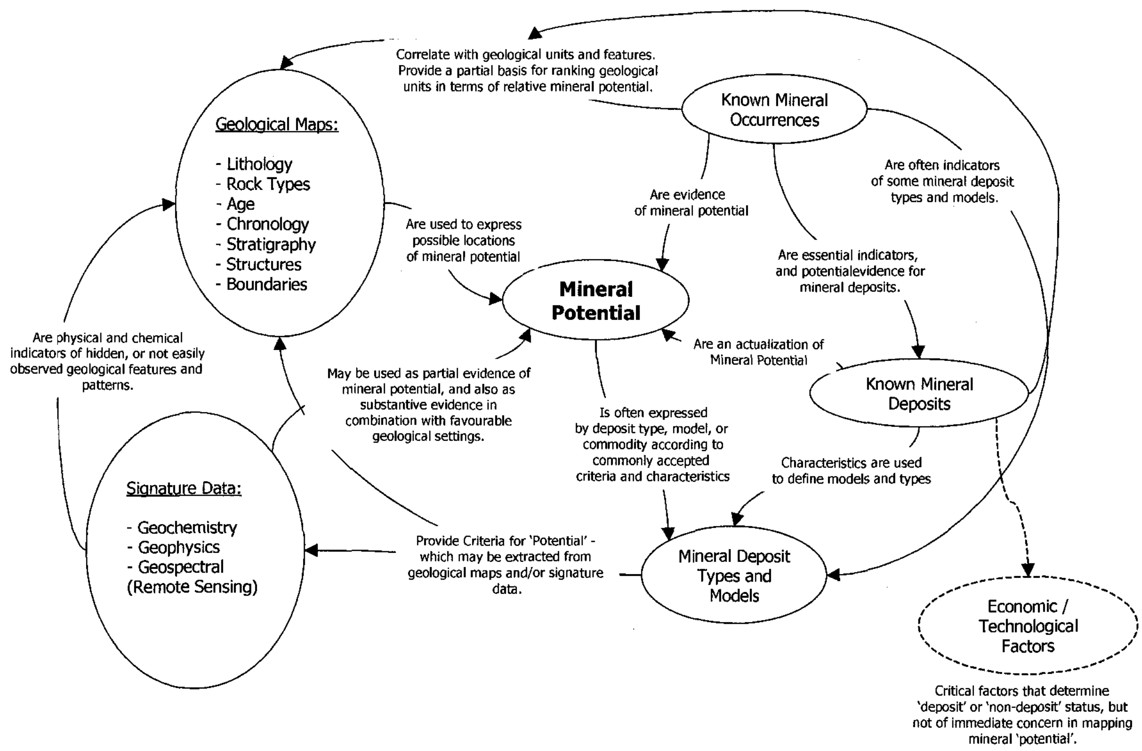


Figure A-1. Subject Relations for geological information in mineral potential mapping (MPM).

DD methods are sometimes favoured over KD methods because they are perceived to be more objective (observer independent), whereas KD methods, being more subjective, are generally perceived to be more prone to bias and error. Such crisp distinctions between subjectivity and objectivity, or the theoretical and empirical dimensions in methodology, begin to dissolve upon a closer examination of data and knowledge flows in both DD and KD methodologies. This has been a source of debate on resource assessment methodology among many resource geologists (IAMG, 1994). Based on the original framework of KD and DD methods (Bonham-Carter, 1994), we here elaborate their mutual relationships so that both can be considered equally valid approaches to MPM.

This framework presented here (Figure A-2) treats data as factual, objective, empirical evidence, and knowledge as subjective, theoretical, or deduced from data. The intrinsic relationship between data and knowledge is viewed here as an iterative cycle. With any methodology, both data and knowledge must be employed, and, neither is considered purely objective or subjective. DD and KD methods are thus distinguished on the basis of which direction the primary information flows during modelling. DD methods rely predominantly on inductive information derived from statistical relationships among locations of known mineral deposits and geological patterns - this is considered here as 'bottom-up' information flow (exploratory, discovery = heuristic). KD methods rely predominantly on deductive information influenced by the degrees of association between geological attributes in the study area that are assigned by an expert to deposit model criteria, and are considered here as a 'top-down' information flow (interpretation = hermeneutic) that requires specialized expertise for each deposit type. Hybrid methods incorporate both inductive (statistical/heuristic) and deductive (interpretive/hermeneutic) information flows.

In this context, all mineral potential maps are outputs of some combination of data and knowledge. In this hierarchy, knowledge supercedes data, and is therefore considered higher or more abstract than data. DD approaches are often preferred because local empirical elements (e.g. WofE statistics) as well as broader theoretical elements (e.g. global mineral deposit models) can be jointly considered. Comparisons of

DD and KD approaches have revealed strong agreement (Wright, 1996; Harris, et. al. 2001) when the same modelling criteria and data are used.

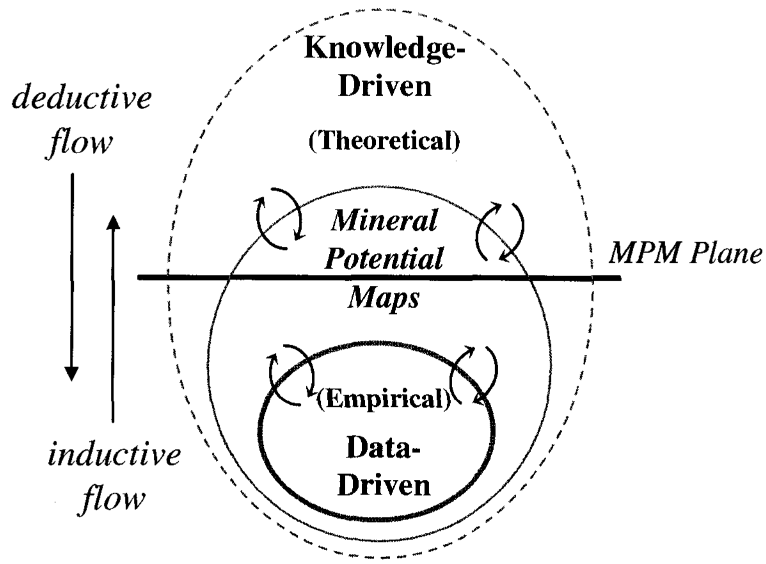


Figure A-2. Some of the main elements relating data and knowledge in producing mineral potential maps (MPMs).

Examining Regional Level Constraints

Rigorous DD approaches can rarely be employed in regional mineral potential studies. DD approaches are more likely to be successful in regions where there are a statistically sufficient number of known mineral occurrences of similar type within a defined study region. In Figure A-3, such regions correspond to the darker tones (more dense regions). Depending on the commodity and relative spatial density, DD methods might be successful in some of the less dense regions, but less so in regions of sparse known occurrences (less than 1 occurrence per 1000 km^2).

Sparsity of mineral occurrences constitutes only one constraint in DD modelling. The distribution and resolution of other geoscientific data, such as geochemistry, multi-parameter geophysics, and mineralogy generally coincides with the density of mineral occurrences. It is expected that studies conducted on more local scales, in areas of higher known occurrence density, will also benefit from the availability of multi-thematic geoscience datasets. Multi-thematic geoscience data tend to be sparse in regions of few mineral occurrences . This results in part from the logistical and economic constraints of distance and climate on speculative data collection and exploration.

It is often within regions of sparse data where mineral assessments are required, especially for regional land-use planning, or grass roots exploration. Discovery of diamonds in the Northwest Territories and the Ni-Cu deposit at Voisey's Bay in Labrador are recent examples of previously unrecognized high mineral potential in both well explored (dense) and relatively less explored (sparse) regions of Canada. Assessment of mineral potential of these regions is critically constrained by the non-uniform mineral occurrence and availability of multi-thematic data sets. Generally, the only consistently available information is reconnaissance level geology. Such maps, when used in combination with specific data compilations, and written reports for the region, often constitute the starting point in estimating mineral potential of frontier regions, by comparison against provincial to global criteria for each commodity or deposit type being assessed. In the case of the MERA process (Scoates, et. al., 1986), all deposit types in the Geology of Canadian Mineral Deposit Types (Eckstrand, et. al., 1995) must be considered, as well as any additional types or commodities that may be known locally but are not formally included in the literature.

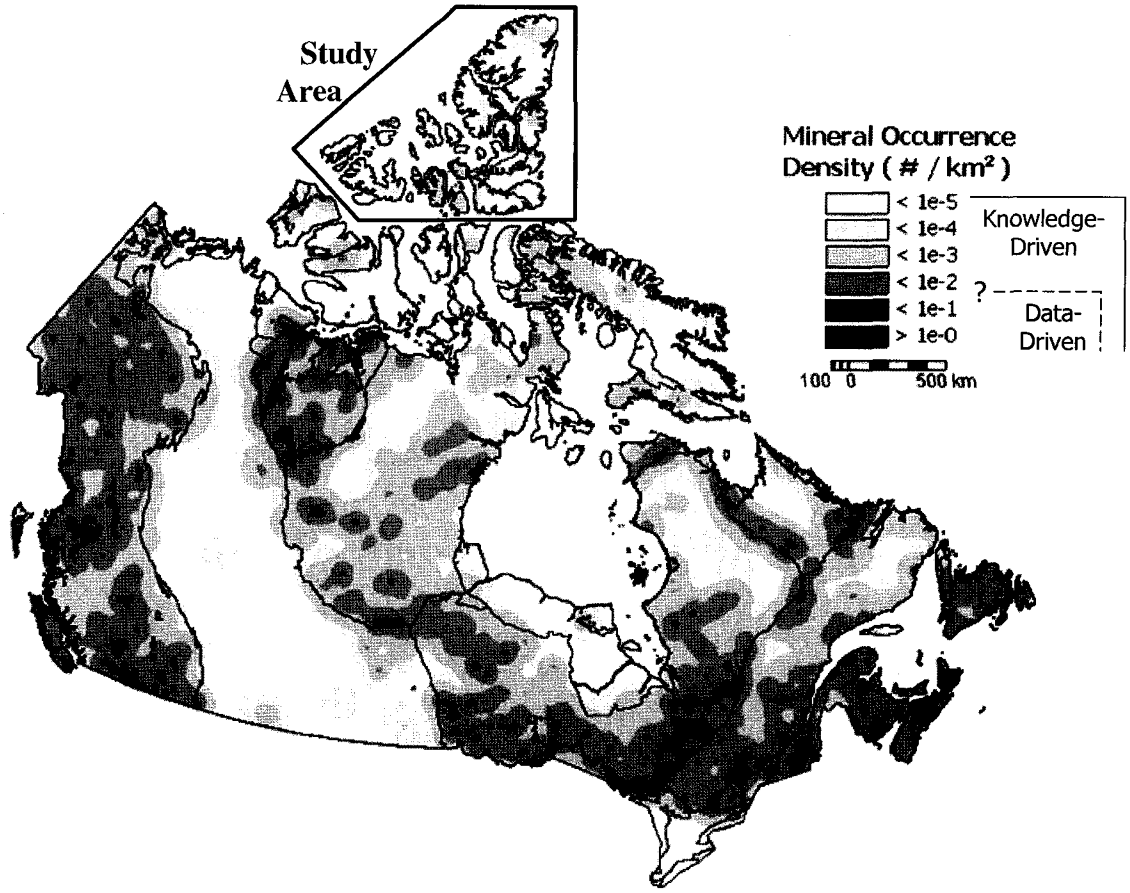


Figure A-3. Density contoured mineral occurrences for Canada from the CANMINDEX database (Picklyk et al. 1978; R. Laramée, pers. comm., 2000). Mineral potential estimation approaches are suggested relative to density. Note: legend shows occurrence density as the number of occurrences per km^2 (e.g. 1e-3 = .001 occurrences/km^2).

A number of complex inter-relationships within the information base must be iteratively analyzed for each commodity and each location under question. Such a task can become laborious for geologists working under tight project constraints. Whether or not mineral potential can be mapped depends very much on the key criteria that characterize a deposit type (i.e. if they are mappable criteria), as well as whether any evidence for these criteria can be derived from geological maps and reports available for the study region. The use of the term 'potential' will have different meanings in different contexts, and the geologist must state the context in which potential is assessed. This is especially true for results directed at non-geologists such as land-use planners, local communities, policy analysts, educators and politicians.

Defining study area boundaries is particularly important in calibrating DD methods such as weights-of-evidence (WofE), because statistics derived from area measurements are sensitive to configuration and aerial extent. In the early stages of a mineral potential study, it may not be known which specific locations, commodity types, policy or economic interests will be of interest. For example, in the MERA process, planning new national park boundaries has frequently shifted attention between different proposed sub-regions within the national plan or within a park region. For reconnaissance exploration, a company may change its interests in exploring one or more sub-areas of a larger region. For these reasons, requirements for a strong GIS method for frontier MPM differ significantly from those of local, information-rich areas. The level of requirements and methodology are, in general, inversely related to map scale (Figure A-4).

Regional level mineral resource studies may examine multiple commodities (MERA) or single commodities (policy/economic analysis or commodity-focused industry), but generally use few input layers. In both situations, geological compilation maps, and their derivatives (e.g. metallogeny, proximity measures, etc.), combined with deposit criteria, are the primary data for regional mineral potential analysis. Conversely, local mineral potential studies tend to focus on fewer commodities and benefit from multi-thematic geoscientific data sets. These inverse relationships also reflect the natural tendency for a greater diversity of deposit types to occur over larger regions, versus more limited diversity within smaller metallogenic domains (although diversity is also related to other factors such as lithological diversity (Griffiths, et. al. 1980, Mihalasky and Bonham-Carter, 2001).

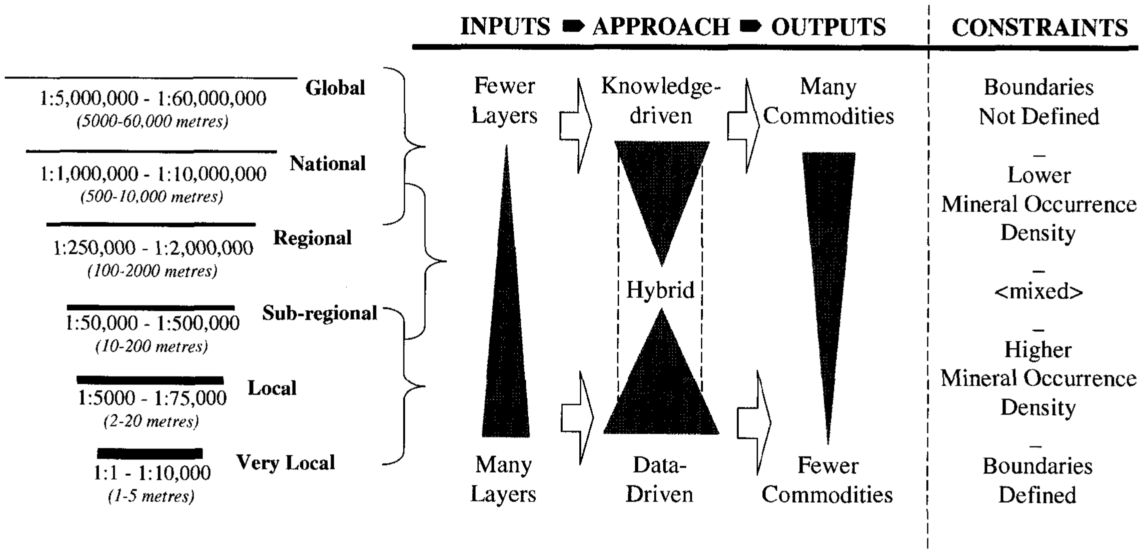


Figure A-4. Relationships between resource assessment requirements, methodology and map scale.

Reconciling these inverse relationships is paradoxical and challenging. Sparse regional data sets force simplicity and use of national to global models. Complex and dense local data sets provide more spatial evidence in relation to specific deposit model criteria, and provide more latitude in experimenting with data, leading to a higher number of possible outcomes (e.g. Harris, et. al. 2001). Regional mineral potential maps may provide a more reproduceable portrayal of mineral potential than what might be expected in local assessments.

This paper focuses on methods for sparse regional data sets, but their application to local multi-thematic data sets is not precluded. In fact, the method is devised such that it must also function at more local levels. To summarize, the principal aims for this methodology include:

- Application to MPM of sparse data sets at regional to global scales, but amenable to incorporate additional data .
- Capability to inter-relate geological features and patterns presented in geological maps (data) with deposit model criteria (knowledge).
- Application at different scales, such as for a compilation of geological maps at different original scales, using the same set of deposit model criteria.
- Provision of a cartographic presentation style that allows geologists to generate appropriate contexts in the portrayal of mineral potential to different audiences.
- Consistency, both theoretically and empirically, with DD methods.

Approach and Methodology

Although the requirements and constraints for regional level MPM appear diametrically opposed to those on the local level, it is important that approaches to each are consistent. This will facilitate integration of local studies nested within regional studies ('zooming in'), as well as expanding local studies across larger regions ('zooming out'). As discussed previously, it is necessary to ensure the compatibility of the fuzzy logic (KD) and weights-of-evidence (DD) methods.

The starting point in any MPM study is a question such as: "*What is the potential for commodity 'Z' at all locations within the study area?*". In cases where mineral occurrences are known, there is an *a priori knowledge of potential*, but without such knowledge, the initial response would be complete uncertainty, perplexity. It is not until data and knowledge are collected that geologists can begin to answer the question. MPM aims to reduce the uncertainty of the answer. The fuzzy logic method produces a relative favourability map within the study area. The weights-of-evidence method aims to produce probabilities of occurrence per unit area that identify areas of higher and lower chances of success in locating a deposit, in relation to a prior probability that is calculated using the known deposits within the study area.

The KD (fuzzy logic) and DD (WofE) methods thus have similar beginnings. These two approaches use different information flow paths, and the types of starting point uncertainties are different. Figure A-5 illustrates some of these relationships using terms derived from the fuzzy logic and WofE methods as reference. The initial WofE calculation is 'a prior, unconditional probability' (representing an '*a priori*' argument), and all subsequent probability calculations are updates on the prior, conditional on the spatial evidence. The method adds various geo-data layers to analyze statistical relationships between occurrences and geological patterns, and where similar relationships exist in the areas without occurrences by producing a 'posterior probability'. There can be both increasive (higher relative potential) and decreasive (lower relative potential) posterior probabilities relative to the prior, and the response map provides the statistical chances of finding a deposit at each location in the study area.

It follows that in a KD methodology, the aim is similar, only in this instance, there may not be a sufficient number of occurrences within the study area to derive a satisfactory statistical relationship, and therefore, there is no *a priori* basis to use as a starting point. Even if there are several known deposits, projecting the mineral potential for the remainder of the study area is problematic for both DD and KD methods because the representativeness of those few occurrences in a large region may be poor.

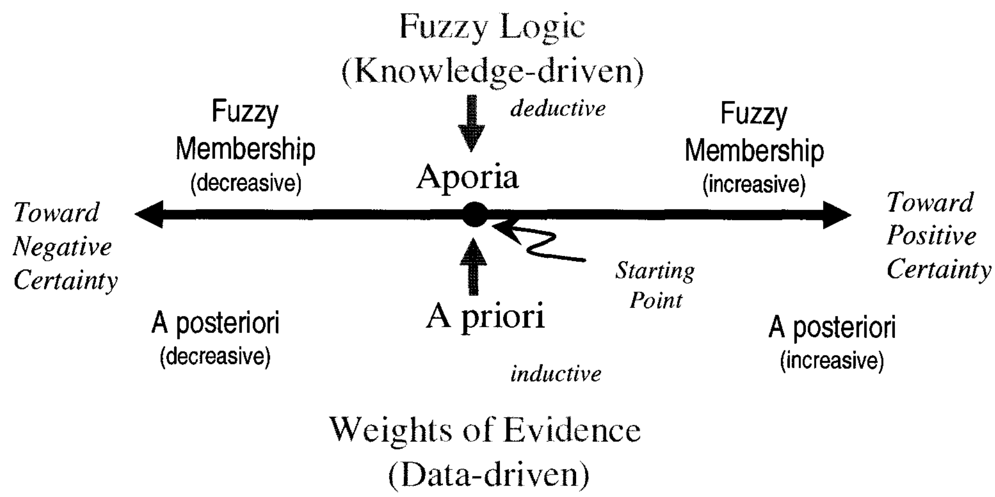


Figure A-5. Relationships between knowledge driven and data-driven methods of MPM, exemplified by fuzzy logic and WofE respectively. The horizontal line represents the MPM plane. See text for discussion.

The KD starting point is a different form of uncertainty, or perplexity, referred to here as '*aporia*', which is a Greek term meaning 'perplexity, complete uncertainty, or two diametrically conflicting truth claims' (Crisp, R. 1999). The terms 'certainty' and 'uncertainty' take on different contexts in deductive and inductive reasoning processes, and therefore the notions of '*a priori*' and '*aporia*' further distinguish the starting points in the DD from KD methods. In comparison to WofE, fuzzy logic aims to reduce *aporia* by discerning between increasive and decreasive 'Fuzzy Membership' of the locations in the response map, to assess the potential for Z at each location.

To address the multi-scale requirement, and to illustrate the inversion between requirements and scale (Figure A-4), we first examine the effects of scale and information detail on the results for each method. Increasing scale tends to improve geological detail, enabling geologists to reduce uncertainty about the spatial evidence. Improved detail will have similar effects on both KD and DD methods by providing some degree of certainty at the starting point (i.e. not *aporia*). The following WofE experiment illustrates the effect of detail. We then show how the level of detail is incorporated in the modified fuzzy logic approach..

A Multi-Scale Experiment in WofE

A WofE experiment was created using a set of random mineral occurrences, and geological maps at three different scales (Figure A-6, Table 1). Map A (Figure A-6) represents a 1:1,000,000 compilation with three primary geological units at the Group level (Gp), Map B represents 1:250,000 geology sub-dividing units at the Formation level (Fm), and Map C represents 1:100,000 geology sub-divided to the Member level (Unit). WofE provides two types of weights (W+ and W-) (Bonham-Carter, 1994), and associated variances.

For the purpose of this experiment, the W+ values will suffice. W+ is the strength of positive association between occurrences and geological units. The full range of W+ values for each map is presented, which provides an indication of the range or variance of W+ values for each of the three maps. The W+ values are centered upon 0.0, which on this logit scale represents neutral evidence that is neither positive nor negative (i.e. lacking predictive power).

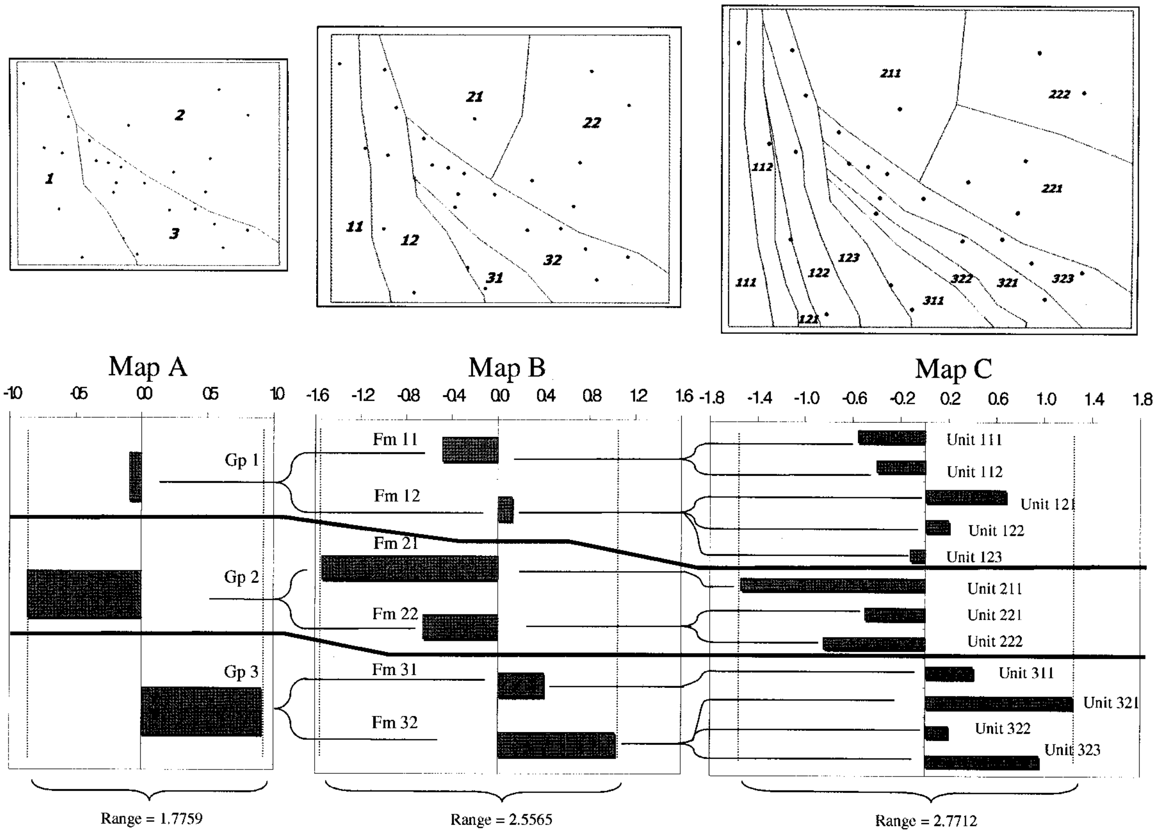


Figure A-6. A multi-scalar experiment in WofE using random mineral occurrences sampled by geological maps at three scales. Data generated for the graphs is listed in Table A-1.

For Map A, the weights indicate a strong positive association for Gp 3, a strong negative for Gp 2, and a weaker negative association for Gp 1. The results for Maps B and C illustrate the effect of increasing map scale on differentiating positive and negative associations and their W+ and range values. In Map B for example, the subdivided values for Gp 1 differentiate the moderate negative influence of Fm 11 from the weak positive influence of Fm 12 that produce the overall weak negative association of Gp 1. Further detail in Map C differentiates moderate and weak positive associations for Units

121 and 122 from moderate and weak negatives for Units 111, 112, and 123. Similar analyses can be made for Gp 2 and 3.

Table A-1. Numerical results for a multi-scale experiment in WofE using random mineral occurrences sampled by geological maps at three scales. See Figure A-6 and discussion in text.

MAP A

GroupID	Area(km^2)	Points	W+	Range*
1	226.7789	7	-0.0906	1.7759
2	415.7244	6	-0.8676	
3	188.4403	15	0.9083	

MAP B

GroupID	FormID	Area(km^2)	Points	W+	Range*
1	11	95.0570	2	-0.4840	2.5565
1	12	131.7219	5	0.1235	
2	21	134.8799	1	-1.5409	
2	22	280.8445	5	-0.6543	
3	31	40.4229	2	0.4006	
3	32	148.0174	13	1.0156	

MAP C

GroupID	FormID	UnitID	Area(km^2)	Points	W+	Range*
1	11	111	51.1287	1	-0.5585	2.7712
1	11	112	43.9283	1	-0.4035	
1	12	121	15.6323	1	0.6728	
1	12	122	49.2338	2	0.1941	
1	12	123	66.8557	2	-0.1229	
2	21	211	134.8799	1	-1.5409	
2	22	221	145.2067	3	-0.5026	
2	22	222	135.6378	2	-0.8459	
3	31	311	40.4229	2	0.4006	
3	32	321	75.0350	8	1.2303	
3	32	322	24.6959	1	0.1908	
3	32	323	48.2864	4	0.9517	

** Note: Total range of W+ values for each map.*

This experiment reveals the effect of increasing map scale on WofE results (Figure A-6). First is the general increase in the strength of the weights as indicated by increasing individual W+ values, which is also reflected in the total range values progressively through maps A to C. Second, sub-units differ spatially and in the increasing values of their relative weights. The strongest positive associations are in Fm 32 (1/3 of Gp 3) and subsequently in units 321 and 323. Although a weak negative association was revealed for Gp 1 in Map A, its Unit 121 has a moderately strong positive correlation (Map C).

To summarize, in the logit scale of W+ values, a zero (0.0) value represents the prior probability (*a priori*). Empirical evidence reveals the ability to better differentiate between positive and negative associations relative to the prior. A similar effect would need to be considered in KD approach. The following section discusses how the fuzzy logic method can be used similarly to map mineral potential at various scales.

A Multi-Scale Approach Using Fuzzy Logic

A brief introduction to the fuzzy logic method is provided as background to its multi-scale application. Fuzzy theory is traced back to Zedah (1965) as a means of accommodating uncertainty in computation and information representation, notably with respect to decision support systems (DSS). Elements of DSS contain embedded knowledge in programming scripts that incorporate many types of 'If, then, else' statements. For example, the general structure of such a script is expressed as:

```
If {condition} (is 'Yes')
        Then {do something}
        Else (if condition is 'No/False')
        {do something else}
End.
```

In many decision support environments, it is not always easy to determine with certainty the conditions of the statement. For example, consider the data for a group of trees presented in Table 2. Suppose a script is needed to perform a classification of each tree according to whether or not it was 'tall', based on reading the height values in the table. Tallness can be a subjective judgment and difficult to program depending on how it is defined in the DSS. This can be resolved by assigning additional values for each tree record (e.g. Table A-2). In one column of Table A-2, a binary value, $\mu_b(x)$, is used to indicate whether or not each tree is tall. Although it is generally more obvious for the tallest and shortest trees in the list, trees with moderate height values are more problematic to resolve. In this binary representation, a 23 ft. tree is classified the same as a 10 ft tree, a clearly unsatisfactory representation for this subject matter.

Table A-2. Three ways of numerically representing 'tallness' of trees as an example of fuzzy logic membership assignment. Knowledge categories as discussed in text are: $b(x)$ - binary, $u_0(x)$ -fuzzy theory, and $u_{0.5}(x)$ - modified fuzzy theory.

Primary Data		Knowledge ('tallness')		
Tree	**Height (x)**	μ_b**(x)**	μ_0**(x)**	$\mu_{0.5}$**(x)**
Maple	23 ft.	1	0.95	0.95
Poplar	~ 10 ft.	1	0.35	0.65
Pine	4'6-1/2"	0	0.18	0.42
Shrub	2 ft	0	0.05	0.05
Fir	{missing}	null	0.00	0.50

In contrast to the classical, or binary form of representation, where objects must be either '0' or '1', fuzzy theory allows a gradation of values in the [0,1] interval, to indicate, for example, the degree to which the height of each tree corresponds to the notion of tallness. The [0,1] interval represents a range from non-membership (0) to full-membership (1). As illustrated in Table 2, $\mu_0(x)$ provides a more flexible means of representing tallness.

Furthermore, data might be missing for some trees, (e.g. height for Fir). In the $\mu_0(x)$ set of values, the Fir is assigned 0.00 (it could be another value such as a weighted mean of the set). This approach to assigning fuzzy membership values was introduced for MPM by An. et al. (1991) and incorporated by Bonham-Carter (1994), Eddy (1996) and Wright (1996) among others. Generally, a value of '0' (non-membership) is equated with low favourability, or low compliance with the proposition, whereas a '1' (full membership) is equated with high favourability. If a linear model is applied, a value near 0.5 would be considered moderately favourable (Figure A-7). This approach is valid for applications where the data are relatively similar in scale and quality. However, it is constraining for applications that require the analysis and presentation of mineral potential at multiple scales and contexts.

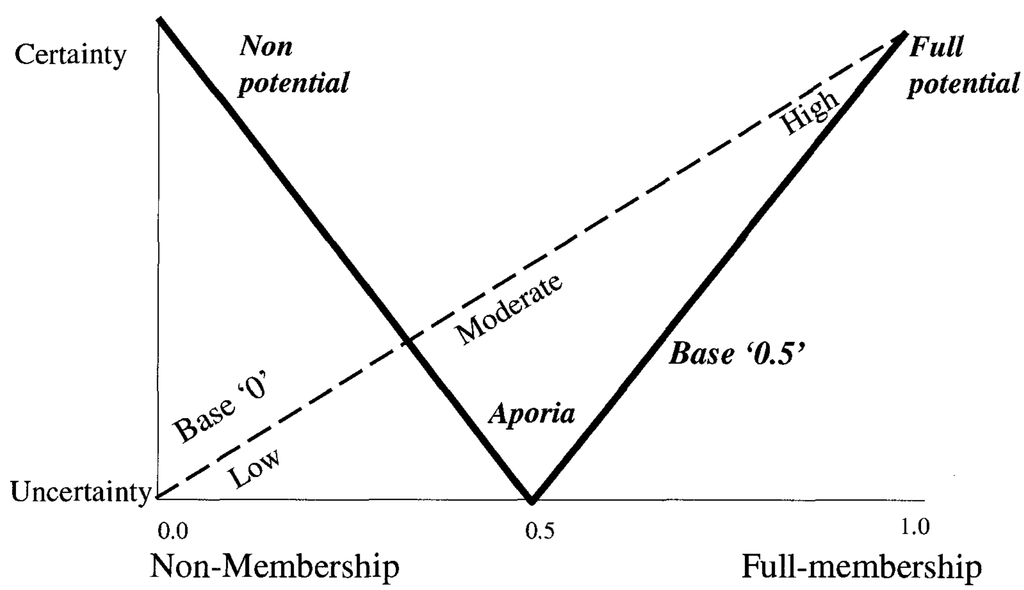


Figure A-7. Classification of membership for fuzzy logic applications, using Base '0' (dashed line) vs Base '0.5' (heavy solid line, modified fuzzy logic).

The modified fuzzy logic approach (also Figure A-7) considers the end-members of the [0,1] interval as pure certainty (*non-aporia*). The mid-point, 0.5, represents *aporia* - high uncertainty with no answer. The '0' and '1' end-members correspond to either a 'No' or a 'Yes', (False or True) with respect to the proposition "*There is potential for commodity Z at location x,y*". In other words, values approaching '0' do not just indicate low favourability, they further indicate the certainty of 'No potential', and conversely, values approaching '1' strongly indicate 'Yes, there is high potential'.

The modified fuzzy logic evaluation scale thus rates favourability as a continuum of values, as well as representing uncertainty. In this scheme, low favourability falls in the 0.5 to 0.65 range, because favourability in the positive sense is in the 0.5-1 range. The values in the 0.0-0.5 range, do not represent low favourability per se. Instead, they represent non-favourability, or no potential with varying degrees of confidence. This approach is represented in Table A-2, where the fuzzy membership values assigned to each tree using the Base 0.5 approach ($\mu_{0.5}(x)$) are different than those for the Base 0 ($\mu_0(x)$), with respect to the proposition *tallness*.

The benefits of this approach for multi-scale application are two-fold. First, setting a 0.5 value as maximum uncertainty (*aporia*) provides an anchor point from which geologists can assign fuzzy membership values to spatial evidence, in both positive and negative directions. Geologists can determine an appropriate range of values that are permissible with each source map used, following the general guideline that with increasing spatial evidence (associated with factors relating to scale and information quality), and the range of fuzzy membership values can expand accordingly. *Aporia* provides a common starting point for each piece of evidence, and makes it easier to assign values with greater consistency.

Second, missing data can be represented with the 0.5 value, as opposed to a 0.0 value, or a relative weighted mean value. In the Base 0 approach, attributes that are judged as low potential can be conflated with instances of missing data. In this modified method they are more clearly differentiated (Table A-2). Approaches that use a relative weighted mean value are problematic for multi-scale data sets because these values will vary from one scale (or source map) to another. Hence, the 0.5 value can be used consistently with maps of multiple scale (and information detail), and as a starting point for both missing data, and for data that remains completely uncertain.

This modified approach to fuzzy logic is ideally suited to mineral potential mapping (MPM) in consideration of the various types, levels of resolution and scales of available data. The inverted relationship between data and scale (Figure A-4) is combined with the empirical results of the WofE experiment (Figure A-6) to guide the assignment of fuzzy membership ranges at different scales (Figure A-8). As in the WofE (DD) approach, the horizontal scale represents a relative favourability legend for the results. Values assigned to features derived from regional geoscience data, such as compilation maps, can be narrowly confined within the middle range of the [0,1] interval. If higher resolution data are used, values can be assigned to broader range in the [0,1] interval to indicate a better match between the proposition (knowledge) and the evidence (data).

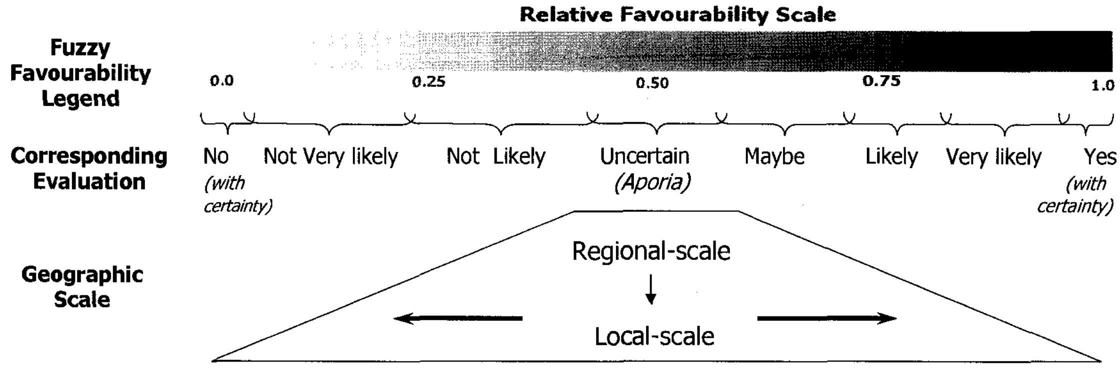


Figure A-8. Guideline for the assignment of fuzzy membership ranges at various scales.

It is worth noting that spatial scale is only one factor that affects the detail of information on geological maps. Geologists will need to consider other factors (such as lithological diversity, cartographic detail, etc.) while establishing appropriate scale ranges for each source map used. To help illustrate the scale effect, Table A-3 provides fuzzy membership values that correspond to the maps used in the above WofE experiment. The effects of increasing scale on empirical results are incorporated. The values for Map A range from 0.37 to 0.63, Map B: 0.26 to 0.68 , and Map C: 0.14 to 0.83. Some values in Map C remain very close to the 0.5 zone of *aporia*, reflecting the relative uncertainty of the values for these units in Figure A-6. This illustrates that increasing resolution, while improving differentiation and certainty in many cases, may not do so for some units, even at local scales.

Table A-3. An example of fuzzy membership values assigned to W+ values used in the WofE experiment (Figure A-6, Table A-1).

Regional $\longrightarrow$ Local

Group	$\mu_{0.5}(x)$	Formation	$\mu_{0.5}(x)$	Unit	$\mu_{0.5}(x)$
1	0.48	11	0.44	111	0.41
				112	0.45
		12	0.53	121	0.62
				122	0.52
				123	0.47
2	0.37	21	0.26	211	0.14
		22	0.41	221	0.43
				222	0.33
3	0.63	31	0.56	311	0.56
		32	0.68	321	0.83
				322	0.53
				323	0.72

The assignment of fuzzy membership values using the Base 0.5 approach represents only the first step in the fuzzy logic method. The next steps involve: (i) more detailed analysis of multiple criteria; (ii) analysis of evidence derived from geological data represented at multiple scales, and (iii) calculation of a map result based on a combination of all evidence available through the use of an inference model. These elements of the method are presented in more detail below. To summarize, the Base 0.5 approach presented here allows empirical (DD) and theoretical (KD) approaches to be more easily aligned, and to be applied at multiple scales. This is similar to other approaches that treat the mid-point on the [0,1] interval as a hinge-line (Burrough and McDonnell, 1998). The following section describes in more detail how this method is applied in mapping MVT Pb-Zn potential in the Canadian High Arctic.

Application to Multi-Scale MPM

The modified Fuzzy Logic method was applied in mapping the potential for MVT Type Pb-Zn in the Canadian High Arctic using four different geological maps compiled at four scales. The principles of the three-step process are first illustrated for part of the larger study area, then employed at four scales.

Step 1. Setting the Context – Model Criteria

A small sub-set of data were extracted from a digital geological map from Bathurst Island, Nunavut, in the Canadian High Arctic (Harrison and de Freitas, 1998). This subset is presented in Figure A-9, with corresponding map results, to illustrate one specific representation of mineral potential for MVT-Type Pb-Zn, using a criteria statement simplified from Sangster (1995) as follows: '*The mineral potential for MVT Type Pb-Zn will occur in locations occupied by platform carbonate rocks, and especially where these rock types exist in close proximity to unconformities or faults*'.

Step 2. Building Content – Providing the Evidence

Four sub-themes were extracted from the source geological map: 1) rock units, 2) proximity to unconformities, 3) proximity to faults associated with the Cornwallis Fold Belt (CFB), and 4) proximity to faults associated with the Parry Islands Fold Belt (PIF). The weighting for each evidence theme is represented by the columns of fuzzy membership values assigned to the class categories (Figure A-9).

Unit #	Abbrev.	Unit Name	Value
16	DPI2	Parry Islands Fm. Member 2	0.05
18	DBE	Beverly Inlet Fm. (undivided)	0.05
21	DHB	Hecla Bay Fm.	0.05
23	DHB-l	DHB Lower part	0.05
24	DBI	Bird Fiord Fm.	0.25
26	DBL	Blue Fiord beds (undivided)	0.75
31	DE	EIDS beds	0.25
35	DDB	Disappointment Bay Fm.	0.68
37	DPA	Prince Alfred Fm.	0.05
38	DPA-c	DPA c-facies	0.30
39	DPA-r	DPA r-facies	0.30
40	DPA-s	DPA s-facies	0.30
41	DG	Goose Fiord Fm.	0.30
44	DBA-s	DBA s-facies	0.50
45	DBA-c	DBA c-facies	0.57
48	DBA-l	DBA l-facies	0.30
49	SDBA-o	SDBA o-facies	0.05
50	DBA-t	DBA t-facies	0.05
53	SDDI	Devon Island Fm. (u. Sil/l. Dev)	0.25
54	OSCP	Cape Phillips Fm.	0.65
56	OCI	Irene Bay Fm.	0.85
57	OCT	Thumb Mtn. Fm.	0.85
58	OCB	Bay Fiord Fm.	0.63
ID	Abbrev.	Proximity to Unconformities	Value
1	100	100 metres	0.70
2	200	200 metres	0.60
3	500	500 metres	0.40
4	1km	1000 metres	0.10
5	2km	2000 metres	0.05
6	g2km	> 2000 metres	0.02
ID	Abbrev.	Proximity to CFB Faults	Value
1	100	100 metres	0.85
2	200	200 metres	0.80
3	500	500 metres	0.65
4	1km	1000 metres	0.30
5	2km	2000 metres	0.20
6	g2km	> 2000 metres	0.10
ID	Abbrev.	Proximity to PIFB Faults	Value
1	100	100 metres	0.65
2	200	200 metres	0.60
3	500	500 metres	0.40
4	1km	1000 metres	0.30
5	2km	2000 metres	0.10
6	g2km	> 2000 metres	0.05

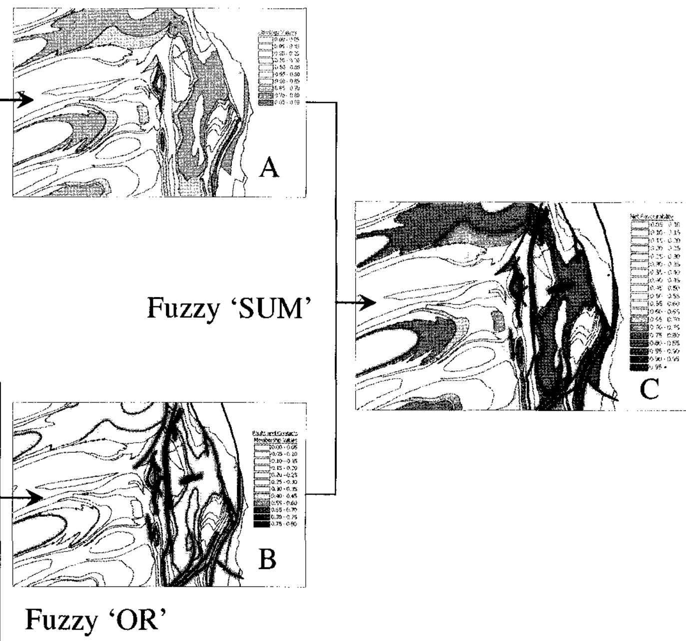


Figure A-9. Example of a fuzzy inference modelling process using a sub-area of Bathurst Island.

Each geological unit, and each proximity class interval is assigned a membership value, following the Base 0.5 approach outlined above. Geological units that are determined to be not carbonate, or not platform carbonate related, are assigned values close to 0.0, whereas geological units that are carbonates, or especially identified as platform carbonates, are assigned weights closer to the 1.0 end of the scale. Units for which such a clear distinction cannot be made are assigned values near the 0.5 value. For example, the value of 0.85 assigned to the Irene Bay and Thumb Mountain units indicates that these units are highly likely to contain platform carbonates suitable for hosting MVT Pb-Zn deposits. Conversely, the value assigned to the Bird Fiord Fm. (0.25) indicates this unit is not likely to include favourable strata. No pure values are assigned to any unit because the modeller judged that uncertainties exist between the criteria statement and the map unit description. For example, some units might be described as simply carbonates, some as platform succession rocks, some as carbonates within shales, or shales associated with platform carbonates. These words and their connotations do not exactly match the words "*platform carbonate rocks*" in the criteria statement. At most, the modeller can infer an association between the criteria and the geological descriptions provided in maps and reports, but such units are generally assigned moderate values in the 0.60-0.70 range to indicate the degree of association.

The spatial relationships between the geological units and linear features, such as faults and contacts, are established using three proximity maps. The values assigned to the proximity intervals increase with closeness to the respective feature, and also follow the Base 0.5 approach. Values higher than 0.50 represent increasing closeness, whereas values less than 0.50 represent increasing 'not closeness'. The distance interval used to represent *aporia* generally depends on the opinion of the geologist but might be derived empirically. The actual values assigned among the three maps indicate the relative importance of each type of linear feature based on the model criteria. In this example the values assigned to the PIFB faults are significantly less than those assigned to the CFB faults which were differentiated by orientation and location. CFB faults occupy the eastern portion of the area and are predominantly N-S oriented, whereas PIFB faults occupy the western portion of the area and are mostly E-W oriented. The intersection between the two belts is structurally complex (north-south zone at the centre of maps in Figure A-9). Some CFB faults may be syngenetic to uplift of the platform carbonate units, an important local factor for Pb-Zn mineralization (Anglin and Harrison, 1999).

The PIF faults are associated with a later event, and are considered to be less important for MVT Pb-Zn, but not exclusive.

Step 3. Modelling Mineral Potential

The evidence themes are then combined so that they accurately reflect the criteria statement. In Fuzzy Logic and expert systems, this is termed *inference modelling*. Figure A-9 illustrates a three part inference net for the calculation of Map C from Maps A and B. Fuzzy Combination (inference) rules (Table A-4) combine themes in different ways to reflect different contexts. For example, a given deposit model may state that certain critical factors must be combined at one location. Here the fuzzy AND operator would apply the minimum value of the set at each location. Other factors may be present unconditionally, in which case the fuzzy OR operator would apply the maximum value at each location. Where the co-presence of two or more favourable factors is desired, their combination would be modelled using the fuzzy SUM operator, to produce values higher than any individual value in the set. Conversely, net values may be decreased using the fuzzy PRODUCT operator that combines negative evidence. If conflicting evidence is recognized, the fuzzy GAMMA rule is used, where the value of γ [0,1], operates as a sliding scale between the increasive effects of the fuzzy SUM and the decreasive effects of the fuzzy PRODUCT. Each sub-theme that is used as an evidence layer is considered a factor in the net calculation. In this example, the first calculation combines favourabilities according to proximity to linear features (Map B), as set out in the criteria statement.

Table A-4. Five fuzzy combination rules commonly used in MPM. After An, et. al. (1991), and Bonham-Carter (1994).

Rule	Formula
AND	$\mu_c = \mathrm{Min}(\mu_i)$
OR	$\mu_c = \mathrm{Max}(\mu_i)$
PRODUCT	$\mu_c = \prod(\mu_i)$
SUM	$\mu_c = 1 - \prod(1 - \mu_i)$
GAMMA	$\mu_c = 1 - \prod(1 - \mu_i)^{\gamma} * \prod(\mu_i)^{1-\gamma}$

Map B represents the 'best of' (Fuzzy OR) combination of the three linear feature maps. A grey-scale legend indicates the net value calculated at this node. Map C displays increased values (using the Fuzzy SUM operator) assigned to the geological units where favourable rocks are proximal to unconformities or faults. The range of values in the legend has increased from 0.85 in Map A and 0.80 in Map B to 0.95+ in Map C, which represents net favourability with respect to the selected criteria.

This example is only part of a larger inference modelling process. Usually, the criteria used are taken from deposit model literature, and/or provided by experts. The inference modelling process provides critical factors to the net calculation of relative mineral potential. It also produces an audit trail to which the geologists can return for discussion, experimentation and refinement. The following section discusses how these three steps are applied using evidence derived from four different geological maps.

Application for Mapping MVT Pb-Zn in the Canadian High Arctic

Step 1. Setting the Context – Model Criteria

Parks Canada held a multi-disciplinary workshop in 1992 to consider representation for Natural Region 38 of the Canada Parks System Plan (CHPC, 1997) (Figure A-10). The fuzzy logic project reported here was initiated in 1993 to provide an early analysis of the Parry Islands Fold Belt and thus influence selection of a park study area with relatively low mineral potential. Although the primary area of interest was on northern Bathurst Island, the planners were also considering other sites throughout Region 38, including northeastern Melville Island (west of Bathurst Island in Figure A-10). The park study area was, nevertheless, finally centred on the zone of highest potential that had been outlined by the first author in preliminary maps (refined in Eddy, 1996). The MERA process for this region was then initiated in 1994. The subsequent 1:100,000 scale MERA project (Anglin and Harrison, 1999) collected substantial geoscience data, discovered Pb-Zn occurrences and confirmed Eddy's assessment. Nevertheless the sequence of events unfolded much as exemplified by the experiment presented in Figure A-6, with the second assessment providing more detail and higher confidence in locally reduced or increased potential for many commodities including hydrocarbons. The consistency of the sequential assessments contributed to a recent intergovernmental agreement that has now excluded the highest mineral and energy potential from the park proposal, subject to public consultation. As discussed above, until a final boundary is legislated, the boundary of the study area may still change in response to new information or other considerations, thus changing the context for MPM.

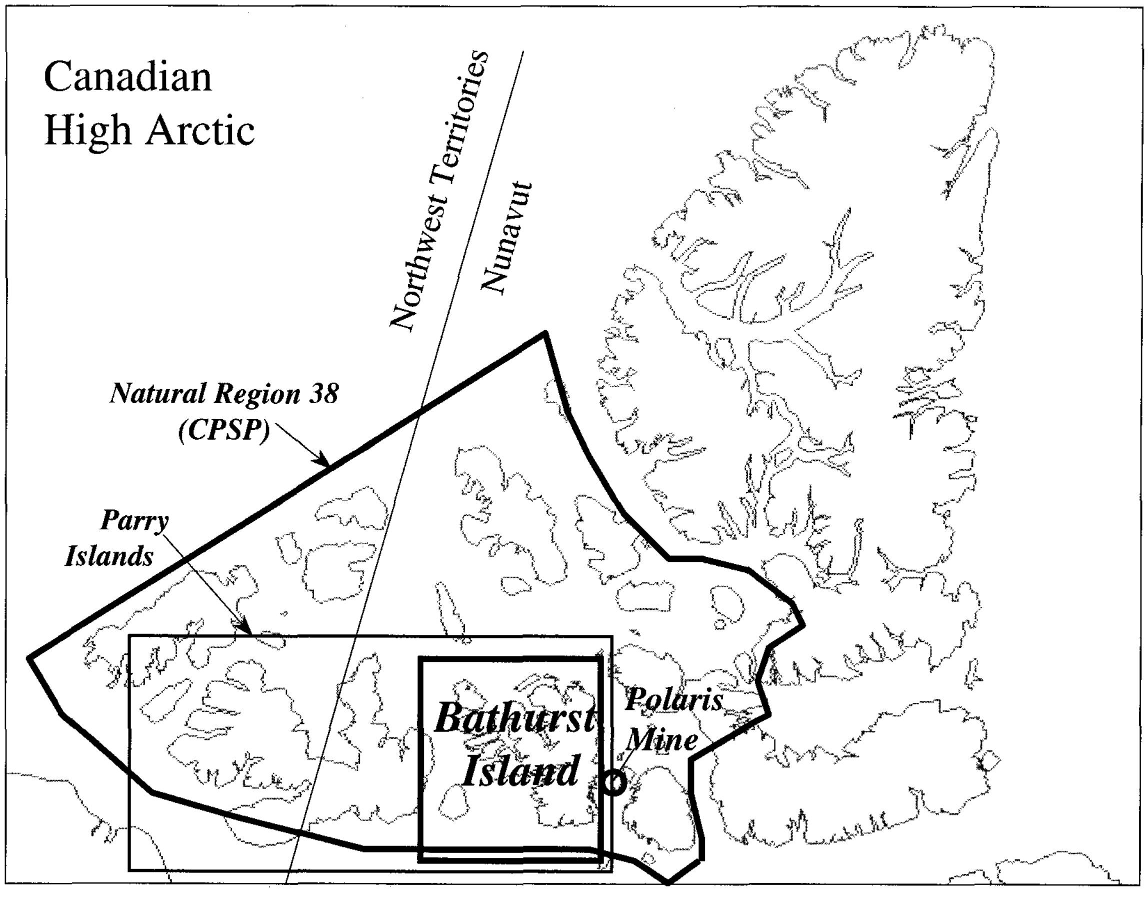


Figure A-10. Location map for the Natural Region 38, Canada Parks Systems Plan (CPSP), and the different boundaries of areas where subsequent MERA work was focused.

Among the many deposit types and commodities that were under consideration, the potential for MVT Pb-Zn was critical because of the existing Polaris Mine on Little Cornwallis Island, immediately east of Bathurst Island (Figure A-10). With an existing workforce and infrastructure in place in the region, the potential for a similar deposit on Bathurst Island was considered a strong possibility, and played an important consideration in negotiating the final boundary. Whereas the potential for many commodities were presented in the final MERA report (Anglin and Harrison, 1999), here we focus on MVT Pb-Zn potential. The context includes both global and local criteria used to define MVT Pb-Zn potential for the Cornwallis and Parry Islands fold belts. The global criteria were derived from Sangster (1995), and the local criteria from Anglin and Harrison (1999).

Global MVT Pb-Zn Criteria (from Sangster, 1995)

- Predominantly galena-sphalerite in brecciated carbonates
- Host rocks are platform carbonates ranging in age from Neoproterozoic to lower Carboniferous, most in Canada being lower-mid Paleozoic in age.
- Most deposits occur below unconformities/disconformities
- Host platformal carbonates were deposited contemporaneously with distal orogeny
- Deposits are discordant in detail, but form stratabound clusters of 1-10 Mt with 5-10 % Pb-Zn.
- Ore filled spaces in dolomite, brecciated through dissolution collapse
- Ore comprises primarily Pb, Zn and Fe sulphides; with associated Cd, Ge, Ba, and F , and local minor Cu, Ni, Co and Ag.
- Associated minerals include pyrite, marcasite, sparry dolomite.
- Zn/(Zn+Pb) ratios are commonly > 0.5, but range between 0.1 to 1.0
- Compositional zoning is common around many deposits

Local Criteria (direct observations, Anglin and Harrison, 1999)

- Known deposits and occurrences are within and associated with the Thumb Mountain and Irene Bay Fms, and Blue Fiord Beds,
- Occurences are associated with N-S oriented faults in the CFB domain.

Most of the local characteristics are consistent with the global, with the added association of N-S faults. Although faults are not considered to be a major global characteristic (Sangster, 1995), they are considered to be significant in the Bathurst Island locale, as syngenetic with the Boothia Uplift. They may have provided channels for fluid migration through the platformal carbonates. E-W faults of the Parry Island Fold Belt domain may have provided similar, though less significant, fluid pathways. The above criteria were used to construct the following criteria statement (knowledge proposition), to guide inference modelling of MVT Pb-Zn potential using Fuzzy Logic:

> *"MVT Pb-Zn potential is mainly associated with the Thumb Mtn/Irene Bay Fms, and the Blue Fiord beds, for which significant MVT-type deposits or occurrences are known. Other Paleozoic strata that contain dolostones or platform carbonates have lower, but still favourable potential. For these favourable bedrock units, mineral potential tends to increase near unconformities that are overlain by less permeable shaly units. Known occurrences are spatially related to N-S faults that are mainly within the CFB structural domain. The influence of E-W faults in the PIF domain is weakly favourable and uncertain."*

Step 2. Building Content – Providing the Evidence

Four different geological maps were used at different levels of mapping and assessment (Figures 11 and 12). These include (in order of increasing scale):

- Map A - Digital Geological Map of Canada (Map 18560A) (Wheeler, et. al. 1996 – 1:5M)
- Map B - Bedrock Geology of the Parry Islands Fold Belt (Eddy, 1996 – 1:1M synthesis of Map C with a regional 1:1M compilation by Okulitch (pers. comm., 1993)
- Map C - Geology of Bathurst Island Group (Eddy, 1996 - 1:250K synthesis of Kerr, 1974 and Okulitch, ibid), and
- Map D - Bedrock Geology, Bathurst Island Group (Harrison and de Freitas, 1998 – 1:125 k).

Map B covers Bathurst, Byam Martin and Melville Islands. The geometry and location of geological units on Bathurst Island, as represented by Kerr (1974) at 1:500,000, are incorporated in the 1:1,000,000 compilation, using a revised stratigraphic model to reconcile the two scales and currencies of data. Map B retains the geometric resolution of Kerr for the Bathurst Island portion, but uses Okulitch's generalized legend (pers. comm. 1993) for the Parry Islands Fold Belt.

Each map was used independently to extract evidence for MVT-Type Pb-Zn criteria. The ability to extract evidence from each geological map depended upon spatial resolution of maps, legend descriptions and accompanying reports. Table A-5 summarizes the key model criteria (based on the above knowledge proposition) and their correspondence to the evidence from each map. Although Map A does not provide enough detail to map MVT Pb-Zn potential with confidence, it does provide information on the geological age and rock types which permits some differentiation between geological units that are either carbonate, or potentially contain carbonate of appropriate ages. Map B provides significantly more information that addresses more criteria, and Maps C and D provide enough information to consider all of the major criteria.

Table A-5. Illustration of the relative strength of evidence derived from each geological map (A-D) used in the application for mapping MVT Pb-Zn potential on Bathurst Island.

Model Criteria	Map Relation	A	B	C	D
1. Carbonate Rocks	Attribute				
2. 'Platform' Carbonate rocks	Extended Attribute				
3. Overlain by Shale	Spatial/Temporal Adjacency				
4. Close to Unconformities	Proximity				
5. Faults/fractures	Proximity				

Good Evidence   Moderate Evidence   Weak Evidence

The modelling process for each map depended on the criteria that could be considered. For Maps B through D, multiple criteria were considered, including proximity to unconformities and faults, as well as stratigraphic relationships, but the strongest influence on the model results is in the assignment of fuzzy membership values to geological units. Figure A-11 shows the fuzzy membership values for each geological unit of each map that intersects the area of interest on Bathurst Island. For comparison, geological unit boundaries are displayed for a common area in central Bathurst Island to illustrate the changes in resolution with scale. Values were assigned to each map unit based primarily on the legend description for each map. In some instances, cross comparisons and visual correlations among units were made to enhance the interpretation. However, each map is best treated separately because it cannot be assumed that information from one portion of one map can be augmented with more detailed information from another map at the same locality.

Map A - Wheeler, 1995

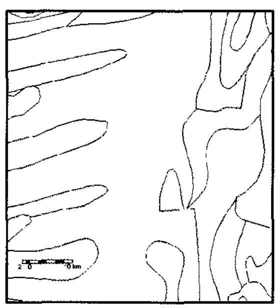
	UNIT	EPOCH	SUBTYPE	FMV
Sverdrup	KT	undivided Cretaceous Tertiary	undivided sedimentary rocks	0.35
	Tr	undivided Triassic	nonmarine sedimentary rocks	0.35
	Tr	undivided Triassic	undivided sedimentary rocks	0.35
	P	undivided Permian	undivided sedimentary rocks	0.37
	CP	undivided Carboniferous-Perm	nonmarine sedimentary rocks	0.40
	CP	undivided Carboniferous-Perm	undivided sedimentary rocks	0.45
Franklinian	uD	upper Devonian	undivided sedimentary rocks	0.50
	uD	upper Devonian	nonmarine sedimentary rocks	0.40
	mD	middle Devonian	undivided sedimentary rocks	0.50
	lmD	lower-middle Devonian	undivided sedimentary rocks	0.52
	lD	lower Devonian	undivided sedimentary rocks	0.53
	OS	undivided Ordovician Silurian	undivided sedimentary rocks	0.60
	OSo	undivided Ordovician Silurian	offshelf miogeoclinal rocks	0.65

Maps B/C - Eddy, 1995*

Abbrev	Unit Name	FMV
Kb	Igneous Intrusions	0.27
KTES	Eureka Sound Gp	0.27
KK	Kanguk Fm	0.27
KI	Isachsen Fm	0.27
JA	Awingak Fm	0.27
JR	Ringnes Fm	0.27
TrB	Bjorne Fm	0.31
TrBF	Blind Fiord Fm	0.31
TrH	Heiberg Fm	0.31
PAT	Assistance/Trold Fiord Fm	0.33
PBS	Belcher Ch./Sabine Bay Fm	0.33
CPCF	Canyon Fiord Fm	0.37
COF	Otto Fiord Fm	0.35
DGB	Griper Bay Group	0.38
DHB	Hecla Bay Fm	0.27
DBF	Bird Fiord Fm	0.33
DBL	Blue Fiord Fm	0.63
DE	EIDS Fm	0.38
DDB	Disappointment Bay Fm	0.60
DSB	Bathurst Island/Stuart Bay Fms	0.50
DS	Stuart Bay Fm	0.50
DB	Bathurst Island Fm	0.45
OSCP	Cape Phillips Fm	0.68
ODTI	Thumb Mtn./Irene Bay Fm	0.75

Map D - Harrison and DeFreitas, 1998

Abrev	Unit Description	FMV
Q	Quaternary Sediments	0.05
TS	Freemans Cove Igneous Suite (undifferentiated)	0.05
KK	Kanguk Fm.	0.05
KI	Isachsen Fm.	0.05
JA	Awingak Fm.	0.05
JR	Ringnes Fm.	0.05
TrPB	Pat Bay Fm.	0.15
TrB	Bjorne Fm.	0.05
PTF	Trold Fiord Fm.	0.05
PGB	Great Bear Cape Fm.	0.20
PBC	Belcher Channel Fm.	0.25
CPC	Canyon Fiord Fm.	0.25
DPI5	Parry Islands Fm. Member 5	0.15
DPI4	Parry Islands Fm. Member 4	0.05
DPI3	Parry Islands Fm. Member 3	0.05
DPI2	Parry Islands Fm. Member 2	0.05
DPI1	Parry Islands Fm. Member 1	0.05
DBE	Beverly Inlet Fm. (undivided)	0.05
DBE-u	DBE Upper part	0.05
DBE-l	DBE Lower part	0.05
DHB	Hecla Bay Fm.	0.05
DHB-u	DHB Upper part	0.05
DHB-l	DHB Lower part	0.05
DBI	Bird Fiord Fm.	0.25
DCB	Cape De Bray Fm.	0.20
DBL	Blue Fiord beds (undivided)	0.75
DBL3	DBL Upper part	0.75
DBL2,3	DBL Upper and Middle parts	0.70
DBL2	DBL Middle part	0.68
DBL1	DBL Lower part	0.85
DE	EIDS beds	0.25
DE-u	DE Upper part	0.20
DE-s	DE local facies	0.20
DE-l	DE Lower Part	0.20
DDB	Disappointment Bay Fm.	0.68
DU	Unnamed Fm.	0.68
DPA	Prince Alfred Fm.	0.05
DPA-c	DPA c-facies	0.30
DPA-r	DPA r-facies	0.30
DPA-s	DPA s-facies	0.30
DG	Goose Fiord Fm.	0.67
DBA	Bathurst Island and Stuart Bay beds (undivided)	0.55
SDBA	Bathurst Island and Stuart Bay beds (undivided)	0.55
DBA-s	DBA s-facies	0.50
DBA-c	DBA c-facies	0.57
DBA-c,l	DBA c/l - facies	0.55
DBA-s,l	DBA s/l - facies	0.52
DBA-l	DBA l-facies	0.30
SDBA-o	SDBA o-facies	0.05
DBA-t	DBA t-facies	0.05
SDBA-t	SDBA t-facies	0.05
SDI	Devon Island Fm. (l Dev.)	0.25
SDDI	Devon Island Fm. (u. Sil/l. Dev)	0.25
OSCP	Cape Phillips Fm.	0.65
OCTI	Thumb Mtn. / Irene Bay Fm (undivided)	0.85
OCI	Irene Bay Fm.	0.85
OCT	Thumb Mtn. Fm.	0.85
OCB	Bay Fiord Fm.	0.63



Map A

Map B/C

Map D

Figure A-11. Fuzzy membership values assigned to geological units for Maps A – D (see Figure 12 for results of one iteration). *Note: Eddy (1995) compilation derived from Okulitch (pers. comm.) and Kerr (1974).

The assignment of values to geological units is used as a means to represent the value of locations that are transected by those map units. The uncertainties considered in the assignment process arise from both the limits of the legend description (whether carbonates are explicitly listed, or need to be inferred through a tectono-stratigraphic association, e.g. miogeoclinal rocks), and the limits of representation of the geological map polygons at different scales. A geological unit that is explicitly defined as a platform carbonate might receive a moderate value (e.g. 0.72) if the resolution of the map is relatively coarse, and therefore mineral potential is considered less certain than for the same unit on larger scale map (e.g. 0.85).

In compiled geological maps, legend descriptions often contain a synthesis of lithological descriptions from two or more sources. In some cases the synthesis is straightforward; in others it is problematic without conducting additional field work. Such uncertainties in legend descriptions are just one example of the elements that must be considered in assigning individual fuzzy membership values at different map scales, and different levels of stratigraphic resolution.

The values assigned to Map A range from 0.35 to 0.65. Values lower than 0.50 were applied to all of the units corresponding to the Sverdrup Basin succession, as these units are interpreted to be deficient in platform carbonates. The only other value lower than 0.50 is assigned to Upper Devonian non-marine strata in the Franklinian Succession (inferred from age, rock type and geographical location). Comparison with the other maps reveals that this unit likely corresponds with the Hecla Bay Fm., which is an extensive, thick sequence of clastic sedimentary rocks that exhibit no evidence of the presence of carbonates. Values at, or near, 0.50 were assigned to units that are described as 'undivided sedimentary rocks' of Ordovician to Devonian age, with a slight increase (0.52, 0.53) in value for units that are lower to mid-Devonian age. These values exemplify *aporia* that results from the relatively equal possibilities that these units may be carbonate or 'not carbonate'. The only two units that were assigned relatively higher positive values are the undivided Ordovician-Silurian sedimentary (0.60) and offshelf miogeoclinal (0.65) units that are here inferred to be equivalent to the Cape Phillips and Thumb Mtn./Irene Bay Fms. respectively, that have prior known potential for MVT Pb-Zn.

The values assigned in this model iteration to Maps B and C are identical and range from 0.27 to 0.75 (a greater range than for Map A). This increase in range of values reflects greater certainty in the ability to differentiate between units that contain carbonates and those that do not. More detail is also provided in their legend descriptions, and associated reports also provide more detail than those of Map A. For the Sverdrup succession, the assigned values range from 0.27 to 0.35, whereas the values for the Franklinian succession range from 0.27 to 0.75. Although most units have been correlated from Maps B and C to A, two additional units are not represented on Map A (Awingak and Ringnes formations, highlighted in grey in Figure A-11). As with the assignment of values to the units in Map A, the lower (< 0.50) values represent locations that do 'not likely' contain carbonates, and units with higher (> 0.50) values represent locations that likely, or very likely contain carbonates. Some units in this legend were mentioned specifically in the model criteria, including the Blue Fiord, Cape Phillips and Thumb Mtn./Irene Bay formations. These units received significantly higher values because they are known to contain platform carbonates, and are capped by less permeable strata and are close to unconformities.

For Map D, fuzzy membership values are assigned to 58 geological units. Many units in this legend are not represented in Maps A to C. This is partly because some units in the previous maps fall outside of the area covered by Map D (exclusively Bathurst Island), but also, new units were discovered as a result of more detailed mapping during 1995 to 1998 (1:125,000, Harrison and DeFreitas, 1998). The additional units are highlighted in grey (Figure A-11). Where units contain no platform carbonates, and are not an appropriate age, a value of 0.05 was assigned. Slightly larger values (i.e. 0.15 to 0.30) were assigned to units that contain some carbonates, but are not considered significant for MVT potential. The slight increase in assignment value indicates a lesser degree of certainty, in that such units are 'not likely' to host potential.

Members of the Bathurst Island and Stuart Bay beds were assigned values that range from 0.05 to 0.57. These units contain interbedded deep water siltstones and fine-grained sandstone, with some limestone, chert, and organic shale. Members that contain carbonate olistostromes or limestones were assigned values of 0.50 or 0.60 to indicate the higher degree of uncertainty as to whether these particular carbonate units could host MVT Pb-Zn-type mineralization. In some locations, the geological map does not differentiate among the members, and these areas are given a value of 0.55 to reflect this uncertainty. The Disappointment Bay and Unnamed Formations were both assigned a value of 0.68 to indicate their favourable lithology. Although no Pb-Zn occurrences are known in these units, their lithologic and stratigraphic qualities fit reasonably well with global criteria.

The highest values were assigned to the Blue Fiord beds (0.75) and Thumb Mountain and Irene Bay Fms (0.85). These values reflect their distinctly favourable lithology and stratigraphic position, as well as the knowledge of MVT-type Pb-Zn occurrences hosted by them. In the case of the Blue Fiord beds where sub-members are differentiated on the geological map, different values were assigned to reflect the individual qualities of each member. The lower member (DBL1) received the highest value because it contains a known Pb-Zn occurrence. Relatively higher values were also assigned to the Cape Phillips Fm. (0.65) and Bay Fiord Fm (0.63). Although these units are not considered directly favourable, their bounding stratigraphic relationship with the Thumb Mtn. and Irene Bay formations provides the possibility, due to the complex deformation in some areas along the CFB, that the latter might be nearby, either at surface or in the near sub-surface.

Step 3.3. Model and Presentation

The lithological factor comprises only a portion of the evidence used in modelling the results. As outlined in Table 5, three other evidence themes were used in combination with lithological favourability, depending on the scale of the map, and the ability to derive the different evidence from each map. Eddy (1996) provided several inference nets that represent various iterations for experimenting with different combinations of evidence themes, and combination rules. An example of one iteration for each of the four maps is presented here (Figure A-12).

The same legend is used for all four maps so that results can be compared visually for different map scales. This legend was designed to provide a gradational fuzzy effect, whereby the medium grey tones represent greater uncertainty, or *aporia*, and the more pure shades as decreasing uncertainty in positive (increasing membership, black) and negative (decreasing membership, white) directions. Lighter tones are used for small-scale maps where the certainty of information presented is rarely as strong (or intense) as information presented on larger scale maps. Additionally, this legend uses a 20 class interval scheme, which segments the [0,1] range of fuzzy membership values at 0.05 intervals. Other class intervals and colour schemes may be used depending on the number of output maps required, their respective scale ranges, and the level of precision used in the assignment and calculation of fuzzy membership values and results (i.e. a 0.001 precision would allow up to 1000 class intervals with as many colours).

Map A shows results that fall within the 0.35-0.65 range. The overall tone of the map is relatively subdued which reflects the higher degree of uncertainty in the results. However, the map succeeds in differentiating broad regional geological domains that are more likely carbonate-bearing versus those that are not likely carbonate bearing. Comparison to the other maps (B-D) reveals internal consistency in the results with increasing scale. The slightly darker grey areas on eastern Bathurst Island correspond with geological units described as Ordovician-Silurian sedimentary and miogeoclinal rocks as described in Figure A-11. The effect of increasing the resolution on the Parry Islands is revealed in Map B where a better differentiation is presented with values in the 0.27-0.75 range of values. Map C shows the same results for the Bathurst Island portion, with a scale representation of 1:500,000. Table 5 illustrates how some stratigraphic factors and proximity to faults were influential in the modelling of Map B (Parry Islands compilation). These factors had a more significant effect in modelling the Bathurst

Island portion (Map C) because the resolution of the 1:500,000 scale map produced greater certainty in the mapping of boundaries and linear features than the 1;1,000,000 regional compilation map (Eddy, 1996). The increase in tone (and value range) in Map C relative to Map B reflects the influence of these additional factors.

Although Map C succeeds in differentiating MVT Pb-Zn potential from non-potential areas on Bathurst Island, Map D provides a significantly more refined representation using the 1:125,000 map prepared by Harrison and DeFreitas (1998). The reasons for the significant difference in representation are two-fold. First, there is a greater range or intensity of certainty in the results of Map D over Map C. The values represented in Map D range from as low as 0.05 to as high as 0.95. The increase in the net value is due to the use of the fuzzy SUM and GAMMA operators where high lithology values (e.g 0.85) are combined with close proximity to favoured faults, unconformities, and/or shale units, which were mapped with considerably greater detail and accuracy. The second reason is the increased resolution of the map units, many of which were differentiated on a sub-unit level, thereby narrowing the spatial extent over which the values are represented, while simultaneously differentiating between relative potential and non-potential sub-units. Some differences are due to the additional geological units mapped at the 1:125,000 resolution. The impact of using the 1:125,000 map over the 1:500,000 map is a significant reduction in the aerial extent over which potential for MVT Pb-Zn is inferred.

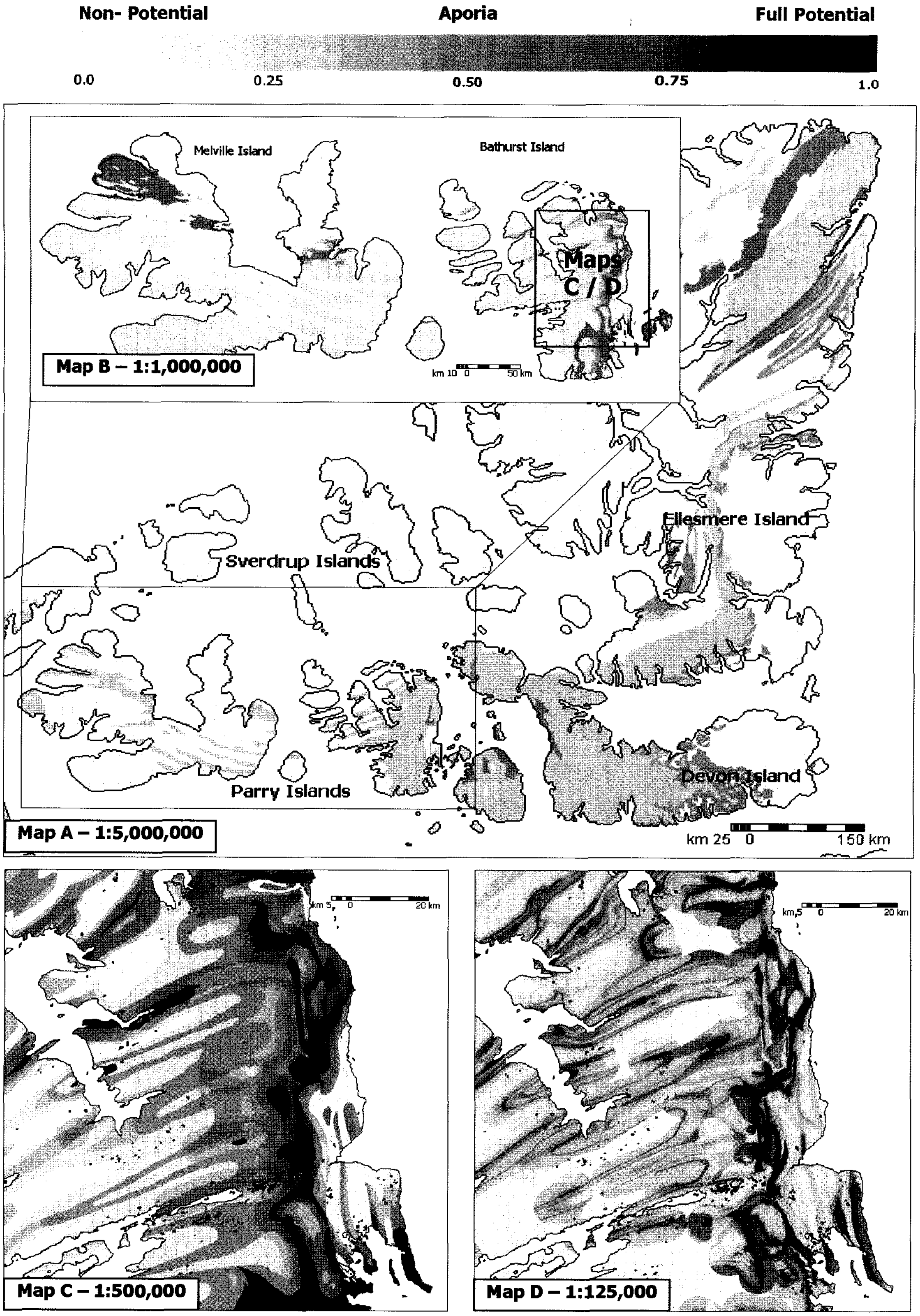


Figure A-12. Mineral potential map results, for MVT Pb-Zn potential, for each of Maps A-D representing scales of 1:5,000,000, 1:1,000,000, 1:500,000, and 1:125,000 respectively.

Discussion

A modified Fuzzy Logic method for generating MPM at multiple scales uses only digital geological maps and deposit model criteria. This specific KD method is developed upon similar principles as the WofE (DD) method, and both methods reveal the degree to which deductive (KD) and inductive (DD) information flow patterns influence each approach. Several guidelines apply to the Fuzzy Logic approach.

The first guide is that evidence themes used in modelling mineral potential must match reasonably well with deposit model criteria. The relative degree of confidence in the results hinges on how well the criteria match the evidence themes used, as well as how the evidence themes are combined to reflect the deposit model as a whole. If the criteria used are more descriptive, there may be a need for considerable iteration and experimentation because the author of the criteria may not explicitly state which criteria are more important than others. If the criteria are derived from a genetic or process-oriented model, the logical constructs of the model can more directly be applied (and tested), which requires less iteration. However, a genetic model may not provide sufficient empirical information to link readily with map data, and descriptions may be mixed with genetic criteria, whether working with formal, informal, global, or local knowledge sources. This issue must be considered in both KD and DD methods. Whereas the chosen criteria influence the strength of the assignment values in the Fuzzy Logic method, as well as how the evidence is combined, the same guideline must be used in considering which mineral occurrences should be included or excluded in driving a DD model. The qualification of individual occurrences, in itself, is a deductive element of the modelling process that may also require considerable iteration and input from experts.

The benefit of both KD and DD approaches is that iterative experimentation can proceed effectively, and most importantly, objectively. Exposing the reasoning processes in the construction of MPMs positions the methodological framework on an objective footing. However, all MPM exercises remain to some degree subjective and open to change. Absolute potential can never be determined because any iterative expression of mineral potential is nested within the context of the study, the data used, and the relative judgements applied by the modeller(s). Through iteration and experimentation, in testing model criteria and assumptions, as well as testing various representations of evidence used in a model, reproducibility should emerge at some point. The overall degree to which results may or may not be reproducible will ultimately determine the strength of the model for a specific application.

In this multi-scale application, reproducibility is considered in both uni-scale (reproducibility of each individual theme), as well as in the multi-scale context (internal consistency and similarity of results across map scales). Various expressions of potential are possible at each scale, however, by subjecting the reasoning process to iteration and refinement, and by applying the same general principles to data across scales, it is demonstrated how reproducibility does emerge across scales, even with varying degrees of certainty (which is objectively made explicit). The result is that mineral potential maps can be presented at a variety of scales for a variety of contexts for different purposes as suggested in Table A-6.

A remaining limitation of the fuzzy logic method for MPM, for both the Base '0' and Base '0.5' approaches, is the lack of a secondary quantitative measure of uncertainty associated with individual fuzzy membership values. Although the term uncertainty is used in a different context in this modified approach, numerically, a primary uncertainty measure is indicated by the difference between a fuzzy membership value and *aporia.* A means for developing a secondary uncertainty measure associated with individual fuzzy membership values has yet to be explored.

Map Result	Scale	Suggested Use
Map A	1:5,000,000	▪ Backdrop to highlight Pb-Zn districts and occurrences, ▪ Mapping metallogenic domains, ▪ National / regional level representation of relative favourability
Map B	1:1,000,000	▪ First phase regional assessment ▪ Identifying target areas for more detailed investigation ▪ Regional land-use planning (early stage)
Map C	1:500,000	▪ Backdrop for more detailed geological information (e.g. geochemistry, geophysics) ▪ Planning tool for reconnaissance exploration or field work ▪ Local land-use planning
Map D	1:125,000	▪ Late-stage mineral resource assessment input ▪ Delineating specific exploration targets ▪ Detailed land-use planning ▪ Quantitative analysis with other geoscientific data (e.g. geochemistry, geophysics)

Table A-6. Suggestions for use and appropriate contexts for map results A-D and corresponding scale.

The handling of secondary uncertainty would need to be consistent with DD approaches. In DD methods, the variance of weights, and variance due to missing data provide a basis for a measure of uncertainty. If this approach could somehow be adapted for the fuzzy logic method, multiple fuzzy membership values for each spatial evidence would be required. An individual modeller may want to experiment with assigning multiple values, perhaps at intermittent periods under a quasi-blind assignment approach, as a means of capturing different ranges of judgment of criteria. Alternatively, values may be solicited from more than one geologist in situations where multiple perspectives are required. In either situation, variances on the range of multiple values (for the same evidence) may serve as a starting point for developing a secondary uncertainty measure.

The development of a secondary uncertainty measure for fuzzy logic might reveal new understanding about the confidence of geological knowledge in relation to map scale (and data resolution, complexity and other factors). Experimental WofE results for multi-scale mapping reveals an increase in variance of individual weights, with increasing scale (represented in Figure A-6 and Table 1 as the increase in the range of W+ values). This suggests that although a higher contrast in relative weights is achieved with increasing resolution, there is a corresponding increase in the relative uncertainty of those results. It would be worth experimenting with the assignment of multiple fuzzy membership values, at multiple scales, using two or more geologists, to examine if a similar affect is produced using fuzzy logic.

If the relation holds for both methods (and this is not assumed), it appears there may be inverted trade-off between the resolution of the data used, and confidence in the response maps with increasing scale. In both the WofE experiment, and the fuzzy logic application, the trade-off appears as an increase in the localized delineation of higher potential areas, at the expense of mathematical certainty. It remains to be seen if there is an optimal resolution at which a specific deposit or commodity type might best be modelled to maximize the contrast in the relative values across a study area, while maintaining minimal uncertainty in the results.

The modified Fuzzy Logic method presented here succeeds in addressing some of the multi-scale requirements, as demonstrated using the application for MVT Pb-Zn modelling for Bathurst Island. This analysis demonstrates the noticeable benefit of 1:100,000 to 1:250,000 geological maps to provide the level of detail required by many mineral deposit model criteria. The ultimate aim of most MPM projects is to assist in land-use planning or exploration programs, which optimally operate within this scale range in the frontier regions of Canada. However, significant portions of the frontier regions of Canada have yet to be mapped at these scales, and the results presented here reinforce the value and need for mapping programs at this level.

Acknowledgements

The authors would like to acknowledge the support of NSERC, the Canada-NWT Mineral Initiative Program under the Mineral Resources Mapping (MRM) Project of the NWT, and the Mineral and Energy Resource Assessment (MERA) program for funding various phases of this research. We are grateful to C. Anglin (GSC, Ottawa), C. Harrison (ISPG), R. Laramée and A. Okulitch (ISPG) for the provision of data, advice and critical review of this work, as well as Simon Dalby (Dept. of Geography at Carleton University) for suggesting the use of the term *aporia* in developing the methodological framework.

Then came the churches,
Then came the schools,
Then came the lawyers,
Then came the rules,
Then came the trains
and the trucks with their loads,

And the dirty old track
Was the Telegraph Road.

Mark Knopfler,
Telegraph Road.

PAPER B

Exploring the Concept of Cybercartography Using the Holonic Tenets of Integral Theory

Brian Eddy and D.R. Fraser Taylor

Geomatics and Cartographic Research Centre (GCRC),
Dept. of Geography and Environmental Studies, Carleton University,
Ottawa, Ontario, Canada K1S 5B6

email: bgeddy@connectmail.carleton.ca ; ftaylor@ccs.carleton.ca
website: www.carleton.ca/geography/GCRC

Keywords: cybercartography, integral theory, holons, information theory

Abstract

The concept of cybercartography draws on theory from a variety of disciplines including the physical and human sciences, geomatics sciences and technology, collaborative research and the humanities. Integration of theory across disciplines is required in such an approach. This chapter examines cybercartography through a trans-disciplinary lens of 'integral theory' which uses a set of tenets describing 'whole-part' relationships, or 'holons' as a basis for theoretical integration and synthesis. Central to this approach is an examination of what we mean by 'information', in particular, with its relationship to data, knowledge, and meaning. Extending conventional user-computer oriented concepts, a 'Cybercartographic Human Interface' (CHI) model is proposed.

Introduction - Cybercartography in the Information Era

An important aspect of cybercartography is how people and society can learn more effectively about the world using geospatial information. In chapter one it was argued that although cybercartography is different from GIS, it includes GIS as an integral part of the cybercartographic paradigm. This chapter considers cybercartography in relationship with the emerging trends in geomatics and geographical information processing, and related technologies and infrastructures. The important historical relationship between geography and cartography is extended by situating these disciplines along a stream of information flow. Such an examination requires taking a closer look at some of the characteristics of 'information'.

From an information theory perspective, we view the role of geography as the theory and practice of studying the world and the generation of numerous types of geographical information. Cartography looks at ways of presenting information about the world - primarily in the form of maps augmented by other forms – with the aim to communicate geographical information to an intended user base. This connection is summarized in Figure B-1 which situates the geographer and cartographer as 'facilitators' of information flow between the world and the user base.

One of the main distinctions of cybercartography is how cyber technology affects the dynamics of this general information flow pattern. As Peterson (1995) argues, the conventional singular, linear, monological flow is now seen as non-linear and dialogical. Users as learners also become part of the process of map making, and the conventional roles of geographers and cartographers, as 'construction workers' of information about the world, also take the additional role of learner in the process. This interaction is part of the socio-cybernetic feedback process discussed in chapter one and by Martinez and Reyes later in this volume (Chapters IV, V, and VI).

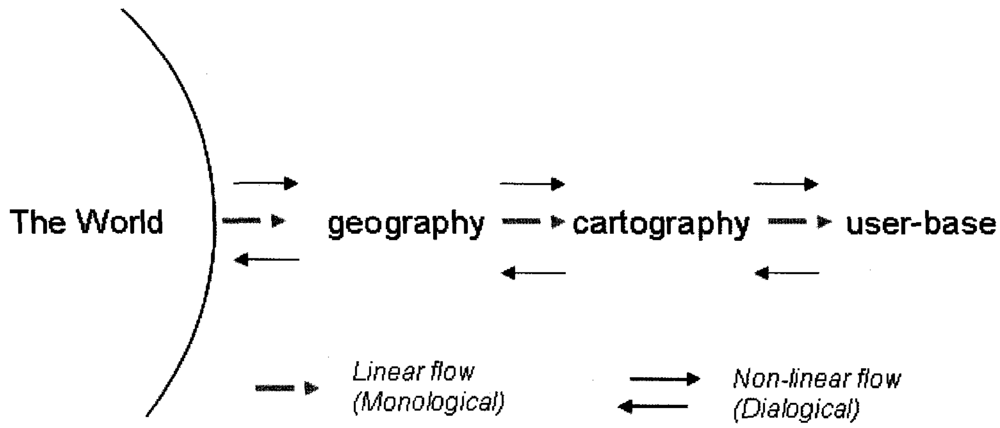


Figure B- 1. Geography, Cartography and Information Flow.

One aim of cybercartography is to provide better information about the world, and this is now both enhanced and challenged by rapidly emerging cyber technologies. There are more maps being generated today than ever in history, and as argued in chapter one, many of these maps are not being formally created by cartographers. The result has been an increase in the quantity of maps and geographical information on the Web, but says little of the 'quality' of information and understanding about the world attained by users. There is certainly greater access to data and knowledge, but we must also ask questions as to whether current practices and modes of delivery are helping to generate better meaning and understanding of the world. How might cybermaps serve to augment 'meaning' as a result of dialogical information processing, and how does cybercartography enhance this process?

One way of approaching this question is to examine cybercartography from an information theory perspective. In doing so, we focus on the complexities of the information flow among the various levels and dimensions among geographers, cartographers and other participants in the map-making process. Examining the characteristics of information flow presents several challenges. What is ‘information’? Is information something different than data, knowledge, facts, or interpretations? How is information presented in the form of a map different than that of a table, a narrative, or a video?

One of the difficulties in exploring these questions is that there does not seem to be a consensus on what 'information' actually is. Dictionaries often quote colloquial and circular reasoning (e.g. Lexicon, 1987), and philosophical examinations, while highlighting important aspects that must be taken into account, do not lead to a clear definition of the term (Adams, 2001; Winder, et. al., 1997). We argue that an understanding of the various concepts of information is required in order to adequately characterize the important dialogical map-making process. What is presented here is intended to initiate a dialogue with respect to how geographers, cartographers and people from many other disciplines situate themselves in the emerging information age or information economy, and more specifically within the emerging cybercartographic paradigm.

Conventionally, geographers and cartographers may not have regarded themselves as information processors or information professionals, with the exception of those who specialize in GIS and geomatics. A scan of various geography, GIS and cartography textbooks indicates that the concept of information is rarely, if ever, examined (Burrough, 1998; Chrisman, 2002; Clarke, 2001; De Blij, 1997; ESRI Inc., 1997; Fisher, 1982; Freeman, 1949; Haggett, 1983; Leung, 1997; Lock 1976; Longley, et. al., 2001; Medyckyj-Scott, 1993; Raper, 2000; Robinson, 1995; Shaw, 1965; Small, 1995; Szegö, 1987; Tomlin, 1990; Ullman, 1980; Wood, 1992). In a few cases, concepts such as 'data', 'information', and 'knowledge', if not simply taken for granted, are often defined vaguely, and in a circular fashion. If cybercartography is to be part of an 'information/analytical package' (Taylor, 2003) then these relationships must be more fully considered.

The need for better understanding of information cannot be understated. Confusion over terminology creates misunderstanding and confusion. We therefore need to explore a working model of information that may be used to better situate commonly used terms such as data, knowledge, facts, interpretations, and meanings and their relative influence in the cybercartographic process. Such a model would need to be built from an integration of the approaches taken to the concept of information by a variety of disciplines. Drawing from multiple disciplines can be challenging, both in practical and theoretical terms, as Lauriault and Taylor discuss later in this volume (Chapter VIII). How multiple disciplines or perspectives intersect or interact can take on a number of forms, including multi-disciplinarity, cross-disciplinarity, inter-disciplinarity and trans-disciplinarity.

In this chapter, we explore the concept of information in cybercartography using 'Integral Theory', which offers itself as a 'trans-disciplinary' framework for integration and synthesis across disciplines. We first introduce some of the basic elements of integral theory, then examine how the concept of information can be examined. We then examine information theories from a variety of disciplines to explore how these may be integrated. Finally, we present a synthesis of our analysis in the form of a Cybercartographic Human Interface (CHI) model, a working model that includes consideration of the most important elements required in considering information flow in cybercartographic applications.

Integral Theory and the Holonic Tenets

Integral Theory was developed by Ken Wilber over several decades of research on ecology and consciousness studies (Wilber, 1995; 1996; 2000). A comprehensive understanding of this subject necessarily involves reconciling numerous fields of knowledge from the physical and social sciences, psychology and anthropology, cultural studies, philosophy, aesthetics and the world's spiritual traditions. Integral theory is both voluminous and complex, and a full consideration of its depth is beyond the scope of this chapter. For an outline of the application of integral theory to geography, the reader is referred to Eddy (in press, b). This section presents some basic elements of integral theory in relation to its application to cybercartography.

Wilber argues that the first step necessary in integrating knowledge from different fields is to consider each as having some important contributions to make in its own right, and that all knowledge domains 'emerge' as a result of the necessity of perspective. In the integral approach, integrating knowledge across disciplinary boundaries starts with examining lines of general agreement and focus, which may sometimes reveal patterns that individual perspectives might not have otherwise captured on their own. Using

Arthur Koestler's conceptualization of 'holons' (or whole/parts) and 'holarchies' (Koestler, 1967), Integral Theory examines where potential interfaces occur by presenting views of the world (ontologies), and knowledge of the world (epistemologies), as series of nested 'whole-part' relationships. It suggests that anything we study is viewed in whole-part relational terms, and is also understood and expressed in whole-part terms. Koestler originally proposed a set of general rules or guidelines that characterize whole-part relationships. Wilber (1995) built upon these, added a few of his own, and summarized them as the 'holonic tenets' (Table B- 1).

To complement the twenty tenets, Figure B- 2 illustrates a simplified model of the base theoretical framework used in integral theory. The following sections examine information from an ecological perspective, and this version of the framework highlights some of the required elements. Specifically, in terms of holonic elements, this model emphasizes the very broad holonic relationships among matter, life and mind, maintaining that all information contains some combination of these basic elements. According to Wilber, there are also different 'dimensions' of these elements that must be taken into account. They are summarized in Figure B- 2 as 'quadrants' that correspond with the intersections among (1) individual and (2) collective dimensions, combined with (3) exterior (physical/bio-physical, societal) and (4) interior (experiential/cultural) dimensions, or aspects of reality. The four quadrants are sometimes used to differentiate intention and behaviour in individuals (the interior and exterior dimensions of the upper quadrants), and culture and society in the collective sphere (the interior and exterior dimensions in the lower quadrants).

Table B- 1. The Holonic Tenets (After Wilber, 1995).

1. Reality is composed, not of 'parts', nor of 'wholes', but of holons (whole/parts).

2. Holons display 4 fundamental capacities:

   (a) self-preservation (wholeness/agency)
   (b) self-adaptation (partness/communion)
   (c) self-transcendence
   (d) self-dissolution

3. Holons emerge.

4. Holons emerge holarchically.

5. Each emergent holon transcends but includes its predecessors.

6. The lower sets the possibilities of the higher; the higher sets the probabilities of the lower.

7. The number of levels which a hierarchy comprises determines whether it is 'shallow' or 'deep'; and the number of holons on any given level we shall call its span.

8. Each successive level of evolution produces greater depth and less span.

9. Destroy any type of holon, and you will destroy all of the holons above it and none of the holons below it.

10. Holarchies co-evolve.

11. The micro is in relational exchange with the macro at all levels of its depth.

12. Evolution has directionality:

    (a) Increasing complexity
    (b) Increasing differentiation/integration
    (c) Increasing organization/structuration
    (d) Increasing relative autonomy
    (e) Increasing telos

This main template of Integral Theory is referred to as an 'All-Quadrants, All-Levels' (AQAL) framework. The quadrants are used to situate different aspects of our perceived reality, as embedded in our languages across cultures, and are also used to help situate many methods for studying the world. There are several ways of studying and understanding the intentions and behaviours of individuals, culture and society, because each of these dimensions occupies distinctively different domains that require specific methods of inquiry. In the upper right quadrant, we have empirical and behavioural sciences that study individual, physical and biophysical exterior realities. In the lower right quadrant, when we examine physical things in their collective dimension, we can draw from ecological, social, and systems sciences.

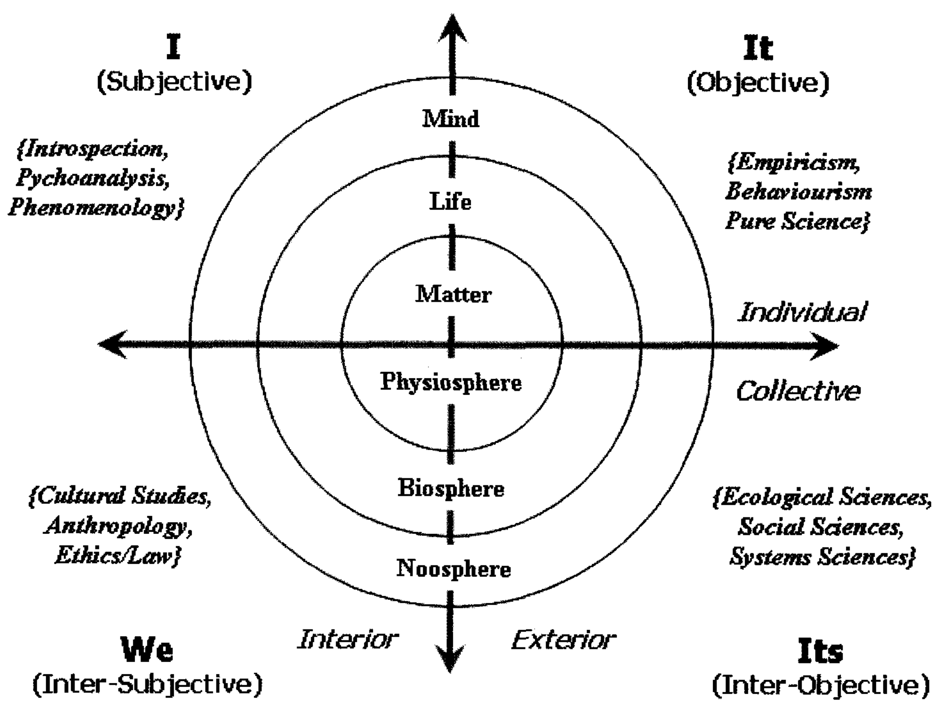


Figure B- 2. The All Quadrants, All Levels (AQAL) Framework used in Integral Theory.

In the upper left quadrant, we make room for disciplines that consider the inner person, from phenomenology to psychoanalytic theory, to aesthetics or perspectives. In the lower left quadrant, the study of collective interior spaces falls within disciplines such as cultural studies, cultural anthropology, ethics, law, linguistics and various approaches to collaborative inquiry.

Wilber describes the AQAL model in common cross-cultural language as representing ways of orienting 1^{st}, 2^{nd} and 3^{rd} person perspectives corresponding with I, We and It. In other areas, he summarizes the AQAL model in terms of Art/Aesthetics (I), Morals/Ethics (We), and Science (It/Its), or as Self, Culture, and Nature (see Wilber, 1996 for an elaboration on these parallels). It is this facet of integral theory that provides a trans-disciplinary framework and language to fill various information gaps drawing on various disciplines as required. Integral theory suggests that in order to be comprehensive, it is important to take 'all quadrants, and all levels' into account as best as possible. If any quadrant or level is missing from an approach, then we are likely leaving out something very important - or 'integral' - to the reality we are studying. These basic theoretical elements of the integral map will be expanded upon in later sections. We now turn to how geographical information and its representation and communication can be examined within the integral framework.

Understanding Information – An Integral Perspective

An integral approach takes as broad a perspective as possible, taking into account all quadrants and all levels (to which other elements may be added). It is assumed that information is intrinsically holonic. Every piece of information, or any information event or element can be said to be holonic, and its emergence follows the holonic tenets. For example, a letter (as a symbol) is a part of a word, which is part of a sentence, which is part of a paragraph, and so on. In geography, a place is part of a region, which is part of a nation, which is part of the world. But we are not only concerned with the things we see visually or physically. There is also an 'ephemeral' dimension of our perceived reality that sets the 'context' within which information 'content' is situated. This suggests that information be placed in a holonic 'content-context' relation (Figure B- 3).

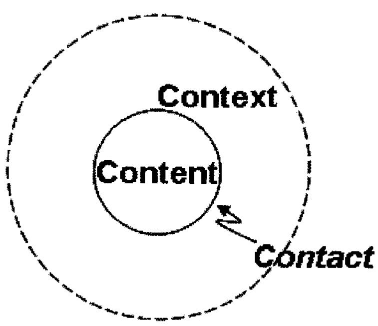


Figure B- 3. Content, Context, and Contact as a Holonic Relation.

In one sense, information 'content' can be touched, seen, or sensed because it is 'bounded' in some way. The 'context', however is ephemeral, fluid, or 'unbounded'. Some of most significant challenges in information processing occur at the 'interface' between the content and context, or what is considered here as various points of 'contact'. The three elements of content, context, and contact (the 3-C's) are integral to the concept of cybercartography as originally suggested by Eddy (2002) and elaborated in Taylor (2003). To elaborate their intrinsic characteristics and further explore their potential relevance to cybercartography, it is necessary to look at different 'types' of holons as treated in integral theory.

Holon Typology

Although integral theory considers everything to be holonic, not all holons share the same characteristics. Each AQAL matrix is considered to be some mixed combination of holonic interaction among three general holonic typologies. The integral terms used include: 1) Sentient and Non-sentient, 2) Individual and Social, and 3) Artifact and Heap. Sentient holons are those that emerge above the matter-life boundary, generally corresponding to 'perceptive, living creatures'. Non-sentient holons are those that occur below the matter-life boundary. From an ecological perspective, one of the distinctive differences between sentient and non-sentient holons is that sentient holons (living creatures) have the capacity for 'perception' and 'adaptation', and in the process, have developed additional capacities for both sensing and registering environmental conditions, and changing environmental conditions as part of the adaptation process (e.g. see Wicken, 1987 for an elaboration of this ecological perspective).

The distinction between individual and social holons, in this context, is that an individual holon has a 'dominant monad', and has some form of discernible physical boundary (i.e. an animal or a person) (Wilber, 2002). A social holon does not have a dominant monad, but rather, is characterized by a 'regnant-nexus' of inter-subjective (internal) and inter-objective (external) interactivity among holons (e.g. a flock of geese, or human societies). Artifacts can be either sentient or non-sentient, or 'hybrid' holons that are created by sentient holons to provide some form of extended functional utility (e.g. a beaver dam, an automobile, an information system, or biological weapons). By contrast, a 'heap' is any holon that is progressively undergoing self-dissolution (Tenet 2d), losing its intended functional integrity, or innate drive for higher telos. Human holonic artifacts are often used to mark eras in the development of human societies from hunter-gatherer, to horticultural, to agrarian, to industrial, to information societies (in the lower-right quadrant of the AQAL framework). In all cases, artifacts are created to serve or extend some human function, and in many ways have augmented our ability to adapt to environments that would not otherwise be possible. Here, we focus specifically on the use of 'information and communication media' (ICM) as material holonic artifacts of human information processing and communication.

Information and Communication Media (ICM)

Information and communication media (herein referred to as ICM) emerged in various forms throughout history, from stone writings and pictures, to the development of languages and script, to books and libraries, to radio and television, to advanced computer networks. Each new form builds upon the preceding forms, which is stated in the holonic tenets as the lower (or previous) sets the possibilities of the higher (or latter). Today's advanced computer and telecommunication networks are the most advanced form of ICM development, affecting not only how we capture information about ourselves and our environment, but also the rate and quality of information that we communicate with each other. Whereas most artifacts of the industrial era serve to function as extensions of human needs for 'mechanical' work (corresponding with matter and the body in Figure B- 2), ICM extend the function of 'mental' work (corresponding with the mind or the noosphere in Figure B- 2) (Stonier 1997). From an integral perspective, such a distinction marks a boundary between the body and the mind. Wilber has argued that this distinction marks a shift from the modern industrial era, to the post-modern information era affecting economy, society and culture in all aspects. Our use of ICM is essentially 'cybernetic', and this has significant implications for the fields of geography, cartography and geomatics.

ICM serve as an extended storage medium for both short-term and long-term memory, and partly a communication medium that significantly reduces the space, time and effort required for transmission of information among people. They also function as new environmental phenomena unto themselves, enhancing human imagination, and further reinforcing cognitive development and other aspects of human potential, complexity, and interaction. The emergence of modern and post-modern forms of ICM raises a number of important questions. Although mechanical artifacts serve well to extend human mechanical work functions, to what extent do ICM serve their intended function? Can the fullness of the human mind and experience be replicated in, or by, ICM? To what extent do ICM contribute and redirect the human mind and experience (from alternative pathways that might have otherwise occurred)?

These types of questions are central to various philosophical debates in information theory, such as whether artificial intelligence will ever supersede human intelligence (depending, of course, on how we define 'intelligence'). While such questions are not our primary concern here, some aspects of these questions are relevant for developing a working model of information, and especially for addressing human expectations of ICM in human-computer interaction. This is discussed in later sections of the chapter, but we now turn to an examination of how integral theory supports the view that ICM are constructed to mimic, in many ways, the human mind.

Vertical Levels of Information Processing

If we extend the ecological view of information processing, all 'incoming and outgoing' multi-sensory, cognitive and behavioural activity can be considered as a composite of information processing. All humans and all living creatures are continually processing information received from their environments, and react and behave in response to information they receive. Figure B- 4 summarizes several basic elements involved in information processing from a vertical (or individual) holonic perspective (modified after Eddy, et. al., in press, a). In trans-disciplinary terms – we look at how our common language references notions such as in/out, up/down, top/bottom, higher/lower, or before/after in terms of holonic relations among information processing elements.

Figure B- 4 illustrates some of these basic relationships in terms of data, knowledge, and meaning. The primary upward flow of information is regarded as 'data', which is most commonly defined as raw, sensory-based, factual information. Different types of data (not limited to quantitative or scientific data) can be captured from each of the four quadrants using various methods such as those outlined in Figure B- 2. Retention of all past and current data reconciled in various cognitive capacities, is considered as 'knowledge'. Whereas all data is considered here as incoming (from any of the four quadrants), it is illustrated here as the 'bottom-up' flow (from a holonic perspective). Data that has been retained and previously reconciled with experience as knowledge, exists *a priori* to any current incoming data stream. Prior knowledge works 'upon' incoming data, and therefore is seen to have a 'top-down' influence on the incoming data stream. The updating of knowledge by new data is considered here as *a posteriori* affect. In this view, 'deductive' processes are defined as prior knowledge working upon data (top-down), whereas 'inductive' processes are data working on, and updating, knowledge (bottom-up). All human cognitive functioning involves some complex mixture of both inductive and deductive processing, using corresponding data and knowledge respectively (see Copi, (1982) on inductive and deductive reasoning).

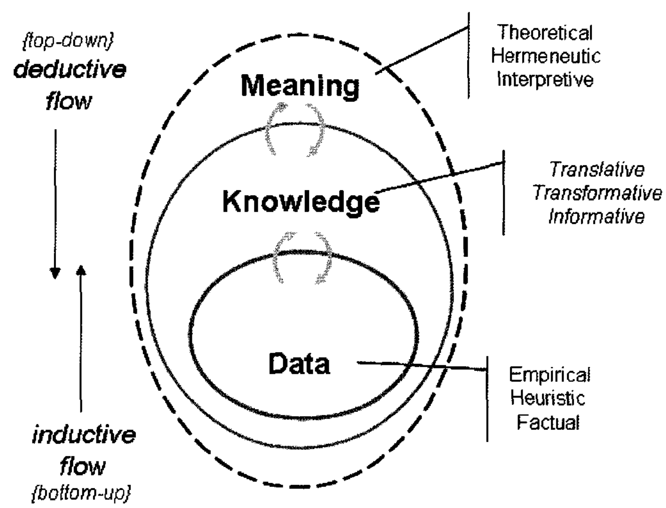


Figure B- 4. Holonic Relations among Data, Knowledge, and Meaning in Information. Modified after Eddy, et. al. (in press, a).

There is also a third general level, or capacity, in all information that goes beyond both data and knowledge that must also be taken into account. For the purposes of this analysis, we will refer to this as the existential level of 'Meaning'. Meaning can be used in a definitive sense to denote or ascribe meanings of symbols within a semiotic stream, and these are necessary for our cognitive capacities to function. More significantly, it is used here in a connotative sense, wherein it is that which gives resonance and reconciliation to both incoming data and prior knowledge 'relative to a given existential context' of experience (as a composite of all three levels). Whereas knowledge supercedes data, meaning supercedes both knowledge and data, and is therefore dependent upon knowledge and data. At the level of meaning, deductive flow is extended by one level, and the inductive flow (from knowledge to meaning) is also extended by one level.

This view outlines the depth, or 'all-levels' aspect of information flow and processing. Data is primarily sensory in that all forms of information have material states of transfer. For example, the reading of this text involves the transfer of photons from the page to the eye. This sensory process is then extended through neurological capacities of the body –through complex biochemical and biophysical processing, and then into the 'mind'. In the collective dimensions, information is embedded in corresponding physiospheric, biospheric and noospheric forms. The emerging internet, mass communications, and the media, may be considered holonic artifacts of a global noosphere, providing us a new level of infrastructure upon which the emerging information economy functions.

In considering Tenet 8, where 'each level produces greater depth, and less span', we see the reflection of many ways of looking at the *hierarchical* dimension of information flow (a *heterarchical* dimension is discussed below). What this suggests, if looked at as a holonic relation, is that there are always more data elements than there are knowledge structures to act upon them. And subsequently, there are always many knowledge structures that are combined to form any given meaning. Looking at it from the top down, we see that any given meaning requires a synthesis of many knowledge elements, which in turn requires synthesis of many more data elements. Applying this model in the collective dimensions gives rise to a plurality of information processing pathways and contexts.

Horizontal Information Transfer and Exchange

A critically important aspect that the AQAL model illustrates is that all singular (individual) information processing contexts do not occur in isolation. There is also a corresponding collective or social dimension that is simultaneously taking place. Whereas the above singular processing streams were treated holarchically as 'bottom-up' and 'top-down' processes in the vertical dimension of holarchy (the *hierarchical* component), the social, ephemeral dimension is treated as the horizontal dimension of inside-out and outside-in relations, referred to here as the *heterarchical* component. Although the general levels and information processing structures (of data, knowledge and meaning) are available in all individuals, the specific contents and contexts of all individual holons are different due to unique circumstances in space, time and place (the information environment). Additional complexity is added by the need to reconcile horizontal information exchange invoked by differences of experience and perspective among individuals.

Integral theory makes use of the concept of 'involution' as a top-down (or from higher to lower) pull on evolutionary processes (as derived from the philosophical perspectives of Teilhard de Chardin, (1969)). This is to say evolution (through bottom-up, inside-out holonic relations) proceeds by way of involution (top-down, outside-in holonic relations). More simply, in order for something to evolve (as an agency, or a whole unto itself), it must simultaneously 'involve' (as in a communion, or a part of a social holon). Evolution can be seen as that which 'ascends' hierarchically, and involution can be seen as that which 'descends' heterarchically through horizontal exchanges among ‘agencies-in-communion’. The convoluted mixing of individual contexts and circumstances are what constitute the horizontal or relational aspect, as summarized by Tenet 11. Content-context relations can also be examined using this tenet, wherein they carry intrinsic levels of depth and extrinsic extensions of span across social holonic space, and serve to qualify information for its authenticity (depth) and legitimacy (span). At this point, it is helpful to incorporate an understanding of ‘entropy’ as it may relate to information processing.

Information Entropy

If individual contexts could be quantified, considering all dimensions of space, time, circumstance, or 'place' of any group of individual contexts, then the number of 'possibilities' of content-context relations expand exponentially as the number of individuals involved is increased together with the complexity of the levels within which information is processed. Here, the concept of 'entropy' is useful as a means for conveying the intrinsic aspect of these relational possibilities. Wicken (1987) examines entropy as applied to information in the context of the evolution and emergence of complex living, self-adaptive systems. As Wicken’s analysis reveals, ‘information entropy’ is not always (nor necessarily) synonymous with disorder, randomness, or noise, but rather pertains to the 'number of possibilities' available to any given micro-macro (or content-context) relationship. Our adaptation of this view is that entropy is not limited to measuring the complexity of information 'content', but rather information 'activity' will contain corresponding levels of complexity in relation to the depth and span of content-context relationships.

A generalized relationship can be stated that the 'higher' the information processing through the three general levels of data, knowledge, and meaning (or depth), and the 'wider' the number of potential contexts to which some information potentially applies or is used (the span), the higher the entropy of information. In this analysis we are concerned with different orders of information entropy associated with primary (data-oriented), secondary (knowledge-oriented) and tertiary (meaning-oriented) levels of a cybercartographic processing environment.

This general understanding is used as a central feature in examining the concept of cybercartography from an information processing perspective. Essentially, we view cybercartography as aiming to address the higher entropy 'meaning-oriented' levels of information processing and use in society, where the same content (map or map elements) can have virtually unlimited numbers of potential contexts (users, interpretations, or meanings derived from the content). This level necessarily transcends and includes the many sciences, technologies, and disciplines engaged in the data and knowledge levels of an information process. It is therefore useful to construct a synthetic model of information processing that helps to differentiate these levels and domains, to help bring clarity to the types of integration necessary in any given cybercartographic environment. Before doing so, we summarize some of the main elements from this integral analysis.

Summary of Integral Elements

The preceding sections introduced some of the basic elements of Integral Theory and examined how it can be applied to better understanding 'information', in particular, within the context of geographical information and communication in cybercartography. This integral perspective leads to the following general statements:

- Information is intrinsically holonic, in both individual and collective capacities, and with both interior (personal/cultural) and exterior (expressive/societal) forms.
- Any complete information package includes three general levels of 'data', 'knowledge' and 'meaning'. The intersections of these three levels become increasingly complex as the number of individuals that an information package aims to serve increases, corresponding with higher degrees of information entropy.
- Information is processed in sequential, hierarchical, evolutionary patterns in response to non-sequential, heterarchical, involutionary needs and demands.
- ICM aim to mimic human information processing capacities, but in themselves are not (presently) 'sentient' processing environments. Human-computer interaction is essentially an interaction between sentient and non-sentient ecological entities (people and technology), and this has a significant influence on how we approach human-computer interaction.

- All information processing occurs within broad cultural-societal contexts, within which individuals are situated and therefore have differences in perspective and user context.
- Information systems and maps 'emerge' in response to needs within the context of human affairs.
- Information artifacts may emerge as some combination of bottom-up (or science/technology 'push/supply') activities and top-down (or market 'pull/demand') requirements. The aim of cybercartography is to find an appropriate or optimal balance within this dynamic, non-linear interaction. Here the perspective of second order socio-cybernetics as outlined in chapter one and by Martinez and Reyes later in this volume is informative (Chapters IV, V, and VI).

We now turn to looking at how these elements can be used to synthesize a number of multi-disciplinary and inter-disciplinary perspectives on information and cartographic theory.

Integration and Synthesis

In this analysis, we highlight in Figure B- 5 four models that cover the disciplines of Critical Theory and Science Studies (Latour, 1999), Information and Organizational Management (Reeve and Petch, 1999), Systems Engineering and Ecological Interface Design (Rasmussen, 1999), and Visualization and Cartography (Lindholm and Sarjakowski, 1994).

Latour's work (and others like it) provides an important starting point to allow questions to be asked with respect to the societal needs and circumstances in which cybercartographic applications emerge. His relationship between *dictae* and *modis* is considered as one form of content-context relationship; the *dictae* representing the content of information, and the *modis*, the societal circumstance within which the content emerges.

Extending this model to fit more closely with a systems-environment level, another form of content-context relation is evident in Ecological Interface Design (EID). The more immediate environment of a given information system can be considered a 'micro-modis' nested within a broader societal context. Encompassing a holistic approach to system design, taking into consideration the electro-mechanical constraints of a system and the human environment, EID makes use of an 'abstraction hierarchy'. Bottom-up and top-down interactive flows are considered in relating low-level, physical objects and specific functions and processes (considered here as non-sentient ICM and their information contents), to high-level, more abstract process-oriented environments (sentient human environments).

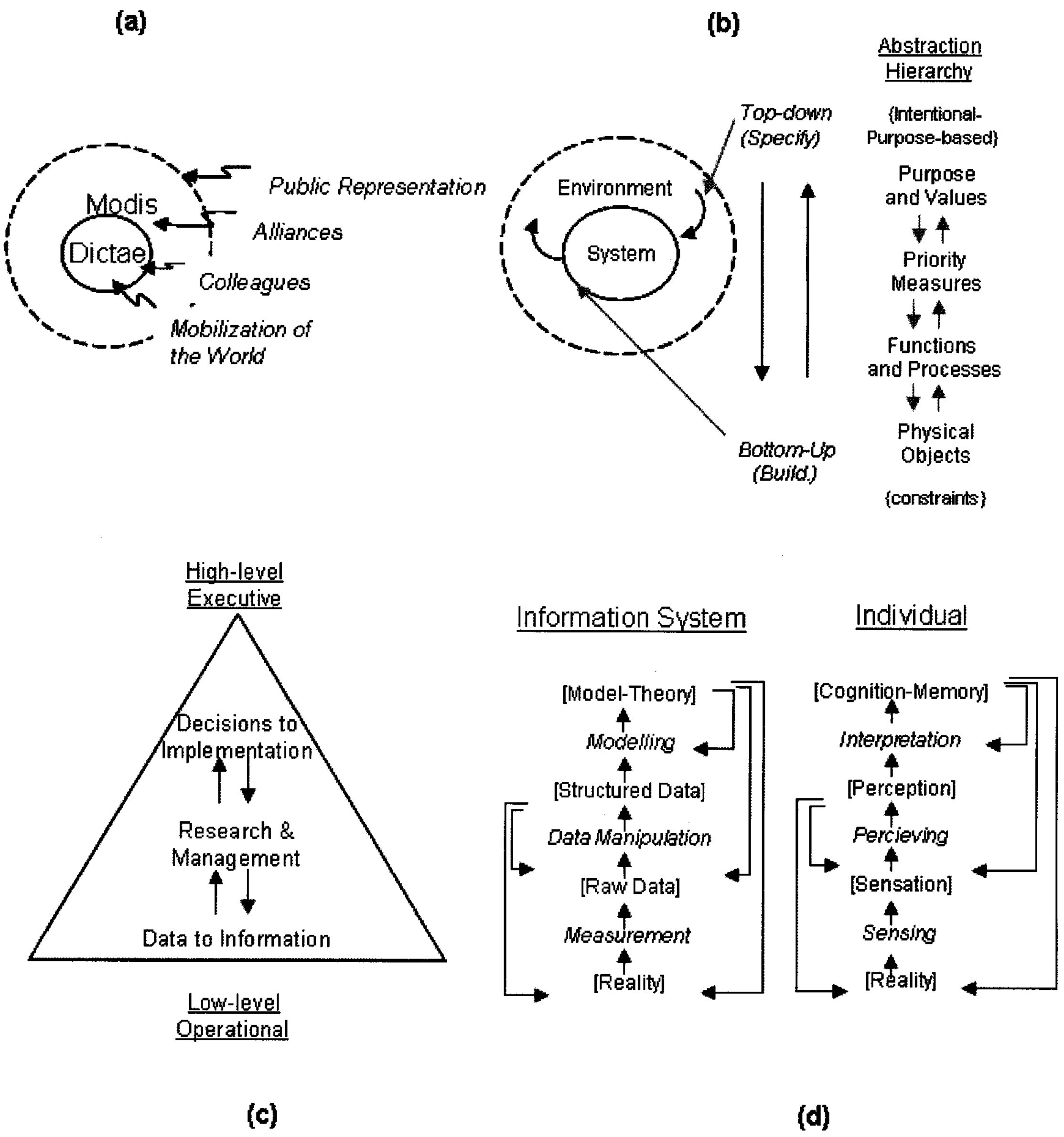


Figure B- 5. Multiple perspectives on information flow and use adapted from (a) Latour (1999) in Science Studies, (b) Rasmussen (1999) for Ecological Interface Design, (c) Reeves and Petch (1999) on Information and Organizational Theory, and (d) Lindholm and Sarjakowski (1994) in Visualization and Cartography.

The organizational pyramid model presented by Reeve and Petch (1999) extends many of these aspects of information processing to an organizational scale. As with the EID model, their model also emphasizes top-down and bottom-up dimensions of information flow. Lindholm and Sarjakoski (1994) present interactive flows more explicitly as parallel distinctions between that of the individual user (a sentient processing holon) to those of an information system (a non-sentient holon). Their model reveals a more explicit linkage between system components and information processing stages as mirroring similar information processes and capacities in individuals. In this scheme, primary measurements and observations about the world, as represented in raw data, extend the human sensory capacity to an ICM form. Structured data and models/theories embedded in ICM extend higher level human cognitive functions. Note also their explicit reference to top-down and bottom-up information flow and feedback functions.

The inclusion of these particular models highlights a number of general aspects that we believe should be considered as a minimum in any cybercartographic application. We used these four models to highlight different scales as follows:

- **Societal Level** – how and why cybercartographic applications and maps are used in society, and to draw from various schools of critical theory, science studies, and post-modern studies of the emerging information society, including socio-cybernetics.
- **Organization Level** – how information is used at an individual organizational scale, and the relations among mandated organizations, all of which are nested within broader societal contexts.

- **Information Processing Level** – how information is structured, stored, processed and managed internally within a cybercartographic environment in ways that mimic human information processing, nested within a variety of organizational contexts.
- **Infrastructure Level** – designing, engineering and maintaining systems to adapt to ever changing human environments; again, nested within and supporting all of the above levels.

To provide additional support for this approach, we propose a synthesis of these models that can be used as a guideline or 'map' for finding our way through a cybercartographic environment. This constitutes one of the directional sign posts for the paradigm of cybercartography as discussed in chapter one.

A Cybercartographic Human Interface (CHI) Model

A synthetic 'Cybercartographic Human Interface' (CHI) model is illustrated in Figure B- 6. This model combines some of the main elements of each model presented above, and follows the principles derived from an integral perspective on information flow and use. First, we outline three broad domains for consideration: 1) A Cyber Domain (or Cybercartographic or Content Processing Domain), 2) A Human Domain, and 3) An Interface Domain.

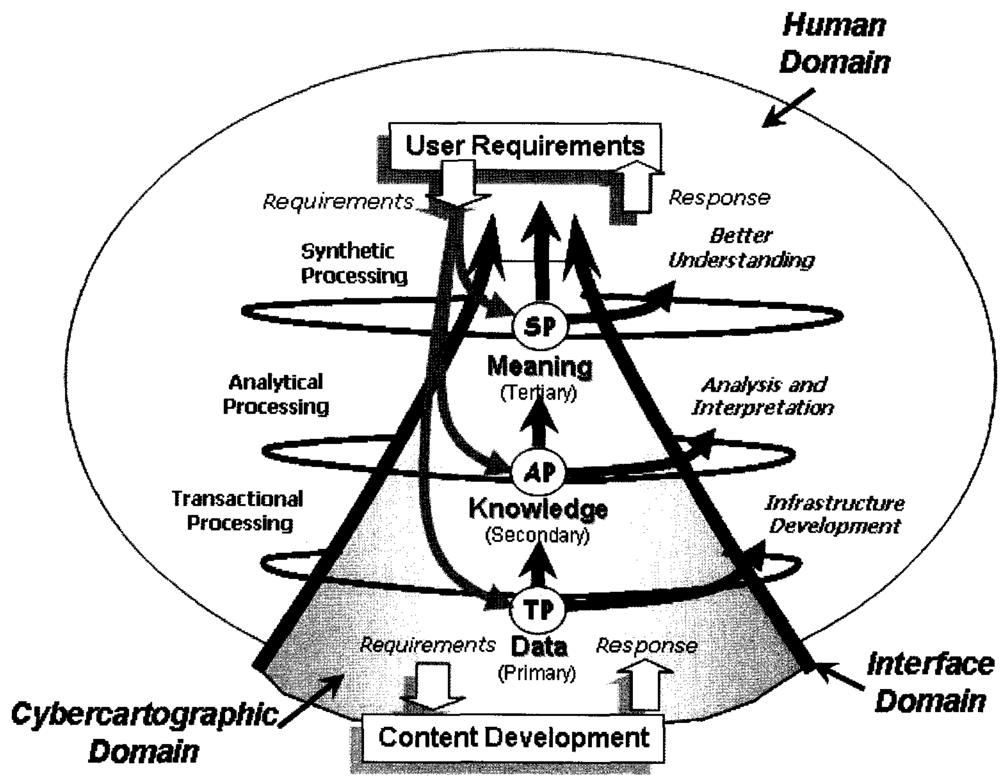


Figure B- 6. A Synthetic Cybercartographic Human Interface (CHI) Model. Note: TP, AP, and SP refer to interfaces appropriate for transactional processing, analytical processing, and synthetic processing respectively. See text and Table B- 2 for additional information.

Any ICM used in a cybercartographic context is considered to be a Cybercartographic Domain. The societal, organizational and operational environments in which applications are used is considered the Human Domain, and the various points of direct interaction between people and the cybercartographic domain comprise the Interface Domain. In this model, we prefer to make an important distinction between 'Human' and 'User'. Many computer-user models focus on normative approaches to understand user needs and behaviour at the immediate interface level of human-computer interaction. Some of these approaches are described in subsequent chapters in this book such as that by Lindgaard and Brown (Chapter IX), Roberts et. al. (Chapter X), and Trbovitch et. al. (Chapter XI). Such studies are of great value to cybercartography, but we believe it is important to also consider users in a broader societal or 'human' context (considering methods such as critical and social theory of information, or broader philosophical and aesthetic perspectives). A socio-cybernetic approach to cybercartography as described by Martinez and Reyes in this volume (Chapter IV, V, and VI) is an example of the value of this broader societal and cultural context in creating cybercartographic products.

In addition, no distinction is made between 'providers' and 'users' in this model because of the dialogical dynamics involved in cybercartography. We view cybercartographic applications as constructed, maintained and used by people who fill a variety of roles and levels of expertise at different stages in the process. A programmer, for example, may eventually be a user of an application, and similarly, a high school student may add content to an application, or embed one application within their own.

More significantly, it is important to differentiate and place emphasis on the human-sentient environment within which non-sentient ICM emerge. The characteristics of each of the three domains are fundamentally different, and often diametrically opposite in many ways. Some of the more significant challenges occur at the 'interface' of the cyber and human domains. Interface designers must take into consideration both the scientific and technological aspects of the cyber domain, as well as the broader human and cultural context for which the content is intended.

Figure B-3 depicts both vertical (hierarchical) and horizontal (heterarchical) dimensions as a series of successively nested content-context relationships along different levels of information processing. The three broad levels considered here (in Figure B- 6) are data-oriented (primary), knowledge-oriented (secondary) and meaning-oriented (tertiary) application environments. Elements from Lindholm and Sarjakowski's model, or other models of information processing may be used to provide additional detail. It is our belief that most cybercartographic applications aim to support tertiary level requirements, but unlike conventional maps and cartographic systems that remain detached from their primary and secondary information sources, a cybercartographic environment provides the possibility for maintaining access to multiple levels of information, supporting different levels of general public or general purpose use, to policy and scientific analysis, to experts and organizations who collect and maintain primary information sources.

The triangular information flow depicting the cyber domain also captures Taylor's three dimensions involved in cartographic visualization and communication (Taylor, 2003), whereby the principal elements of cybercartography intersect in different ways at each level. The funnel symbol in Figure B- 6 may also be used to symbolize organizational and information pyramids, whereby larger volumes of primary data are condensed into smaller volumes of synthetic information packages at the tertiary level. An important differentiation is also made with respect to the different types of interfaces that correspond to different levels of information processing. Interfaces that are used by the general public or for educational purposes have different requirements and operational environments than interfaces used in analytical or transactional levels. Table B- 2 summarizes additional characteristics for these three general levels.

Primary content that flows upward to a secondary level is often subject to the application of statistical or theoretical models, or at least, selection and processing criteria stipulated in part by some specific need. This is equivalent to what Pulsifer has identified as *geographical mediation* in the cybercartographic process (Pulsifer and Taylor, Chapter VII). It is the deductive element of prior knowledge working upon primary data, which when implemented in a standardized spatial data infrastructure, involves selecting aspects of geographic data that are required for analysis and presentation. The retrieved data stream, in turn, updates the secondary level of knowledge, and this process is often iterative and heuristic.

Secondary level content is considered to be primarily objective-based information set in a knowledge-oriented context. Different theories and models can be applied to the same data, which often yield different results and interpretations, and this signifies the introduction of an increasing element of subjectivity in the processing stream. The choice of model or analysis is partly dependent upon the intended or desired application of the information output at the tertiary level. Tertiary level information aims to contextualize secondary content through the addition of 'meaning' for specific contexts. The transition from secondary to tertiary level representation and synthesis is equivalent to Pulsifer's 'cartographic' mediation. This is often a very challenging boundary in the development of any information system, because tertiary level information carries higher degrees of entropy. But it is also the level to which aesthetic creativity and innovation can be applied more freely in making information more appealing and meaningful for an intended user base. As argued by Taylor in chapter one, cybercartography is both an art and a science and is qualitative as well as quantitative, and all of these factors need to be taken into account in interface design and content development.

It is important to note that Figure B- 6 is a simplified and somewhat idealistic representation of a singular CHI context, such as an individual organization, or a specific cybercartographic application. In reality, no organization or geographical information environment exists in isolation. Each CHI context is at least partly dependent upon information flow from other CHI contexts (domains in other organizations). This is similar to the importance in differentiating individual and social (or collective) holons with respect to their mutual inter-dependencies. In the collective domain, different CHI models necessarily interact on different levels. Although primary, secondary and tertiary levels can be differentiated internally within a given CHI, they are 'relational' in the collective dimension. Secondary level content from one organization may serve as a primary input to another, or tertiary level content from one domain may serve as a secondary input to another CHI domain.

Conclusion

Although cybercartography appears primarily oriented around tertiary level applications, all such tertiary level applications 'transcend and include' primary and secondary issues and environments in some way. The construction of a cybercartographic atlas, for example, must take into account the CHI environments and types of information processing that need to occur on the primary and secondary levels. It is the potential for this interconnectivity in both vertical (intra-domain) and horizontal (inter-domain) dimensions that marks a significant distinction between conventional cartography and cybercartography.

Table B- 2. Characteristics of Cybercartographic Human Interface Levels.

	Primary	Secondary	Tertiary
Inputs	**Internal:** recorded observations and measurements that are of primary importance to the CUI context. **External:** outputs of other domains that are similar or related to the primary level of the internal CUI domain.	**Internal:** any output produced on the primary level, the selection of which, is framed within the context of a given theoretical framework. **External:** outputs of other domains that are similar or related to the secondary level of the internal CUI domain.	**Internal:** any output produced on the secondary level, the selection and presentation of which, is framed according to its higher level meaning in a given context. **External:** outputs of other domains that are similar or related to the tertiary level of the internal CUI domain.
Processing and Mediation	**Transactional Processing:** Primarily those associated with validating and authenticating primary data, structuring, organizing, and management according to working data models.	**Analytical Processing:** analysis of patterns in primary data according to various theoretical and knowledge-based frameworks constructed from prior experience.	**Synthetic Processing:** reporting and presenting secondary information (and where necessary primary also), for specific contexts and intended use. Tertiary products provide meaning to an immediate context of decisions relating to real world affairs.
Outputs	**Internal:** extracted data elements that are fed upward to the secondary level **External:** outputs of primary data elements to other domains (for primary, secondary or tertiary level input)	**Internal:** secondary, knowledge-based products that are fed upward to the tertiary level **External:** secondary outputs to other domains (for primary, secondary or tertiary level input)	**Internal:** different types of secondary content that are meaningful to a particular context. **External:** tertiary outputs to other domains (for primary, secondary or tertiary level input)
Infrastructure	Generally more complex matrix of data recording instruments, with VLDB (very large database) capacities, restrictions, and highly specialized operations.	Generally more localized matrix of analytical processing tools, with moderate (often temporary) storage capacities, less restricted, but still may be highly specialized operations depending on the types of analyses.	Generally tools that are most commonly used for broad public consumption, and compatibility within a full range of possible end-user environments (web browsers, office desktops, CD/DVD, personal communication devices, multi-media),
Types of Interfaces	Very technical and highly specialized depending on the primary data, on-line transactional processing (OLTP)	More analytical oriented tools, expert systems, or on-line analytical processing (OLAP)	More product/report oriented tools that allow ease of use, general purpose interfaces, regarded here as on-line synthetic processing (OLSP)
Visualization, Abstraction and Cartography	Primary control, calibration, abstraction as data symbolization and modelling, visualization and representation of primary data. Cartography as a component of transactional processing/map-based data capture.	Multiple forms of higher abstraction and scientific/analytical visualization, geographic and non-geographic, cartography as internal to GIS science.	Visualization and abstraction, as part of a realization process and enacting of real world context and use. Broader, and more immediate domain of cybercartography. GIS science as internal to cybercartography.
Communication and User Base	Complex and specialized and often restricted and highly secured communication networks, limited technical user base.	Localized and somewhat less restricted communication networks, limited scientific/analytical user base, often in clusters of specialized communities	Broad communication networks, multi-media, both public and private, potentially very large user base (i.e. public internet environments, mass media)
Examples	Primary geospatial data collection (field to computer, GIS/GPS input, remote sensing capture and calibration), different forms of geographic and non-geographic transactional processing.	Specialized GIS modelling and applications (e.g. forestry, resources, environmental, human demographic modelling), policy and scenario analysis. Non-geographic knowledge-mapping (e.g. AQAL map).	Educational, mass communication, public education and information consumption. Day-to-day pragmatic use. Simplified, intuitive and easy-to-use cybermaps.

Different types of interfaces and corresponding infrastructures are usually encountered at these different levels. If connections to these levels are retained in a cybercartographic environment, these need to be considered in the vertical integrative dimension. The concept of 'intra-operability' in the vertical stream must also be considered with 'inter-operability' issues in the horizontal exchange dimension. There are not only different infrastructures, but contrasting human domains, which from an operational standpoint are often culturally different. Different levels and types of decision-making need to occur to permit information to flow from one level to another, and inside and outside of any given domain. The CHI model may also be used to examine visualization, abstraction and cartographic practices associated within different levels. These suggestions indicate that a variety of cartographic practices and different forms of visualization are to be expected in these environments.

If there is something unique that integral theory offers to cybercartography, it may be its panoptic view of where we find ourselves at the pioneering edge of the emerging information age in laying foundations for new forms of visualization and communication about the world. Wilber draws an approximate contour associating formal-operational cognitive capacities with modern rationalism, and he uses the term 'vision-logic' to denote higher and deeper level cognitive capacities that transcend (and include) rationalism and modernity into post-modern forms of representation, discourse, epistemology, expression and being. Vision-logic is essentially 'trans-rational', and therefore more apt to better contextualize levels of meaning beyond strictly factual or codified knowledge, and is presently emerging as the next wave of human consciousness. Formalisms, as represented in various texts, narratives, statistics and conventional maps, all have limited capacity to respond to the increasing need to put very large amounts of information into forms that are meaningful to society. This creates an opportunity for cybercartography to advance itself as an important tool for this emerging vision-logic capacity, as a means to help integrate, synthesize, visualize and communicate very complex information in ways that go much beyond the conventional use of the geographic map, thereby giving maps and mapping a new level of application and meaning in the information era.

Acknowledgements

This chapter is based on research completed by the first author as part of a PhD comprehensive examination in the Department of Geography and Environmental Studies at Carleton University. We are therefore grateful to the members of the examination committee, Fran Klodawsky, Ken Torrance and Iain Wallace, for their constructive and critical review of the integral theoretical framework. We are also grateful to Donna Williams at the Atlas of Canada, Michael Peterson, as well as members of the CANE project for their review and suggestions on earlier versions and presentations. We thank Patricia Trbovich for bringing our attention to the Ecological Interface Design literature. The material contained in this chapter remains the responsibility of the authors.

**Once I rose above the noise and confusion,
Just to get a glimpse beyond this illusion,
I was soaring ever higher,
But I flew too high.**

**Kansas,
Carry On My Wayward Son**

PAPER C

Integral Geography: Space, Place and Perspective

Brian G. Eddy

Dept. of Geography and Environmental Studies,
Carleton University, Ottawa, Canada

Abstract

An integral view of space and place is presented as the concept of Integral Geography, providing an additional basis to examine perspectives in Integral Ecology. An ecological AQAL model is presented that helps situate the diverse scientific disciplines used in geography, giving equal consideration for their respective contributions in knowledge and understanding of the world. Further consideration is paid to a model for incorporating perspectives provided in the arts and humanities in situating scientific understanding in relation to historical and geographical contingency, to that of the aesthetic and cultural aspects of 'being and becoming'. An example GIS-based map model illustrates how biophysical and social holons can be viewed and analyzed from a geographical perspective, and how integral places can be examined for both their similarities and differences.

KEYWORDS: AQAL, Ecosystems Modelling, GIS, Integral Geography, Mapping, Perspectives.

Introduction

One of the most suitable applications of integral theory is its application to geography. The introduction of the concept of 'Integral Geography' is presented here as a basis for addressing questions of 'when', 'where' and 'why' in addition to the 'what', 'who' and 'how' of Integral Ecology. From an integral perspective, ecology is seen as not just a complex web-of-life comprised of energy and material exchange among an uncountable diversity of species, but also as a spectrum of consciousness giving rise to diverse perspectives; including those of humans at different geographical scales of interaction. The study of ecosystem dynamics stands to benefit from considering the role of consciousness and the multi-perspectivism intrinsic to ecological structure, function, intention and behaviour.

Integral theory and integral ecology benefit from the use of multiple forms of expression, representation, and understanding of the world. Such perspectives, to be adequately understood, must also be effectively communicated. The application of geography to integral theory may offer additional means. Augmenting integral narratives with geographical maps may help communicate similarities and differences in perspective, and will more certainly be helpful in examining contemporary issues such as globalization, development, sustainability, biodiversity, and geopolitics.

A literal interpretation of geography suggests it is in many ways about describing events, processes and phenomena happening on the surface of the Earth, and as such, the geographical map represents an important tool for analysis and communication. For many geographers, the practice of describing implies that one also has adequate theoretical frameworks within which observations and descriptions are placed.

Although 'space' is fundamental, it does not always influence or determine a geographer's approach to research. Drawing from as many methods as Integral Methodological Pluralism (IMP) has identified (Wilber, 2002), many sub-fields have advanced different approaches for situating humans in relation to 'place'.

The concept of Integral Geography is presented here with several intentions. First, one variant of the AQAL model, herein referred to as an 'Eco-AQAL' model, is used to tie integral theory, ecology, and the spectrum of sciences used among these disciplines into a more inclusive and comprehensive framework. Second, Integral Geography offers a concept of 'place' as an amalgam of AQAL moments, herein illustrated as a conceptual *phanerogam.* Primary spatio-physical dimensions of the Gross realm are included in consideration of the more esoteric realms of being and becoming, and inner perspectives of space and place. What is conveyed through Integral Geography is the identification of Eco-AQAL tensions that arise in relation to space and place, in particular, with consideration given to different types of holons at different scales of influence, interaction, partnership and conflict. This approach may prove to be important for better understanding how perspectives change in relation to changing human-environment relationships and life conditions.

An Eco-AQAL Model

Integral Theory provides an outline of perceived epistemological-ontological realms in the Kosmos as energy, matter, body, mind and Spirit; or in other cases, as the physiosphere, biosphere and noosphere (Wilber, 1995). One variant of an AQAL ontology for addressing human-environment relations is presented here as an Eco-AQAL model, where the ontological realms are represented by primary global ecosystem spheres differentiated against the AQAL matrix (Figure C- 1). In addition to ensuring the differentiation between external and internal dimensions of each level (and their respective modes of inquiry), this holarchical ordering of ecosystem spheres also highlights the intrinsic dependencies of one level upon another, and corresponds to their relative evolutionary emergence on Earth.

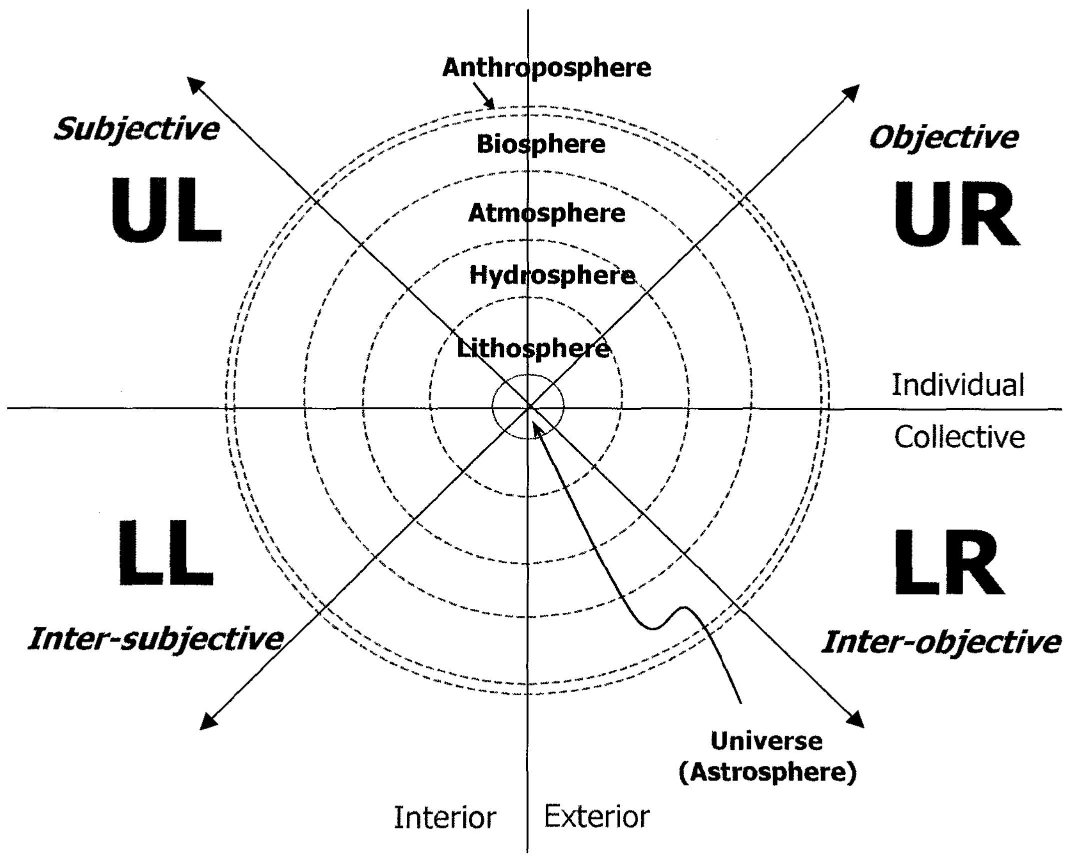


Figure C- 1. Eco-AQAL Model showing holarchical relations among six primary global ecosystem components.

There are several important aspects to this arrangement. First, from a conventional environmental science or ecosystems modelling viewpoint, many conventional ecosystem models often only consider the hydrosphere, atmosphere and biosphere, and sometimes 'land' as primary ecosystem components. The Eco-AQAL model makes explicit the addition and inclusion of the universe (astrosphere) and the lithosphere, and provides further differentiation of humans and the biosphere by demarcating an anthroposphere. This extension of depth (in both directions) presents the Eco-AQAL model as a Kosmocentric model, in contrast to biocentric or anthropocentric approaches. The model makes explicit the intrinsic relations of one level upon another level, and contrasts the more fundamental with the more significant. Wilber illustrates this 'not vice versa' principle through the holonic tenets; if you destroy one level, then all levels above are destroyed, but none of the lower levels. If the biosphere is destroyed, then the anthroposphere is also destroyed, but not necessarily the atmosphere, hydrosphere or lithosphere.

Second, the anthroposphere is proposed here as that which constitutes the place of human activity, dwelling and infrastructure, including the many non-sentient holons (artifacts and heaps) humans have constructed. It is the geographic domain of primary human influence, reflecting a plethora of activity corresponding with the further reaches of the spectrum of consciousness differentiated from those of other species in the biological pyramid. In relation to the noosphere, the anthroposphere constitutes the higher cognitive and moral levels in Wilber's AQAL model, specifically from symbolic/mythic to vision logic, and corresponding moral contemplative capacities. Although the anthroposphere is differentiated from the biosphere in this model, the 'transcend and include' tenet maintains the biosphere as embedded 'in' the anthroposphere, which it therefore maintains its dependency. This integral approach is one attempt to extend and complement (transcend and include) both earlier and more recent aspirations of geographers for comprehensive theoretical frameworks (Kropotkin (1850), Mackinder (1887), Semple (1911), Sauer (1925), Hartshorne (1939), Leopold (1949), and Vidal de La Blanche (1927-48), Harrison and Livingstone (1980), Couclelis (1992), Wynn (1999), Gober (2000), and Gregory (2000).

Figure C- 2 elaborates some of the principal subject-object relations between human-environment boundaries, life-matter, and matter-energy, set in relation to types of holons (sentient and non-sentient), and the pure, natural and social sciences, and humanities, and their own respective holarchical dependencies. An important aspect corresponding to the ontological component of the model is the holarchical arrangement of the spectrum of scientific knowledge corresponding to the different levels (corresponding to the epistemological component).

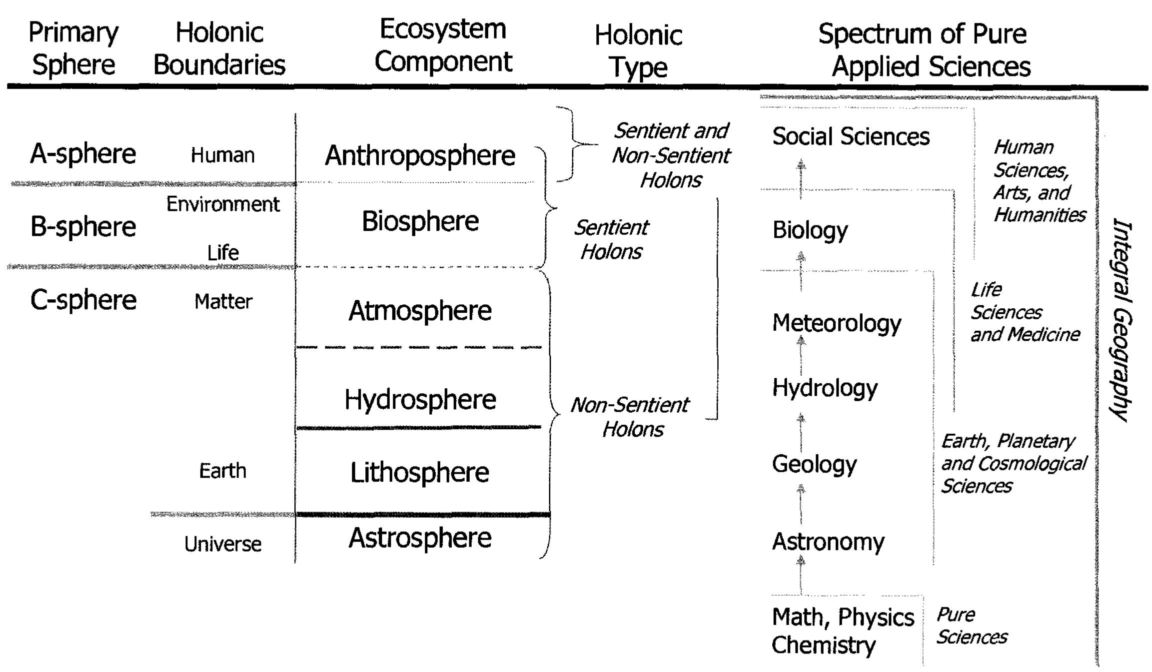


Figure C- 2. Stratified A-B-C Ecosystems Model showing the relations among primary global ecospheres, significant holonic boundary conditions (propensity shifts), types of holons, and the associated spectrum of pure and applied sciences, and the arts and humanities.

This model begins to address some concerns of feminist geographers, as expressed by Harding (1986, 250), where physics and math are not placed dominantly at the top of the spectrum (as was done by the Vienna Circle), but are more appropriately placed at the bottom of the spectrum (being more fundamental to all other sciences). The pure and natural sciences are positioned at the bottom of the holarchy relative to their objects of study, and their respective grooves or probability waves (Wilber, 2002). From an integral perspective, the lower the level, the more *fundamental* the knowledge base (and therefore more persistent). The higher the level, the more *significant* the knowledge base (but less persistent).

The astrosphere initializes an understanding of space-time relations (in mathematics) and substance (through physics and chemistry); the lithosphere, hydrosphere and atmosphere can be regarded as the 'solid, liquid, and gaseous' components corresponding to geology, hydrology, and meteorology (the Earth Sciences), and the biosphere is covered by the biological sciences (or Life Sciences). The anthroposphere is represented by the social science and humanities fields (Human Sciences), which in an integral context, would necessarily include, and be dependent upon, knowledge contained in all of the preceding sciences (but not restricted to, nor reduced to those sciences). In their entirety, each science would necessarily employ different combinations of methods provided for in the integral methodological pluralism (IMP) approach. The Eco-AQAL model is also intended to provide some guidance in outlining a comprehensive research approach. The horizontal and vertical dimensions of holarchy (hierarchy and heterarchy) appear to correspond well with the *intensive* and *extensive* approaches (respectively) to research identified by Sayer (1992, 242); and further identifies alternative approaches for framing latitudinal (extensive, horizontal) and longitudinal (intensive, vertical) studies.

Extending the claims of integral theory, it is also recognized that data and knowledge alone (science) cannot solve ecological crises. Decision-making contexts necessarily require transcending and including both hard and soft scientific knowledge within the contemplative realm of being and becoming. What can be made known or interpreted by the sciences through Eco-AQAL modelling, must be further situated within a broader trans-holarchical realm of 'being'. The arts and humanities are positioned at the top of the disciplinary holarchy to situate scientific knowledge within the moral, ethical and aesthetic realms of decision-making concerned with human and ecosystem well being. The following provides an aesthetic model for situating science within these contemplative capacities.

An Integral Phanerogam

Much of what is presented in the Eco-AQAL model is oriented around what can be disclosed by the sciences. In one way, it is seen to represent the evolutionary dimension of the world. Exploring present and future AQAL moments requires transcending scientific knowledge; which from an integral perspective, involves bringing the human contemplative capacities to the fore. These capacities are considered to be 'transcendent', partially because they in fact do transcend conventional knowledge of the past and present (all science and reason). The contemplative realm embodies 'paradox' as a means of expression, and to accommodate both the logical and the paradoxical in one expression, a mandalic-paradoxical construct is proposed that makes room for all that can be disclosed through science (the evolutionary dimension), while also considering the dimension of being and becoming among individuals and communities (the involutionary dimension). It is at this point where grounds for 'place' in the base AQAL model begin to appear more vividly.

As Wilber (2002) elaborates, each moment at each location is a shifting AQAL matrix. Being in the world appears as a constant shifting transition along the boundary between evolution and involution (i.e. past, present, and future; here, there and everywhere). Involution is invoked not only by knowledge of past occasions, but desires to transcend circumstances and a broadening of perspective in response to historical and geographical contingency. In society and human-environment relationships, AQAL tensions arise, in part, from a myriad of complex and convoluted intersections between evolutionary and involutionary currents. The broader the social base under consideration (i.e. from individual or local communities to the world at large), the more complex and multi-layered the contours of these tensions appear. Notwithstanding the complexities involved, integral theory provides a general construct upon which tensions may be examined at a variety of geographical scales and perspectives.

The intersection of evolutionary and involutionary currents can be visualized in different ways. Here, a conceptual *phanerogam* is provided as a base template to situate people, communities, or any holon as *places* of integral moments and their historical pathways and pathologies (Figure C- 3). The term phanerogam is used metaphorically to accommodate AQAL moments arising from a combination of both closed (bounded, immanent) and open (unbounded, transcendent) dimensions. Figure C- 3 illustrates the holarchical relations among the Gross and Subtle realms (i.e. their transcending and inclusive relations), and also attempts to convey the convoluted pathways that emerge from the intersection between the evolutionary (ascentionary) and involutionary (descentionary) realms. Their intersection gives rise to complexity and diversity in all locations of space, time, substance and circumstance; and to many forms of situated knowledge and partial perspective (Haraway, 1991). Gross realm manifestation varies considerably, giving rise to diversity in both inter-objective and inter-subjective structures and pathways in relation to place.

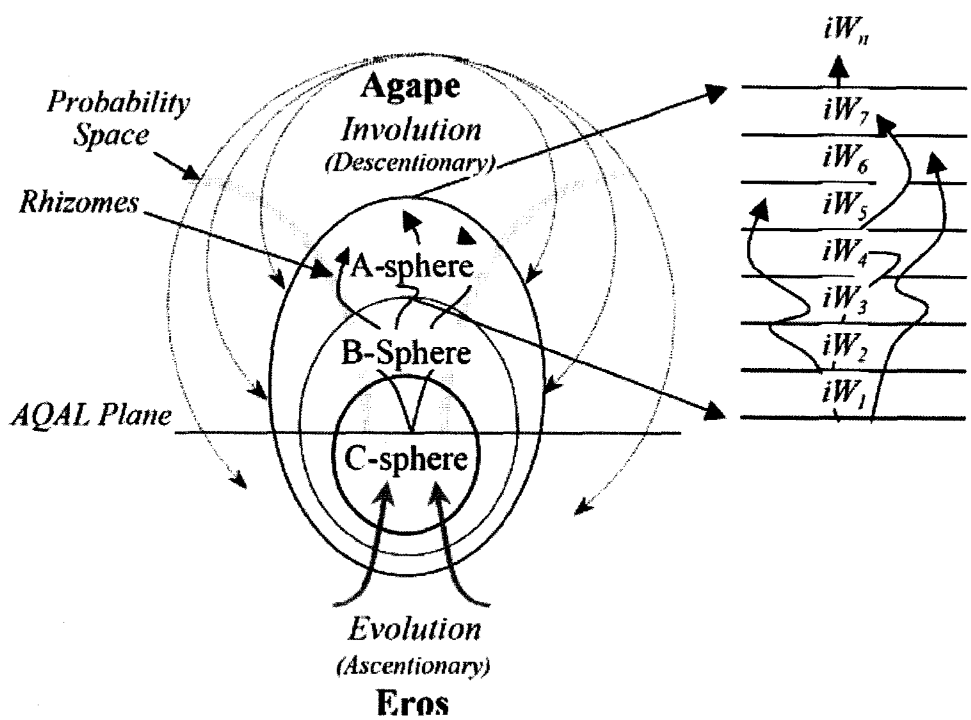


Figure C- 3. Integral '*phanerogam*' illustrating Hargens (2002) concept of the 'rhizome' as pathways of emergence, set in relation to the A-B-C Eco-AQAL model. See text for elaboration of iW*n* nomenclature.

Hargens (2002) proposes the use of the term *rhizome* to depict the many unique, complex and convoluted pathways of emergence with focus on human pathways of consciousness. His analysis presents an overlay of rhizomes upon Wilber's spectrum of consciousness model, illustrating that although the general structure and levels of the spectrum appear to pre-exist (in a hindsight ontology), the actual pathways that individuals and communities manifest against this background can be quite variable. Each rhizome can be thought of as either a collective or individual pathway, or as lines or sub-dimensions of individual or collective pathways. Pathways and pathologies emerge from reconciling tensions of evolutionary development, which are simultaneously and continuously invoked by the pull of the involutionary realm.

In an ecological or integral geography context, rhizomes (or rhizome complexes) can be seen to emerge from unique circumstances of past inheritances; specifically those relating to dependencies and constraints of human existence (A-sphere) within the biosphere (B-sphere) and cosmosphere (C-sphere). The upper-right window in Figure C-3 shows several *inferred waves of emergence* (iW0–iW7) that approximate (but are not necessarily equivalent with) the vMeme colours of the Spiral Dynamics model (Beck and Cowan, 1996). Considered here, a set of rhizomes can represent either an individual personality, or a collective socio-cultural profile; each with many convoluted lines (some bent and battered, some striving and thriving). Integral geography aims to identify the relations between the geographical setting of human emergence to constraints and liberties provided by A, B and C sphere conditions as they vary across geographic spaces and places, as well as identify tensions with other communities in the Eco-AQAL complex.

The Geographic Dimension

Wilber (2002) outlines an AQAL *moment* as an AQAL instance that passes through time from the past, into the present, and into future moments. In application to the complexity of world affairs, Integral Geography considers the 'spatial' dimension to pertain to the involutionary, communal, immanent dimension of Kosmic unfolding. Individual holons representing the upper quadrants have a relative spatial location, which in part, defines their partiality within a supra-holonic complex in relation to lower quadrant correlates. Agentic subjective and objective structures of the upper quadrants are partly manifest by their relation to the communal inter-subjective and inter-objective structures of the lower quadrants.

Extending the rhizome concept to the collective requires invoking the geographical dimension at different scales and levels of resolution. When both the temporal and the spatial are explicitly considered as base dimensions in the AQAL matrix, the background, or environmental context for an AQAL moment is comprised of the geographical setting (which includes time and history), from which consciousness and relative perspective unfold. This is one means of representing 'places' that emerge through the ecological holarchy as a basis from which the context of place (as a geographical rhizome) is apprehended.

Integral geography provides a means to explore consciousness from a geo-spatial perspective, and conversely, can be used to examine how space and place can affect consciousness. Consciousness remains a central focus from which human-environment interaction is explored, and from which a variety of other issues may be examined; such as geo-political tensions, ecological and environmental values, socio-cultural settings, levels of techno-economic production, and global trade; to name a few. Figures C-4 and C-5 aim to illustrate some basic applications of this concept. They are used here to expand upon the elements of the *phanerogam* (Figure C-3) in the geographic dimension by respectively elaborating the vertical (agentic, evolutionary, Figure C-4) and horizontal (communal, involutionary, Figure C-5) dimensions of holarchy.

Integral geography requires rhizome complexes be explicitly located by geospatial position as a starting point of investigation. In doing so, unique relations among the A-B-C complex become evident. Figure C- 4 helps illustrate holonic tenet six, which states “the lower sets the possibilities of the higher, and the higher sets the probabilities of the lower”. It can be seen how C-sphere patterns are transcended and included in B-sphere patterns (i.e. certain plants require specific soil conditions, which in turn, form under the influence of underlying rock types and weather patterns). B and C sphere patterns, in turn, set the possibilities of patterns of emergence in the A-sphere. When all three levels are combined in composite, the unique combinations of A-B-C intersections constitute a spatial rhizome complex, or in short, an *integral place* (spaces with A-B-C contents). The two levels of representation are regarded as levels of differentiation (A, B, and C spheres treated separately), and levels of integration (the A-B-C complex treated as a whole). If one is to examine socio-cultural or demographic patterns, or assess levels of consciousness from a geographical perspective, it can be hypothesized that the physical environment within which a portion of the anthroposphere has emerged has inherited both constraints and liberties provided by its bio-physical geographical setting (B and C-spheres). Some of the bio-physical sub-dimensions that might be considered include the local or regional ecology, climate, and physiography (as it might also affect transportation and mobility, and cultural interaction); or the natural resource base to which a region has title for use, economic development, trade and inter-connectivity with other levels of the globe.

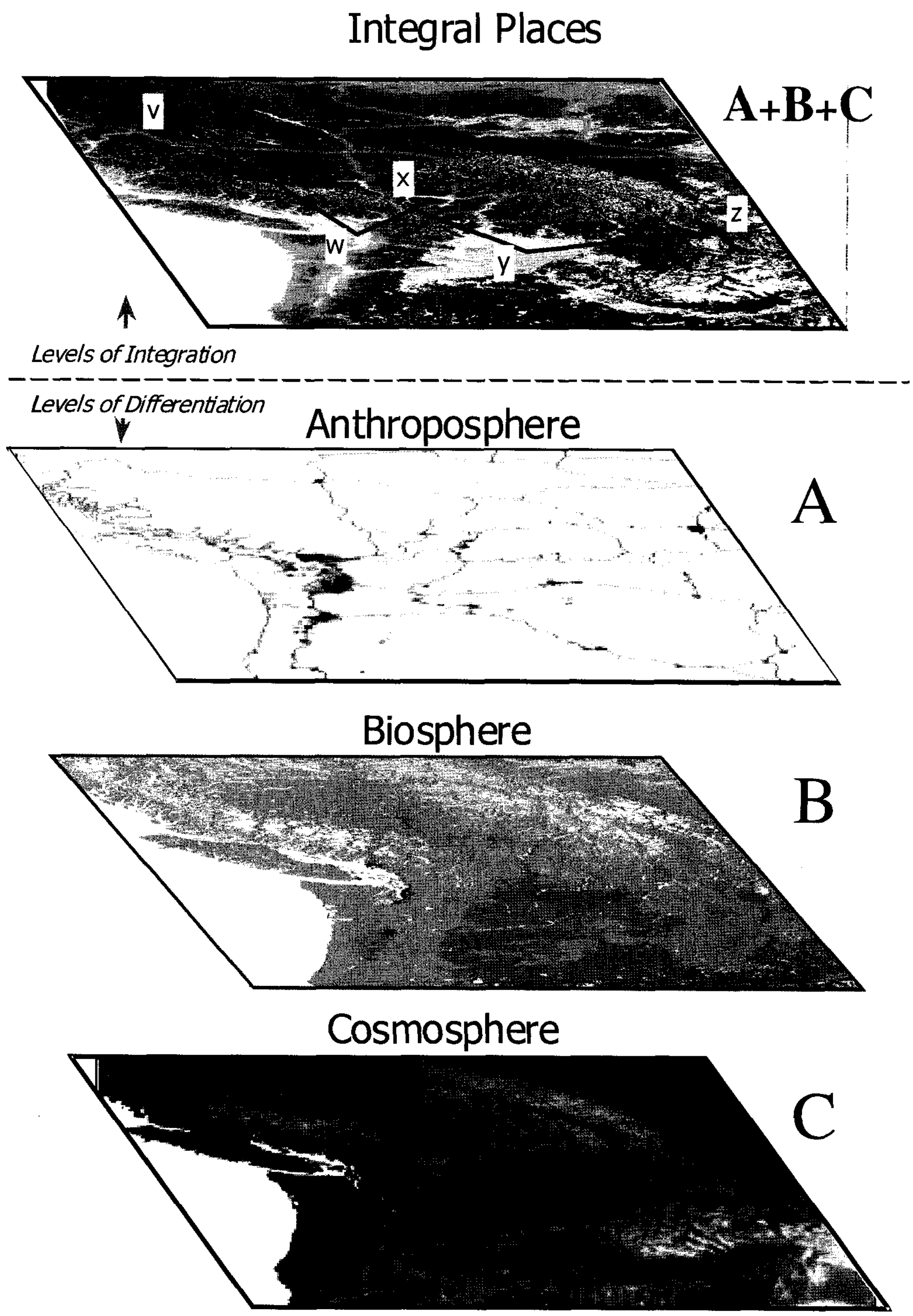


Figure C- 4. GIS-based model for constructing integral places from anthropospheric, biospheric and cosmospheric geographical information layers. See Figure C- 5 for elaboration of V-Z line. (Primary data layers compliments of the United States Geological Survey (USGS)).

Biophysical conditions influence the type and level of technological and socio-economic base attainable on a locational basis. Climate, soil properties, forest and mineral resources, and water-based transportation systems have historically been a major influence on human settlement patterns for all cultures. Modern and post-modern human settlement patterns necessarily transcend and include these histories. This remains particularly important for resource dependent communities in rural and frontier regions (agriculture, fisheries, forestry, minerals, hydro, and energy) for all cultures and areas of the world. Many alternatives are provided by this approach for differentiating and aggregating socio-cultural geographical profiles of the anthroposphere; such as urban-rural and frontier settlement patterns, sub-national, national and trans-national regions, industrial and economic profiles, as well as possibilities for examining similarities and differences in education, language, religious and cultural values.

For human-environment relations explored geographically through the lens of integral theory, several important principles must be kept in mind. Before elaborating those principles, consider the following example. It can be said that the dominant mode of consciousness for North America is centered upon the secular-liberal-free market-democratic values (roughly equivalent with the Orange vMeme in the SD system), straddled by smaller portions of traditional conservatives (Blue vMeme), and pluralistic-egalitarian-ecological sensitives (Green vMeme). Integral geography would examine how such a profile would more literally map against other sub-dimensions of the A-sphere with respect to their geographical location, and in relation to other A-sphere places, as well as examine the constraints of the biophysical environment. This approach is important for considering policy alternatives (e.g. resources, environment, and sustainability) in determining which alternatives are more appropriate for specific socio-cultural-bio-physical contexts. A-sphere complexes are not only influenced by evolutionary constraints of the B and C spheres, but also by involutionary tensions of other A-sphere locations (in the horizontal dimension), and by evolutionary and catastrophic changes in B and C-sphere conditions (e.g. the affects of climate change on land-use and habitat). The example cross-section shown in Figure C- 5 illustrates a number of conceptual socio-cultural profiles (as phanerogams) for a line of inter-connected hypothetical places (a reference cross-section is shown in Figure C- 4).

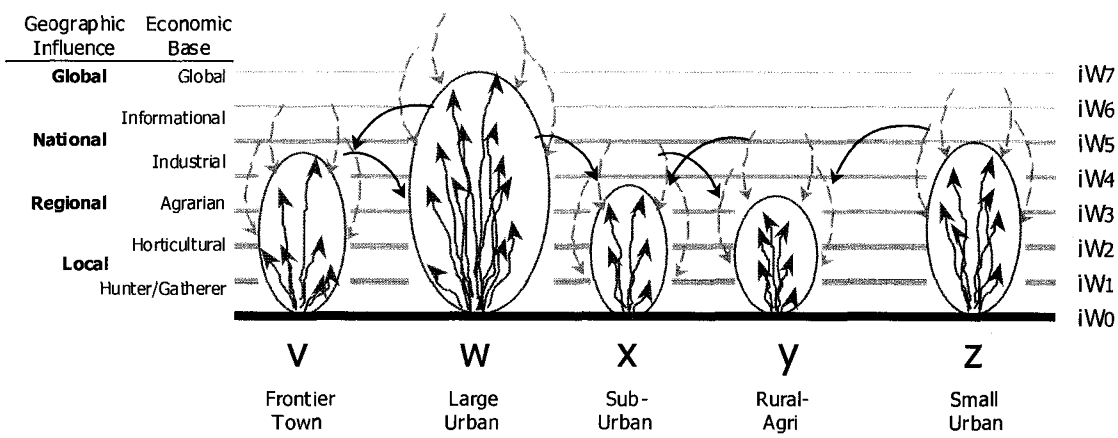


Figure C- 5. Example illustration of integral places and involutionary gradients.

Five types of human settlements are shown for comparison, and although this example is geographically set in the west central North America, similar profiles may be examined anywhere. The five types used here include large urban areas, sub-urban areas (in relative close proximity to large urban areas), rural towns (usually resource dependent communities), small urban areas (smaller cities, or regional hubs), and frontier towns (which may be either native settlement areas, or one-industry towns dependent on mining, forestry or energy-based industries). Example rhizome complexes for each type location are shown against a gradient of the inferred waves of emergence (iW0-iW7). Each level corresponds to an inferred techno-economic mode of production attained by each location.

Two theoretical points of illustration in Figure C- 5 are to demonstrate the range of profiles possible for individual places, and their communal involutionary influences upon each other. Not only does each location strive for success and prosperity (agentic, evolutionary; pulled by the aspirations of its higher visionary waves), each place must negotiate emergence and transcendence in communion with other communities of a region. Such negotiation primarily involves matters of jurisdiction, economic development, trade, community development, and a host of other issues depending on the current state of affairs. Larger populated areas (with higher, more powerful knowledge-power structures) can exert pressures on lower populated areas resulting in suppression of growth, or possible social, economic, or cultural oppression. Integral theory would suggest both positive and negative aspects would need to be examined, and to especially identify levels or thresholds upon which transcendence to new propensity levels are succeeded or dissolved.

Summary

For many contemporary issues, such as globalization, ecology and environment, security, and foreign policy, different approaches for understanding ourselves in relation to the world at large are needed. From a general theoretical standpoint, the concept of Integral Geography presented here adds to integral theory by suggesting that for many applications of integral theory, consideration be given to the 'locational' dimension of AQAL moments when examining consciousness and perspective, which therefore has much relevance to Integral Ecology.

A view from an integral perspective may question what the world will look like five, ten or fifty or more years from now in terms of human consciousness on local to global scales. Integral Geography is proposed to assist in such examination, visualization, and transformation. In order to deal with such issues, Integral Geography would assert that it would be best to first start with more adequate representations of the world, in spite of all of its complexities. The amount of geographical data now available, even on a global scale, is growing exponentially. While limitations of data and knowledge are recognized, it is also important to realize that never before in history have we gathered so much information and insight about ourselves and our global environment. In this 'information age' the time is ripe for applying these data in novel ways, some of which have been outlined here.

From an Eco-AQAL perspective, while much of the focus in contemporary issues is on the anthroposphere; we realize that it is not an isolated anthroposphere, but an emergent that is part of a more inclusive global ecological system, and something more broadly called by us the Kosmos. It is this vantage point that practitioners must keep in mind in order to maintain an integral perspective on issues. Integral geography offers a comprehensive approach to studying the anthroposphere in relation to the biosphere and cosmosphere in terms of examining their structures, functions, meanings and values from a geospatial framework. Through the explicit use of geographical mapping, it is presented here as a means for visualizing our being in the world in ways that transcend, compliment and support the many narratives written about the state of world affairs. In this way, 'integral maps' might offer a tool for transformation and communication. If vision-logic is the emerging wave, Integral Geography may be one of its main tools of analysis, visualization and communication about our place in the world and the Kosmos.

I'm a stranger here on this place called Earth
and I was sent down here to discover the worth
of your little blue planet, third from the Sun,
Come on and show me what you have done.

Five Man Electrical Band
I'm a Stranger Here

PAPER D

The Use of Maps and Map Metaphors for Multi-disciplinary Integration in Geography: A Case Study in Mapping Indicators of Sustainability and Wellbeing

Brian G. Eddy

Dept. of Geography and Environmental Studies,
Carleton University, Ottawa, Canada

Abstract

Maps hold a unique place among media for the storage and communication of information and knowledge. Maps that model human thought fall into one category of the concept of a *map metaphor*. Map metaphors provide a means to visualize spatial and topological relations in human thought that cannot be replicated in other forms. This paper explores the use of both conventional maps (geographical maps) and map metaphors for examining multi-disciplinary integration in the field of Geography and Environmental Studies (GES). First, following an introductory example of a map metaphor, the concept is situated in relation to its potential application in exploring contemporary subjects in the discipline, and situated within a model of cartographic theory. Second, an application of a map metaphor is applied in an examination of the comprehensive and contemporary subject of *wellbeing*. The results of this analysis provide a series of maps and map metaphors supporting illustrative arguments that linguistic, value-based statements about the world are *geo-ontologically contingent*. Third, an additional map metaphor is provided as a means for navigating geo-ontological contingency. Referred to as an *AQAL Map*, it provides a conceptual and metaphorical framework for both visualizing topological relations intrinsic in geo-ontological contingency, and provides an alternative means for visualizing a number of methodological boundary relations in the discipline. Topological relations derived from this map metaphor are used to describe how it may be applied to several contemporary issues in human and physical geography, and in geographical information processing.

When I was young,
it seemed that life was so wonderful,
a miracle,
it was beautiful,
and magical.

All the birds in the trees,
they were singing so happily,
so joyfully,
playfully watching me.

Supertramp
The Logical Song

Part A – Theory

Introduction

In the children's literary classic, *The Phantom Tollbooth*, author Norton Juster and illustrator Jules Feiffer make use of a map as a metaphor in a playful story about wisdom and the meaning of life (Figure D-1) (Juster and Feiffer, 1961). The story follows a boy named Milo, who lives in a city and does not see much meaning in the world around him, until one day he returns home to find a mysterious package in his living room. When he opens the package, it contains a *Phantom Tollbooth* with instructions to enter into a journey to the *Lands Beyond*. The first stop on his journey is a place called *Expectations*. There he is told about a *Kingdom of Wisdom* that lies much 'beyond' *Expectations*, and is informed that most people never go there.

Milo decides to be different, and ventures further into the *Kingdom of Wisdom*, but finds the land in complete disarray. He is joined by two companions: a watchdog named Tock (whose job it is to see that people do not waste time), and an insect in a trench coat named Humbug (who habitually casts doubt on all they experience). The metaphorical map in Figure D-1 shows that the *Kingdom of Wisdom* has a number of territories and places; two of which, are central to the storyline: *Digitopolis*, and *Dictionopolis*. The kingdom is in disarray because the King of the Kingdom of Wisdom has two sons, King AZAZ (the King of *Dictionopolis*) and the Mathemajician (the King of *Digitopolis*) who cannot agree with each other. *Dictionopolis* is the place where words are invented, and it was built to combat the *Foothills of Confusion. Digitopolis* is the place where numbers mined, and was built to hold back the demons that live in the *Mountains of Ignorance.* Milo discovers that each place he visits is not working the way it was intended. There are too many word disputes in *Dictionopolis* because people are constantly taking the King AZAZ's words out of context, and the Mathemajician cannot find any *meaning* in numbers alone.

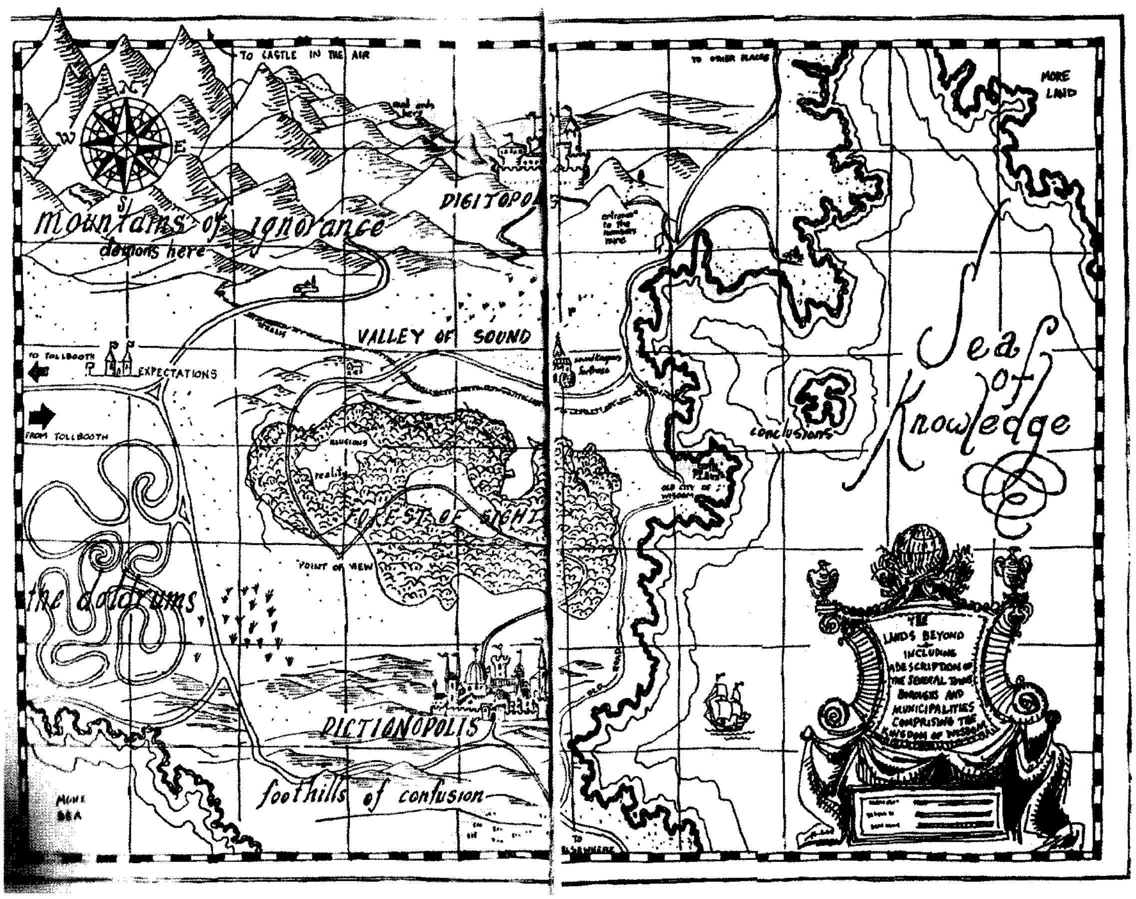


Figure D-1 – Illustration of the use of map metaphor as used in the *Phantom Tollbooth* (after Juster and Feiffer, 1961).

All is not working because the King AZAZ believes words are more important than numbers, and the Mathemajician believes numbers are more important than words. The King had originally delegated two princesses named *Rhyme* and *Reason* to settle disputes between the brothers, and any other dispute that occurred in the kingdom. But the two brothers so strongly disagreed that they eventually banished Rhyme and Reason to the *Castle In the Air*.

Milo's journey involves rescuing the two princesses and returning them to the *Kingdom of Wisdom*. His journey is metaphorically a journey through the human 'inner world' where questions of the relations among words and numbers relate to notions of 'wisdom', 'confusion', 'ignorance', and 'perspectives'. Although intended for children, adults find the book is a playful depiction of some advanced philosophical perspectives on these inner territories of human knowledge and experience. The use of words such as 'beyond', 'to jump', 'mountains' (of ignorance), and 'sea' (of knowledge) exemplify the pervasiveness of the metaphorical use of spatiality and geography in human language. To exemplify, at one point in the story Milo and his companions see a very warm and inviting tropical island in the *Sea of Knowledge* called *Conclusions*. They discover that the only way to get there is by 'jumping'. Once there, the island looks nothing like it did from a distance, and to get back to the *Kingdom of Wisdom*, one must know how to swim through the *Sea of Knowledge*. Most of the people who jump to *Conclusions* remain stuck on the island because they did not learn how to swim in the *Sea of Knowledge* (and consequently, the island is very over-crowded!).

For a complex and elusive subject such as *wisdom*, the use of the map metaphor proves effective in not only its holistic and synthetic quality, but also in its expansiveness and exploratory space that one might feel useful for exploring such a subject. The use of a map as a metaphor in this context provides an element of fun and playfulness that would not otherwise be available in an analytical text on the subject. What is presented in this thesis is somewhat similar. Maps can provide an alternative medium to other forms of knowledge, information and communication; and in doing so, provoke alternative ways for exploring and understanding complex issues in a comprehensive way.

Map Metaphors and Statements About the World

The application of maps as metaphors is used here in addition to the more conventional use of maps that explore geographical patterns or conceptual frameworks. There are many potential applications for the use of map metaphors in this context. The approach taken here begins with a recognition of how the form of human knowledge that is most often recorded or transmitted among people is primarily textual, linguistic or narrative; and as exemplified in stories like *The Phantom Tollbooth*, linguistic communication often contains within it implied geographical or spatial contexts.

The term 'text' is sometimes used as a referent for a narrative. The application of map metaphors suggests that stories can be 'mapped' in some way (as in the case with Milo's journey through the territories of inner wisdom). This view stands somewhat in an inverted contrast to Harley's (1989) critical treatment of a 'map as text' in that it looks at its application through 'text as map'. Here, it is not so much about looking at specific stories or the social construction of existing maps, rather it pertains to using maps explicitly as an aid to help tell a story, and provide a tool for critical analysis of human thought.

The story explored in this thesis concerns the present circumstances surrounding the need for more integration in the fields of Geography and Environmental Studies (GES), and one of the elements of this story is a desire to reconcile apparent dichotomies between human and physical geography, and quantitative and qualitative methodologies (Gober, 2000), as well as enhance geography's visibility and influence in public debate (Murphy, 2006). It must be recognized up front that some of the more significant challenges cannot be reduced to finding a straightforward settlement between the use of words and numbers, as metaphorically portrayed in Milo's journey, but the use of words and numbers are an intrinsic part of the dilemma, especially with respect to the use of geographical information in public debate.

Insofar as geographers are involved in studying the world, and therefore make both qualitative and quantitative statements about the world, it is necessary to explore the relationship between qualitative and quantitative aspects of such statements. Figure D-2 sets a context for this dichotomy in the manner in which much of the discourse or linguistic transmission of information contains within it some mix of qualitative and quantitative referents. Attaining mutual understanding between two or more people in dialogue often requires clarifying the contexts within which words are defined, and in the case were quantitative or locational aspects are involved, how such quantities or locations pertain to qualitative aspects. In presenting the view that a significant portion of linguistic statements about the world contain both qualitative and quantitative elements, it is important to recognize that there are numerous subjects and issues for which there may only be purely quantitative or qualitative approaches (the pure end-members in Figure D-2).

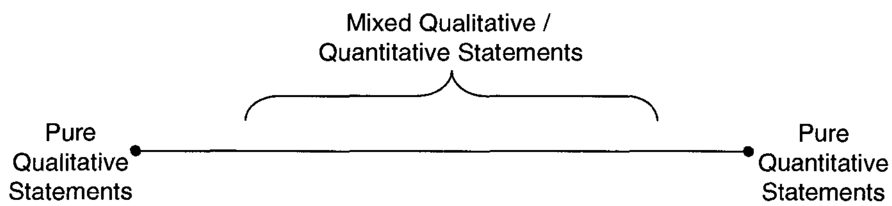


Figure D-2. Schema presenting qualitative and quantitative aspects of making statements about the world as a mixed interval in a range between pure qualitative and quantitative methods.

With qualitative interviews that aim to capture how people feel about a particular issue or circumstance, answers such as 'good', 'poor', 'uncertain', etc., may not require any form of quantification, however, numbers can be used to rank qualitative scales. Conversely, for phenomena such as atmospheric temperature measurement, the definition of 'temperature' must remain stable in order for quantification to be meaningful (i.e. it cannot be purely subjective, or mean different things to different people). These are two extremes that are increasingly becoming more the exception than the rule; in particular in the realm of contemporary geographical and environmental issues.

For example, statements such as: "*73 %* of North Americans believe the economy is getting better" are intrinsically bound with words and numbers, and are commonly interpreted as being factual. The relevance of such statements is often anchored upon statistical (numeric) referents. What is not made explicit is how the terms 'North Americans', 'belief', 'economy' or 'getting better' are defined. Altering any number of these linguistic referents will methodologically alter the context or relevance of the statistic (e.g. such as defining North Americans as including only people from Canada and the United States), and consequently change the relevance or meaning of the statement as a whole.

By comparison, an alternative statement such as "*Many* North Americans believe the economy is getting better" is a similar, and perhaps more general and qualitative. It is not anchored upon a statistical referent, although it is presumed that there is reasonably acceptable evidence that it is 'many' and not 'few' or 'none'. As with the former statement, what is equally problematic is how 'many' is defined. There are two aspects of this statement where quantity and quality are implied: 'many' and 'better'. Both the intended meaning of the statement, and its interpretation depends on the 'context' in which these terms are defined.

For researchers following conventional scientific protocol, subtle differences behind such statements are often agreed upon as part of following the scientific process; but the transmission and translation of such statements into political and public spheres often results in alternative interpretations and contextualization of their meaning. In the current circumstances of global change and the proliferation and use of scientific information in policy and public discourse, there is evidence that following such protocols is increasingly problematic and results in vigorous debates, even among many scientists (e.g. Lomborg (1998), Demerritt (2001)).

It is argued here that what is missing in many of these debates is the use of map metaphors and conventional geographical maps in making more explicit the 'who', 'what', 'where' and 'when' aspects of circumstances to which statements apply, and this aspect is one area of focus in this thesis. What follows in this view is that qualitative and quantitative aspects are intrinsically related to both human and physical geographical dimensions in environmental studies, and that geographical information processing has an important role to play in exploring these relations. To the extent that *words* and *numbers* tend to dominate content in today's scientific-oriented information era (which go unquestioned more often than not), a useful and innovative role for map metaphors can be to help make explicit the mental processing, assumptions, uncertainties, definitions, and overall 'context' within which words and numbers are used as they apply to our perceived reality.

This thesis explores a number of examples for using map metaphors in this context. Its aim is to explore how maps and mapping, and in particular the use of map metaphors, may serve an integrative function in GES. Before describing the approach taken, it is first necessary to situate the use of map metaphors within a cartographic theoretical framework.

Map Metaphors and Cartographic Theory

Maps and mapping are most commonly associated with representing the geographical world, but there are other uses to which maps may serve an important function. Taylor (2003) argues that there are three ways that maps find use: 1) Map as Artefact, 2) Map as Concept, and 3) Map as Metaphor. Map metaphors relate to

Taylor's idea that in the emerging information era, maps will be used increasingly in topics that go beyond themes of conventional human and physical geography (Eddy and Taylor, 2005a). The *Phantom Tollbooth* is a story that provides an innovative example of the use of a map metaphor. As with the many uses and interpretations in literary use of metaphor, map metaphors retain the reflexive quality of an open concept. In general application, the map may serve as a substitute for alternative forms of information (text, video, etc.) with the potential for synthesizing numerous complex elements of a particular topic; such as mapping relational elements among diverse bodies of theory or conceptual frameworks (Laszlo, et. al. 1993).

One distinction that is made here is that the map as metaphor is different from the use of the map as concept in that conceptual mapping is, in itself, a map of a *concept*. It is a tangible artefactual description of a concept, upon which the concept itself depends. Map metaphors, on the other hand, suggest an *as if* form of representation, and serve as a *surrogate* of a complex subject. It is different from conceptual mapping in that the topics upon which they serve do not solely rely upon the map metaphor to function. Rather, map metaphors serve to augment, enhance, or synthesize topical elements and provide a holistic capacity for 'seeing the forest for the trees' in topics that may otherwise be overwhelming for both experts and laypersons. Additionally, map metaphors may be taken seriously or playfully with a reflexive quality; or, in their more innovative forms, a creative combination of both.

As with other forms of mapping, map metaphors may be viewed as a form of abstraction of reality. Two generalized cartographic models that focus on the abstractive utility of maps are presented in Figure D-3. The first (Figure D-3a) is a simplified model presented by Muehrcke and Muehrcke (1989). They place maps along an abstraction continuum wherein maps are conveyed as being less abstract than words or numbers. In an alternative model (Figure D-3b), MacEachren (1995) applies Pierce's (1958) system of semiotics to maps, whereby maps serve as a sign-vehicle for reality in a triadic relation (Figure D-3b). This extends the two dimensional relation presented in Figure D-3a to include *interpretation* as an intrinsic part of mapping process.

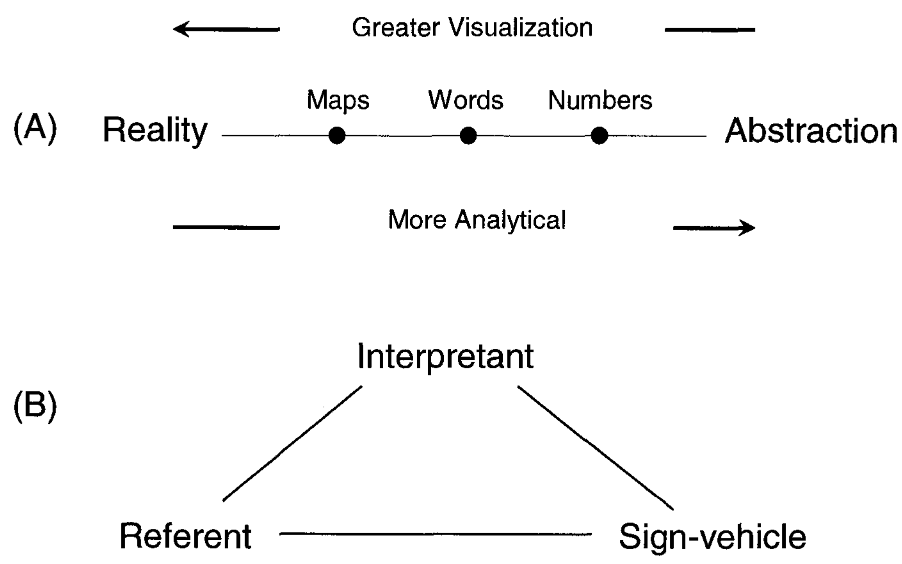


Figure D-3. Two generalized cartographic models used in cartography: (A) a reality-abstraction continuum (after Muehrcke and Muehrcke, 1989), and (B) a triadic semiotic relation (after MacEachren, 1995).

What is presented here is a synthetic adaptation of these concepts in application to the use of maps and map metaphors for integration in the field of Geography and Environmental Studies (GES). The context for the use of map metaphors may be explored through an alternative version of the triadic relation in Figure D-3b. The three elements used here expand upon MacEachren's model, and are defined as follows:

1. **Circumstance** - Defining an issue/circumstance for which the acquisition, production or integration of information is required. Knowing something about the circumstance helps in understanding the 'who' and 'why' aspects of information production and use. That is, asking why such and such a map or a book/text is useful or important; and to whom and for what purpose?

2. **Reality** - Defining what aspects of reality, or the world, to which circumstances apply – or the 'what' aspect. In this sense, reality is taken as the totality of our experience; the world as we see, observe or perceive it to be 'out there', as well as our direct inner experience.

3. **Representation** - Defining 'how' we think about a circumstance and reality; including the many possible types of information content such as text, numbers, maps, visuals and other media. In cases where representations pertain to a 'space-time' framework, this aspect also

addresses questions of 'where' and 'when'. Here representation is not assumed to be, nor taken as meaning how to best represent 'truth' in any relative or absolute sense, rather it discloses the process of abstraction and symbolization of reality used in human mental models.

It is argued here that these three elements may be applied in any form of knowledge construction (as was done with Pierce's original thesis), although the focus is not on 'knowledge-construction' per se, nor solely the technical aspects of a cartographic process (maps as artefacts). The focus is on the composite of *all three* as they operate in human experience.

Figure D-4 looks at three ways that these elements may interface in different approaches to cartographic theory and practice. In the first two (A and B), the focus of cartography is on the world (or reality) and its representation (or abstraction) process. The circumstances that surround the mapping process are often only implied or are considered of third order importance. The model presented in Figure D-3a is an example. Recent works in critical cartography (e.g. Harley, 1989) explore the background contexts of maps with an emphasis on silences or knowledge-power relations usually hidden in the third element. A distinctive difference between A and B is that the production of the information is uni-directional (or uni-lateral) in A, and bi-directional (or bi-lateral) in B. It is also fair to say that A is 'monological' and static – the message being conveyed in one direction; B is 'dialogical' – whereby the representation process is bi-directional and interactive. The latter model considers interactive cartography (such as Internet mapping) as described by Peterson (1995).

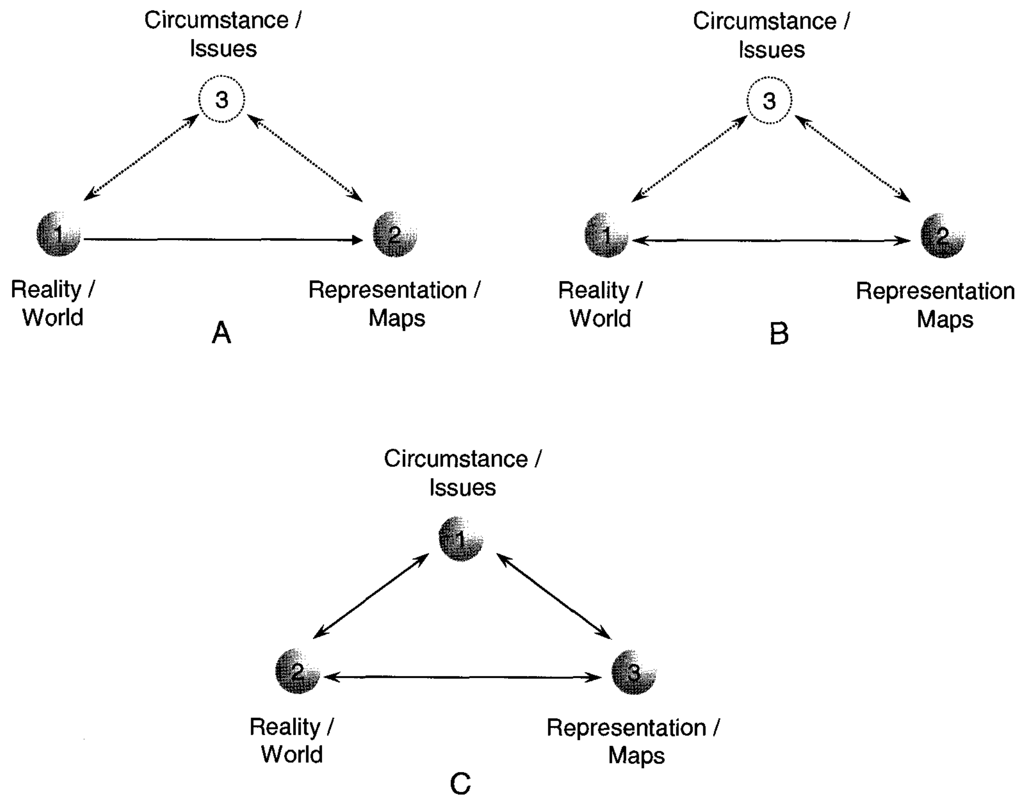


Figure D-4. A three-part model of cartographic practice: A) monological-implied, B) dialogical-implied, and C) trilogical-explicit.

In both A and B, 'reality' or the 'real world' (in whatever sense one chooses to use this term) may remain of primary importance (1), and maps are secondary (2). Cases where maps are seen as primary and reality as secondary include the idea of 'map-fixation', which some cartographers caution has significantly detrimental affects (Muehrcke and Muehrcke, 1989).

It is argued here that cartographic theory or practice that emphasizes only the reality-representation dimension can lead to a number of difficulties, and MacEachren (1995) emphasizes this point with the inclusion of an *interpretant* in his triadic relation. What is described as *circumstance* in Figure D-4 provides a broader context for what MacEachren describes as an *interpretant*. The use of map metaphors fills a critical relation in this circumstantial context. The conventional use of geographical maps provides information about some aspects of the world along the reality-representation continuum (the 2-3 dimension in Figure D-4c). Map metaphors can be used to reveal some aspects of human mental processes that occur in relation to circumstance and representation of reality (the 1-3 dimension). The direct relation between circumstance and reality (the 1-2 relation) cannot be served by maps as artefacts; but only by direct human involvement in the world, with *active mapping* processes involving people embodied in the real world. These relations will surface on a number of occasions throughout this thesis, and this model will be expanded upon in relation to a number of key findings in the final sections.

Approach

The approach taken in this thesis is to explore how map metaphors may be used for integration in GES with application to a broad subject that is of common interest to its sub-disciplines. Part B presents an application of a map metaphor using a global analysis of *wellbeing* (Prescott-Allen, 2001). It illustrates the necessity for integrating multiple fields of knowledge, in particular, those that respectively inform the fields of human and physical geography. The use of map metaphor is extended by applying it further as tool for critical analysis in visualizing multiple perspectives on the subject of wellbeing by both literally and metaphorically mapping wellbeing indicators.

The use of map metaphors in this context illustrates that their application serves more than just a means for abstraction and visualization. Through the exposition of *spatiality* and *geography* intrinsic in human thought, it is possible to use map metaphors as a tool for constructive critical analysis. Part B explores this aspect by presenting illustrative arguments supporting the view that comprehensive statements about the world are *geo-ontologically contingent.* Two types of *boundary conditions* are identified in such contingency: 1) *Internal* boundary conditions pertaining to human mental models used in making value-based statements about the world, and 2) *External* boundary conditions pertaining to aspects of the physical world to which statements apply. It is argued that the *combined use* of both conventional geographical maps and map metaphors provides one approach for navigating these boundary conditions by addressing critical gaps in the three dimensions of the model presented in Figure D-4c. The results of this analysis illustrate how *geographical scale* provides a means to situate *circumstances* surrounding not only maps and mapping processes, but in further situating the meaning and context of statements about the world, and processes of actualization and embodiment.

Whereas the model presented in Figure D-4c is a general cartographic model, it is necessary to make use of a more detailed model to elaborate the boundary conditions involved in geo-ontological contingency. Here, Part B makes use of a *Cybercartographic Human Interface (CHI)* model developed in Eddy and Taylor (2005b), and illustrates its application. One of the key elements revealed in the analysis is the role that *qualitative value judgements* play in making statements about the world; or, what are described as *qualitative transforms* operating in human mental models. Intrinsic relation between words and numbers are explored in relation to *qualitative transforms* in information processing. The method used for elaborating these relations is a modified Fuzzy Logic Method (FLM) presented in Eddy, et. al. (2006). A number of GIS-based maps are used to explore these themes, and the focus is not on GIS-based analysis or methods per se; in fact, the methods used in the preparation of the maps presented in Part B may be considered more simple than sophisticated, but are sufficient for the purpose of establishing the arguments relating to *geo-ontological contingency.*

Insofar as arguments relating to geo-ontological contingency are presented in Part B, these may be read as a reinforcement of long-standing beliefs in the discipline that *geography matters* (Knox, et. al., 2004; Sharpe, 2006). This argument is not new for geographers; nor is it the main argument made in this thesis. What is presented as a contribution to knowledge in this thesis is the use of maps and map metaphors as *an alternative means for conveying this message* both within the discipline, and to others outside the discipline. The unique aesthetic, scientific, and holistic qualities that maps provide help in this regard.

Key arguments concerning geo-ontological contingency presented in Part B reinforce the need for a pluralistic perspective that information vehicles, such as linguistic statements about the world, or maps that aim to convey such statements, are not simply vehicles for 'truth' or 'fact'; rather, the *map* in this context presents information as an *invitation* to explore a world of relativistic information in multiple ways. Geographical scale and the boundary conditions mentioned above are critical dimensions that need to be considered in exploring multiple perspectives on the world. Issues of scale are often a main concern in geography, and in presenting arguments for the contingency of scale may potentially open a debate about the usefulness of any form of information, and geographical information in particular, that claims to be truthful or meaningful in any sense. This is one of the more problematic issues with relativistic information and 'context'; the potential for falling into sliding contexts associated with geographical scale to which readers of geoinformation may find there is nothing to grasp in any meaningful way. This 'de-centered' pluralistic approach may succeed in releasing readers from the chains of modernist rigidity; however, it comes with a new challenge wherein people need to find some means for navigating a world of relativistic information.

In exploring this de-centering of geo-ontological contingency, the map metaphor is used further to provide a *guide* for navigating the world of relativistic information. Part C further illustrates the use of map metaphors by presenting a theoretical framework that claims to address these contingencies. The map metaphor used is derived from the scientific and philosophical thesis of American scientist and philosopher Ken Wilber (1995, 1999, 2000a, 2000b, 2002a, 2002b), in which he presents a framework known as an *AQAL Map*. The AQAL map is a framework that summarizes the key topological elements of Wilber's *Integral Theory*, which is used in Eddy (2005) in outlining an integrative approach to geographical enquiry identified as *Integral Geography*.

One of the main challenges in presenting such a map or framework is communicating its essential elements in a language that is meaningful to geographers, and other experts and laypersons who may not be accustomed to thinking in Wilber's language. The claim here is that the integrative language derived from the AQAL map is intrinsically 'topological', and the author believes Wilber's framework not only provides a means for approaching the contingencies described above (and which are explored in detail in Part B), but it may also provide a framework for navigating and negotiating internal methodological and disciplinary boundaries in the field of GES. The AQAL map is used for differentiating various geographical modes of enquiry used by human and physical geographers, as well as several other dichotomies pertaining to qualitative and quantitative research, and different perspectives on human-environment, human-nature, and society-nature themes.

Although the author succeeded to some extent in outlining several foundational concepts for the application of Integral Theory within geography in Eddy (2005), the context and language used in that journal article was purposely aimed at readers outside the GES field; specifically, others who have been working with Integral Theory in other ways, and to whom the author aimed to illustrate several aspects to which it may be useful for geography, and how geography in turn, may be useful for other disciplines and applications. Consequently, because that article was published as part of a special volume, it does not stand on its own, and some geographers may have difficulty following some of its language and key points. Part of the difficulty lies in its omission of some of the more fundamental aspects of Integral Theory that inform its reasoning. As discussed in Agre (2003), one of the key challenges in academia is learning to navigate the many *languages* that are used across disciplines; and that navigating these waters can be difficult. The particular type of meta-language used in Integral Theory is suggested as one means of approaching this challenge, and in particular, its use of map metaphors.

It is to this challenge that the use of maps and map metaphors used in Part B serves as a basis for more fully elaborating the basic principles of Integral Theory and its potential for facilitating integration in GES. The AQAL map, and its use of the concept of 'holons' and 'holarchies', is elaborated in detail in Part C. Its utility is illustrated by its application in addressing geo-ontological contingencies presented in Part B; in particular, with an additional map metaphor on the subject of wellbeing. The topological relations in the AQAL map provide a visual means for exploring, from an alternative perspective, a number of contemporary issues in the field of GES, from which several ideas for further research are discussed. It is from exploring the potential use of map metaphors in this context that several conclusions are reached.

But then they sent me away,
to teach me how to be
Sensible,
Logical,
Responsible,
and Practical.

And they showed me a world,
where I could be
so Dependable
so Clinical,
Intellectual and Cynical

Supertramp
The Logical Song

Part B – Application

Introduction

Part A introduced several theoretical elements on map metaphors as they relate to general cartographic theory. In Part B, a practical application of a map metaphor is examined in three ways. First, an example of a map metaphor is illustrated using an analytical report on the subject of *wellbeing*. The reason for selecting this subject for illustration is explained in the context of the theoretical elements provided in Part A. In this case, the map metaphor is used to mimic some aspects of human mental processing relating to the concept of wellbeing. A second means for illustrating its application is an examination of how the map metaphor can function in exploring alternative perspectives. This includes an alternative qualitative analysis methodology that provides additional flexibility in addressing several map metaphorical principles described in relation to the circumstance-representation dimension of the model presented in Figure D-4. The method is used to explore several alternative map metaphors for exploring the concept of wellbeing through different perspectives that may be associated with different circumstances. Here, the pervasiveness of spatiality and geography in human language is highlighted, and arguments are presented in relation to the necessity for making the geographical dimension more explicit in exploring circumstances about the state of the world. Part B concludes with a brief discussion on some of the potential implications of the results for geographical enquiry and multi-disciplinary collaborative integration, and in particular, implications surrounding *geo-ontological contingency*.

The Wellbeing of Nations as a Map Metaphor

To illustrate the map metaphor of 'text as map', this section explores the Wellbeing of Nations (WoN) (Prescott-Allen, 2001) as a map metaphor. Reasons for selecting the WoN are explained in terms of the three elements presented in Figure D-4.

1–Circumstance. The principal subject concerns contemporary issues and circumstances relating to 'wellbeing', 'sustainability', 'sustainable development', and 'human-environment' relationships; and numerous related issues such as health, economy, education, gender equity, natural resources and environmental quality (to name a few). These terms pertain to an amalgam of issues and research areas that are of concern to GES, as well as many other academic disciplines and organizations.

2 – Reality. The WoN report is taken as an example of a value-based statement about the world as a whole; a statement that can also be explored in different ways. Prescott-Allen provides substantial transparency in elaborating how his general statements and numerous sub-statements were constructed and, as illustrated below, how these statements were constructed can be expressed using a map metaphor.

3 – Representation. Insofar as the WoN attempts to make a statement about the world, it is intrinsically a geographical subject, and it makes use of maps as a direct means for visualizing and communicating its statements. It illustrates that value-based statements about the world as a whole do not apply equally to all locations (or sub-regions) of the world. This aspect will be explored in terms of the degree of *necessity* of the use of maps as a medium for such statements.

The circumstances surrounding the WoN report involve a concern with wellbeing on a global scale. One of the first issues the WoN report recognizes is the difficulty in defining *wellbeing* in meaningful terms. For Prescott-Allen, defining wellbeing depends upon closely related issues and concepts of sustainability, sustainable development, and human-environment interaction. The use of these terms is contingent upon how they, in turn, are defined. Whereas it is recognized that there needs to be a certain degree of openness with how these terms may be inter-related, there are also holistic tendencies in their use in that they often stem from motivations to improve life conditions of people, places, the environment and the planet as a whole. To elaborate how this subject is used to illustrate the application of map metaphors, it is necessary to provide a brief explanation of the framework used in the WoN report.

Wellbeing Assessment (WA) Framework

The WoN takes a holistic approach in defining wellbeing. It is viewed as a series of inter-related sub-dimensions or issues that are partitioned within an indicator framework (Figure D-5). There are six stages to its Wellbeing

Assessment (WA) method that involve working around the framework in a cyclical manner (Figure D-6); starting with defining the system and its goals and objectives (Steps 1 and 2), to the collection and analysis of indicators (Steps 3-5), to a complete assessment and review of all system components (Step 6). Indicators are selected to represent system dimensions at the element and sub-element level, and are aggregated upward using performance criteria defined in relation to goals and objectives. It is a whole-part structure that sub-divides ecosystem and human system components into nested levels, from the whole system, to sub-systems (people and ecosystems), to dimensions and elements of each of those sub-systems.

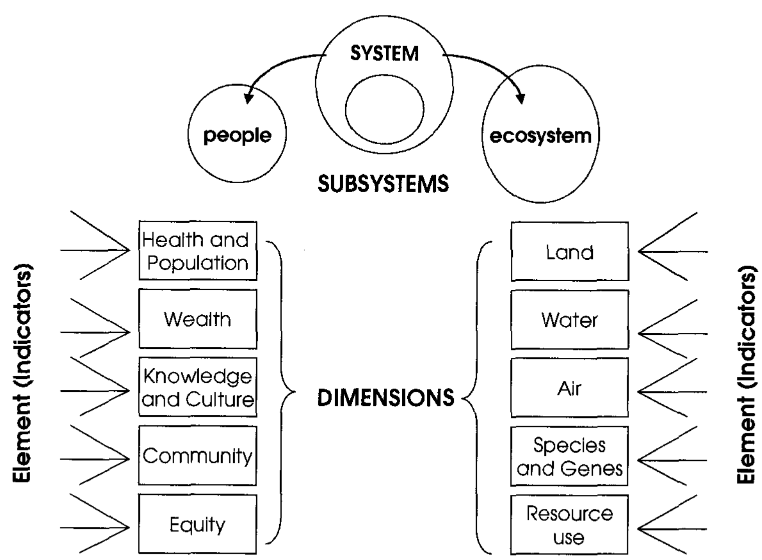


Figure D-5. The indicator framework used by Prescott-Allen in the Wellbeing of Nations (WoN) (Modified after Prescott-Allen, 2001).

The WoN makes extensive use of geographical maps for the presentation of indicators on a country level. Figure D-7 presents a reproduction of two indicator maps for overall Human Wellbeing (HWI) and Ecosystem Wellbeing (EWI). The legend used is a five class qualitative scale indicating conditions assessed as being ‘Good’ to ‘Bad’. The WA framework is used here as an example of a model that fits reasonably well with many conventional approaches to thinking about and assessing wellbeing.

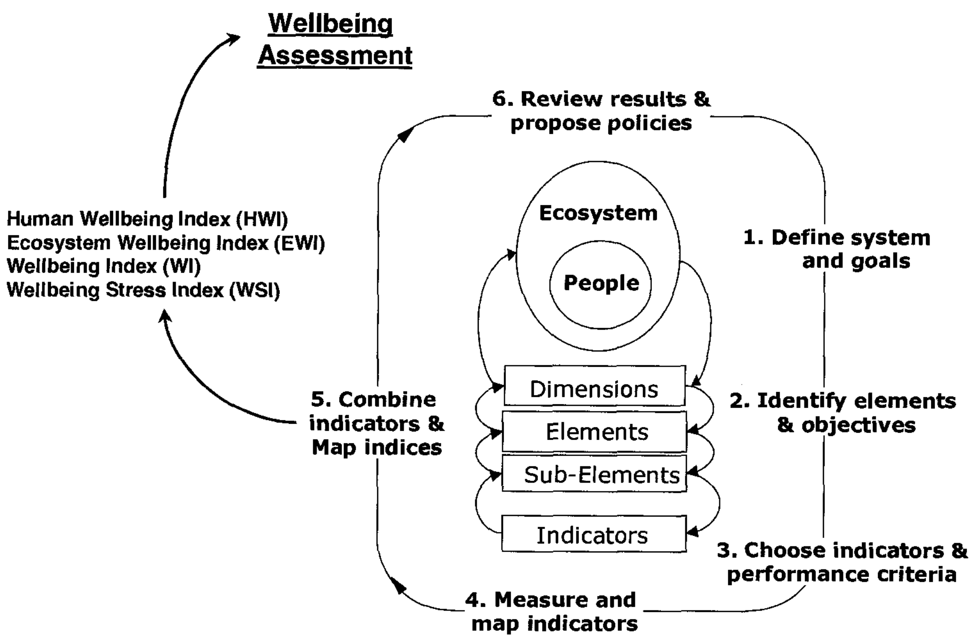


Figure D-6. General overview of the Wellbeing Assessment (WA) methodology (modified after Prescott-Allen (2001), p. 279).

In an implementation of such a model, it is often necessary to consider various debates about definitions, terms, concepts and subjective value judgements, as there can be many perspectives on how terms are defined, and how they may be inter-related within an overall model. The map as metaphor can be helpful in this regard by allowing authors and readers to visualize both: 1) the complexities of the details, and 2) the holistic conceptual elements in the model or process. In this way, maps hold a special place among other forms of representation.

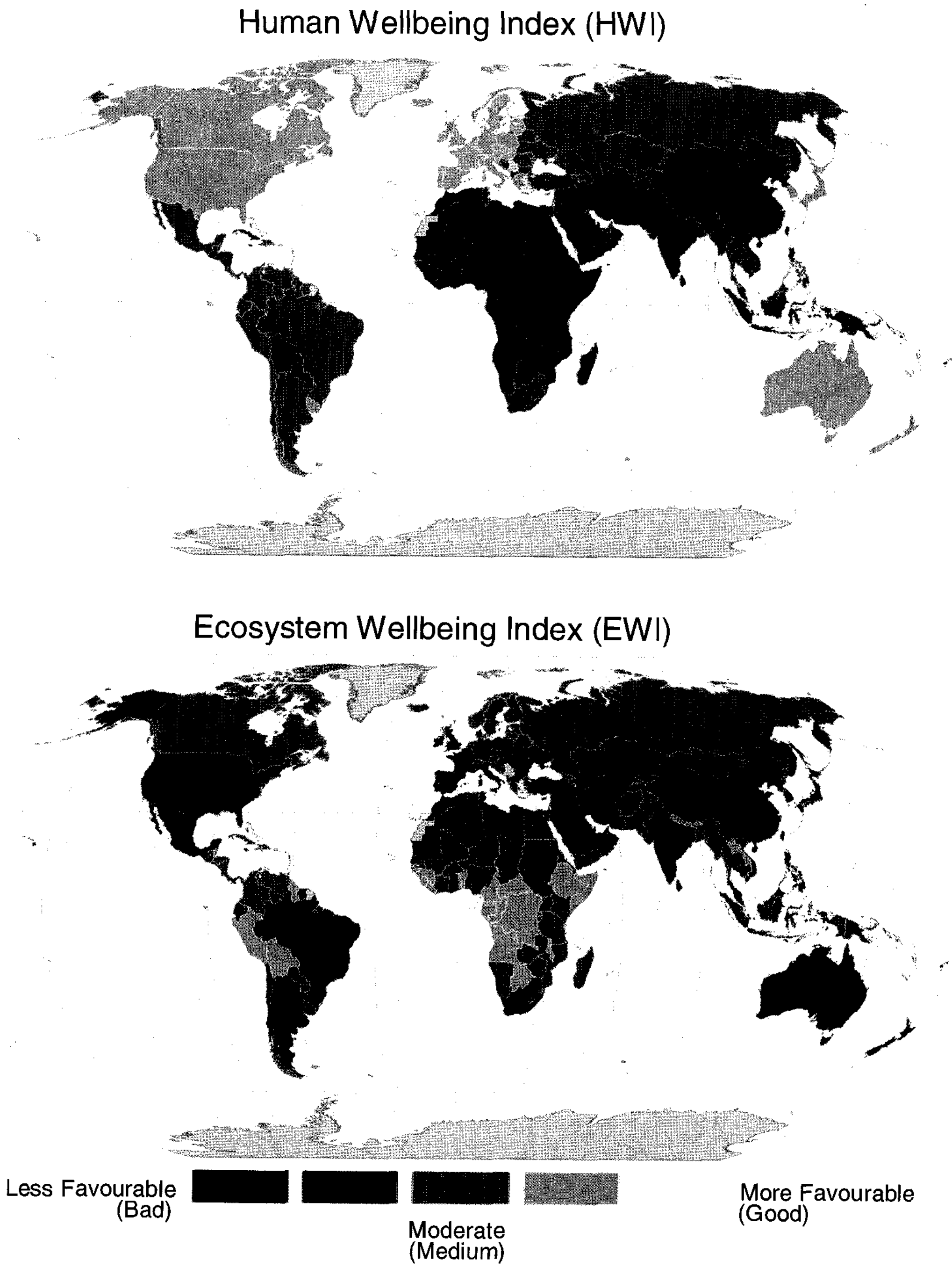


Figure D-7. Two example indicator maps from the Wellbeing of Nations (WoN) (Prescott-Allen, 2001) (note: reproduced from data supplied by Prescott-Allen).

We've got the aeroplane, we've got the automobile,
we've got sky-scraping buildings made of glass and steel,
we've got synthetic food that nearly tastes real,
and a little white pill that makes you feel
a whole lot better when you get out of bed
you take one in the morning for the long day ahead
we've got everything everybody needs to survive -
surely the good life has arrived!

Five Man Electrical Band
I'm a Stranger Here

WoN Map Metaphors

To illustrate, two ways of looking at the WA framework as a map metaphor are shown in Figures D-8 and D-9. The metaphor in this case is the depiction of an enclosed river basin wherein 'information flows' from various 'fields of knowledge' within the framework that Prescott-Allen used to define wellbeing.

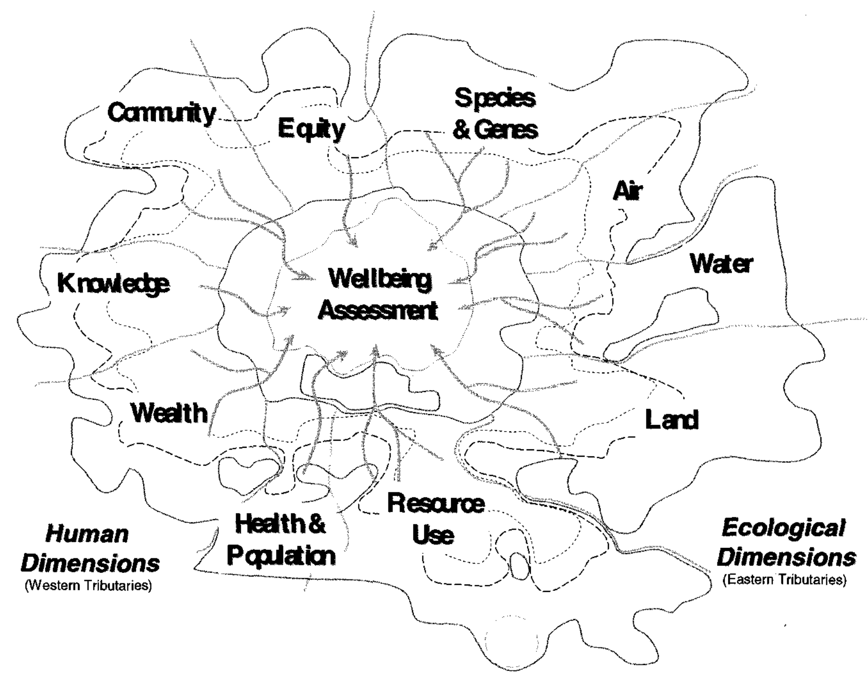
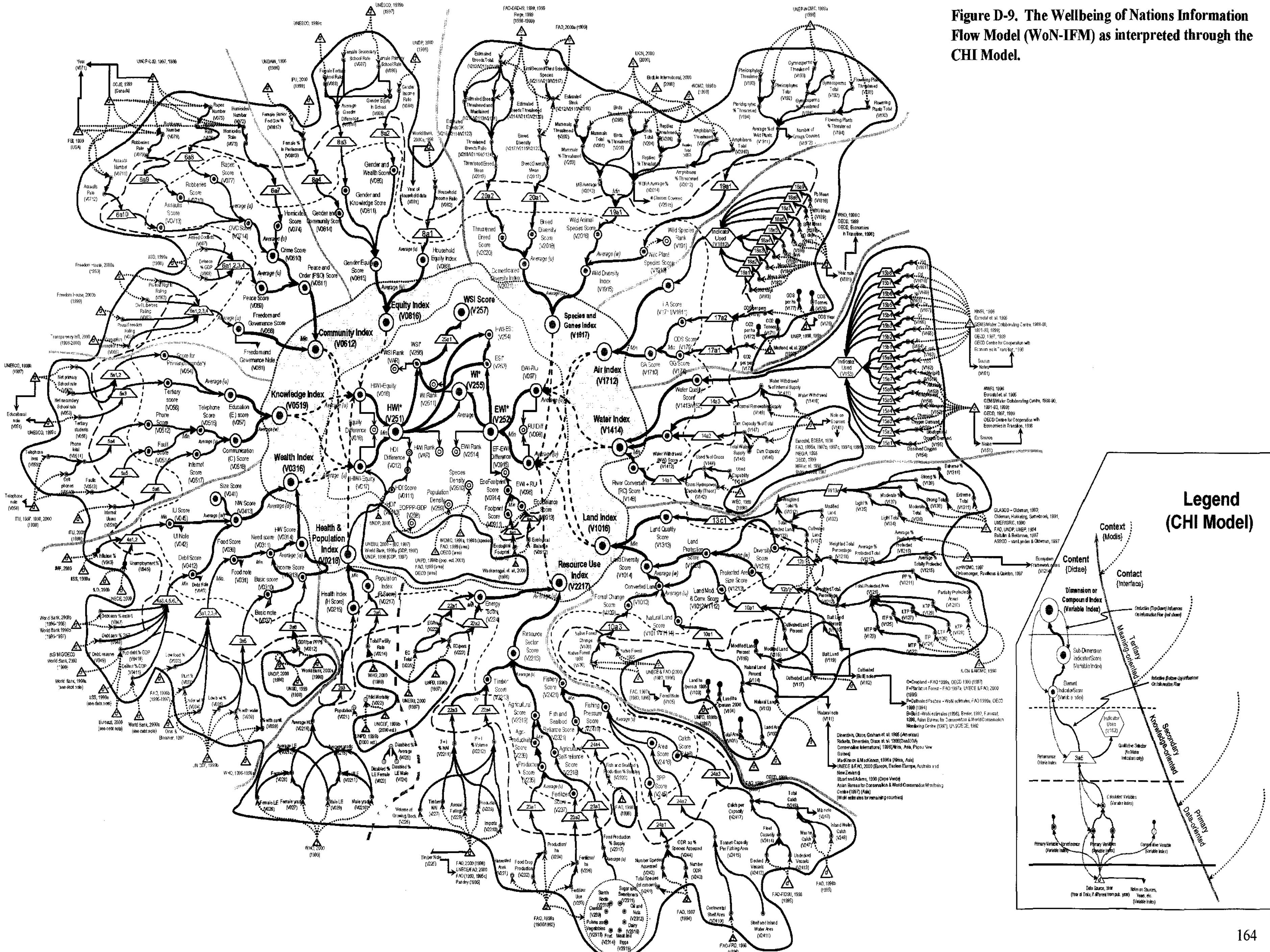


Figure D-8. Map metaphor of a wellbeing assessment framework as an enclosed river basin of information flow.

Figure D-8 is a simplified version of the detailed map shown in Figure D-9, which shows the many detailed elements and processing pathways used in the report. Such a map is typically used as an 'information flow model' (IFM) for technical reference. Here, the same level of detail of an IFM is retained but presented metaphorically and stylistically in a different context. This map will be herein referred to as the WoN-IFM.

Figure D-9. The Wellbeing of Nations Information Flow Model (WoN-IFM) as interpreted through the CHI Model.



The WoN-IFM presents a visualization of the span and depth of information processing that informs the report narrative. It may be viewed as a map of the 'inner logic' of the report as a whole, and serves to compensate for one of the limitations of the medium of a book or 'text', in that the medium of a text only allows readers to view aspects of a subject one element or stream at a time. As is common with many books, there is rarely a comprehensive snapshot of the 'storyline' or 'whole text'. The map metaphor in Figure D-9 provides this type of overview and can be used to provide transparency of process, and a basis for critical review and feedback.

Modelling the WoN data in this manner is a useful example of the main elements of the *Cybercartographic Human Interface* (CHI) model presented in Eddy and Taylor (2005b). Figure D-10 provides a detailed view of the legend in the WoN-IFM map in Figure D-9 and illustrates how the three elements in Figure D-3 fit in relation to levels of information processing. The contours depicted in the river basin represent the main levels of the CHI model across Primary, Secondary, and Tertiary information processing levels, and the tributaries represent the processing streams for the indicators in relation to their data and knowledge sources.

The indicators represent the tertiary (meaning-oriented) level information that aims to communicate more directly to the circumstance. The *performance criteria* applied to the primary data (data-oriented) in the creation of tertiary level indicators represent the secondary (knowledge-oriented) level of information processing. Each primary data variable can be traced to its source (indicated by triangle symbols at the edge of the basin).

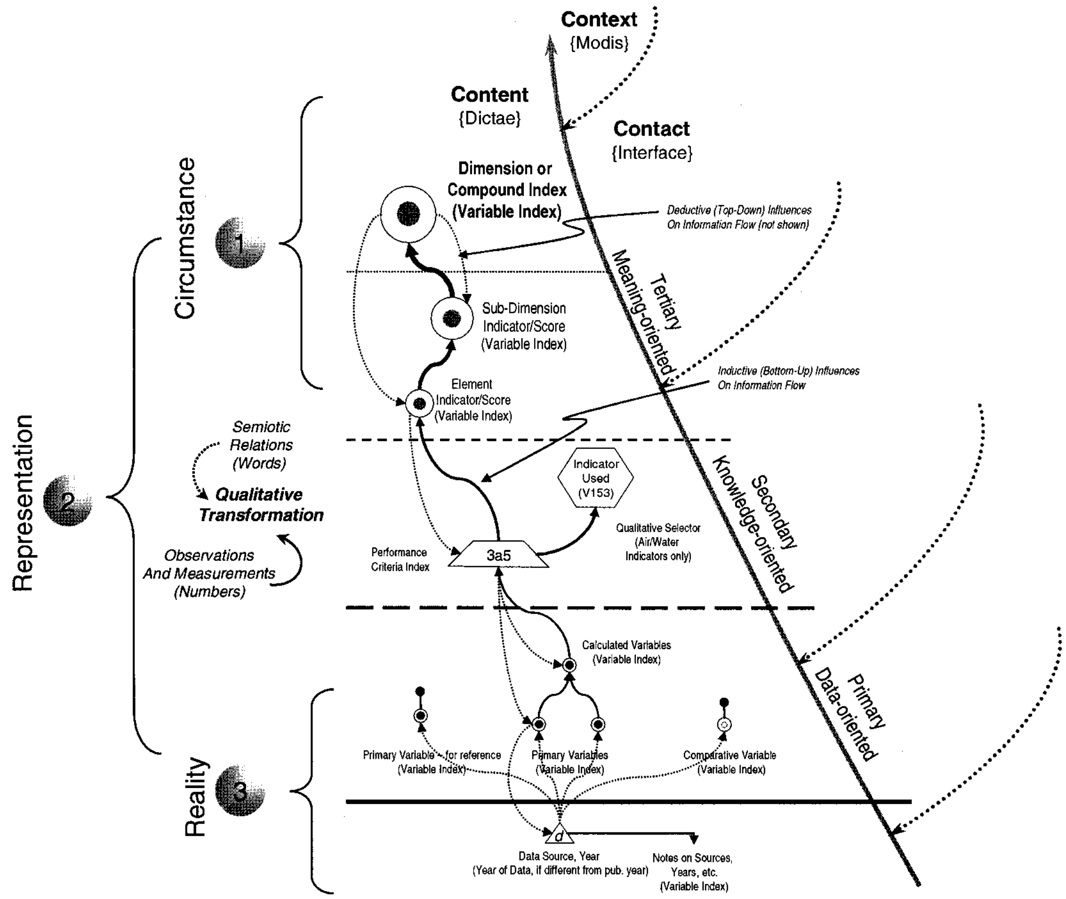


Figure D-10. The CHI Information Flow model illustrating the qualitative transformation of quantitative data in the WoN-IFM (Figure D-9).

The *secondary* processing level of the WoN-IFM involves the transformation of numerous types of data representing multiple fields of knowledge, into synthetic qualitative indicators. Here, the intrinsic relation between words and numbers is evident. Words answer the question 'what is being observed or measured?', and numbers answer the question 'how much?' (a quantity). Numbers are also used to express a qualitative factor in terms of how an indicator is measuring up against its respective goals and objectives; they answer the question 'how good or how bad?' (a value judgement). Table D-1 provides an example of a performance criteria table for a sub-element of the Gender Equity Index shown in Figure D-9. As illustrated, working from the right column to the left column, direct measurements or observations (in this case, gender income ratios) are qualitatively judged according to desired intervals (the right to left transformations in Table D-1 are mapped as bottom up relations in Figure D-10). A 0-100 numerical index is used as a normalizing numerical scale that has corresponding value-based classes in the legend. Various mathematical operations (e.g. min, average) are applied to multiple indicators through the aggregation process to produce higher level or compound indicators.

Table D-1. Example performance criteria table where quantitative data are qualitatively evaluated according to specific value judgements.

{Tertiary} ←	{Secondary} ←	{Primary}
Legend Interval	**Index Value**	**Gender Income Ratio (M/F)**
Good	100	1
Fair	80	1.5
Medium	60	2
Poor	40	3
Bad	20	5
Base	0	9

Although the CHI model differentiates information processing levels, and the actual processing relations are generally hierarchically related (from primary to secondary to tertiary levels), the actual pathways of information flow are non-linear in that a *top-down* deductive information processing structure is imposed upon *bottom-up* information process elements (Eddy, et. al. 2006). The distinction here is that the process is neither purely *inductive* nor *deductive*; rather, that there is some combination of both operating at each level and among levels in the model. This perspective contrasts with those of Harvey (1969) and Copi (1982) who regard inductive and deductive approaches as distinctly separate. The emphasis here is that top-down relations (deduction) determine the structure or *context* within which the bottom-up *content* elements are processed (induction).

Map metaphors may be used further to explore how different higher level indicators can be created depending on the definitive structures that are imposed upon primary data, and these structures can be examined in terms of *topological relations*. Before exploring these alternatives, it is necessary to elaborate on how the map metaphor may be useful in this aspect.

Considering Multiple Perspectives

The WoN-IFM is an example of how people might think of global wellbeing very much depends on the many elements shown in the map in Figure D-9. In this sense, it is not just a metaphor of the WoN report itself, but may also be seen as a metaphor for the volume and complexity of discourse and information streaming around these contemporary issues. It may be viewed as the levels of detail and complexity of information processing required in completing a comprehensive assessment of wellbeing.

I think your atmosphere is hurting my eyes
and your concrete mountains are blocking up the skies
and I don't say that you're telling me lies
but why do I hear those children's cries?

I see the aeroplanes carrying the bombs
why you even find people to drop them on
you know you can't keep what you take by force
but it's only my first impression, of course.

I'm a stranger here – I'm just looking around.

Five Man Electrical Band
I'm a Stranger Here

For topics such as wellbeing and other local to global issues, it is arguable that one of the greatest challenges humanity is currently facing is the overwhelming amount of information that is streaming through various media. Much of the information received by people can often not be adequately critiqued by either experts or laypersons because the technological constraints of the media itself – in relation to the speed of information processing, and its modes of transmission and currency – do not allow people the opportunity to adequately critique the information before its currency expires (or before its social and political forces have taken effect). This characterizes what some refer to as a 'too much information' syndrome to which people are now subjected at this time in the information era, and in our present global circumstance. Debates around these many issues often lead to differences of perspective on the meaning of many terms, especially higher-level issues such as overall environmental integrity, human-environment relations, wellbeing, and sustainability. Very often it is difficult to 'see the forest for the trees', and the possibilities for taking a holistic perspective on issues remains elusive.

This raises the question as to what would be an appropriate medium for carrying out such debates, and would a map metaphor such as the WoN-IFM be useful in this respect? The many dimensions in the WoN model can be seen to represent multiple fields of knowledge, and an ongoing dialogue would necessarily require multiple participants who specialize in these various fields. Prescott-Allen has made a significant contribution to this issue in his work on the WoN and WA methodology, which is only made possible through the provision of the numerous data and knowledge sources brought into his analysis. Bringing such an application into a cyberatlas, or 'living atlas' environment – whereby readers and authors can continuously update, refine, debate and monitor wellbeing – is much beyond the capacity of any individual. It requires *collaboration*; and this is one of the principal elements in the concept of *cybercartography* in that maps of this type – both the WoN indicator maps and the WoN-IFM map metaphor, need to be *multi-authored.*

As emphasized by Eddy, et. al. (2003) and Taylor (2003), one of the distinctions cybercartography makes with modern or conventional cartography is its emphasis on 'multiplicity' and 'plurality' in maps and mapping. Cybercartography places an emphasis on multi-thematic, multi-scalar, multi-modal, multi-sensory, and multi-authored applications of cartography; these are now made more possible with emerging Web-based mapping technologies and spatial data infrastructures (SDI's). Eddy, et. al. (2003) summarized this aspect as "a shift from the *singular* to the *plural*" in maps and mapping practices. In this context, no map is static or 'speaks for itself'. Rather, a cybermap can be viewed is an *invitation* into a spatially organized world of information wherein both conventional and GIS-based maps, and new forms of mapping are used to provide both experts and laypersons an environment for exploration, navigation and discovery of numerous inter-related subjects.

If the WoN-IFM map is used as an interactive interface to a cyberatlas on wellbeing (assuming that open connectivity can be made to all the necessary data sources and supporting organizations), both authors and readers may question the value judgements, the terms used, the overall structure of the processing, and the quality and choice of knowledge and data sources. Such an interface would likely entice numerous debates about all of these aspects in mapping wellbeing indicators because it may be applied to a range of geographical scales and locations.

The development of such an atlas would also require adequate frameworks for engagement. One additional use of the map metaphor principle may be useful in this respect. Differentiating key elements in a framework within which debates and discussion of alternatives can take place can be made from looking at some of the topological relations shown in the WoN-IFM in Figures D-8 and D-9, and their effect on the patterns that surface in the geographic-based indicator maps of the type shown in Figure D-7.

Topological Relations

The WoN-IFM map metaphor reveals the many dimensions, information elements, and processing pathways that are included in the analysis and preparation of the maps presented in Figure D-7. As suggested in the previous section, there can be many alternatives for combining these elements. Alternatives can be viewed in terms of the general structure of the WoN-IFM as viewed through the lens of a theoretical framework such as the CHI model (Eddy and Taylor, 2005).

In Geographical Information Systems (GIS), it is common to think of *topology* as pertaining to how data are encoded and structured in terms of spatial relations among various types of spatial entities (Burrough and MacDonnell, 1998). Primitive data objects, such as points, lines, areas and volumes, can be modelled and structured in various ways depending on the nature of the data and its application. Considering the WoN-IFM as a map metaphor, there are also point, line and area relations within the model that influence the overall structural and functional aspect of the model and its outputs. As a metaphor, it is possible to examine how statements about wellbeing can be looked at *topologically*.

Starting with simple geometries and moving to the more complex, *points* in the map refer to all of the individual processing elements. These include the point sources, individual data variables, and the indicators at the tertiary level. *Lines* refer to the 'streams of information processing' of the indicators. *Areas* represent the various 'fields of knowledge' represented by the dimensions and sub-dimensions in the model, mimicking in some ways nested topological properties of watershed areas in the model. *Surfaces* may represent a particular combination of points, lines and areas wherein the processing pathways are in reality quite complex and convoluted, following the contours of processing elements from *upstream* primary data sources, *downstream* through secondary and tertiary processing levels. Topological metaphors may apply to linguistic statements such as: "The *area* of research I am involved in is....", "What's your *point*?", or "What *line* of reasoning do you use to arrive at that conclusion?". These are characteristic of at least some of the content of everyday human dialogue, and in some ways, exemplify the pervasiveness of spatiality and geography in language.

The WoN-IFM map metaphor serves as a visualization of one type of 'mental map', or 'cognitive map' in this respect; functioning as a visualization of both the holistic aspect of wellbeing as well as its many detailed parts. The subject of wellbeing is portrayed both aesthetically in the WoN-IFM as a complex, inter-connected network of various fields of knowledge that need to be combined and assessed; and analytically as an inference-based information flow model. The resulting statements are contingent upon the topological structure of the cognitive map, and different statements can result from alternative topological relations.

Ontological Boundary Conditions

One way of exploring alternative topologies is to examine a number of distinctive *boundary conditions* in the model. Table D-2 summarizes five types considered here. First, the various fields of knowledge are differentiated by the primary dimensions of wellbeing as defined in the WoN report. These may be considered to be *disciplinary boundaries* in some respect. Second, there are internal processing boundaries within each field that comprise primary (data), secondary (knowledge), and tertiary (meaning) processing levels. These may represent internal *informational boundaries* that differentiate levels of knowledge and experience required in working with data and knowledge on different levels, or they may also represent levels of maturation of a field of knowledge in its ability to be integrated in a wellbeing assessment.

Table D-2. Five types of boundary conditions in mapping wellbeing indicators.

Boundary Type	Description	Map Metaphor	Geographic Map
Dimensions	Fields of Knowledge	Visible	Silent
Levels	Levels of Information Processing	Visible	Silent
Qualitative	Qualitative Legend Intervals	Silent	Visible
Quantitative	Data Inclusion/Exclusion	Visible	Silent
Geographical	Geographical Framework and Scale	Silent	Visible

Within each area, there can be numerous processing pathways (network topologies) depending on the data sources used, the state of knowledge of the phenomenon being considered, and the desired goals and objectives that form the basis of value judgements that are applied to primary data. These can be considered to be *streams of specialization* or interconnectivity within specific organizations or disciplines.

Third are *qualitative boundaries* that differentiate the intervals in the legend as determined by the performance criteria applied to map the indicators. Qualitative boundaries are the degree to which some aspect of being is considered 'well' or 'not well'. Fourth, is a *data boundary* that pertains to what data is 'included' and what data is 'excluded' from the model in terms of specific data variables and/or quality of data. The fifth type pertains to the spatial or *geographical framework boundaries* to which primary data elements are intrinsically bound. In the case of the WoN, the spatial framework is the country political boundaries used to present wellbeing indicators on a global scale.

These boundary conditions can intersect in different ways depending on one's ontological perspective. *Ontology,* in a more general sense involves the 'study of being' and the context in which it is used here is considered both in terms of the analytical, or exoteric school that aims to describe 'what there is', and the more esoteric school that is concerned with 'how things might be' in terms of *being*. This integrative approach to ontology has received renewed interest in recent decades (e.g. May, 2005), and the WoN-IFM is used here as an example of a holistic ontology that contains aspects of both schools of thought.

One means for examining texts or statements made about the world may be in exploring how these boundary conditions intersect in a mental model; their totality is taken as an expression of a *geo-ontology*. As indicated in Table D-2, it is only in the *combined use* of both map metaphors and geographical maps that all boundary conditions can be made visible. It is argued here that many statements about the world may not be contingent on specifying which geographical regions to which statements apply. Such cases may be considered *non-geographical ontologies* in their context; or what is considered here as *common ontology*. Common ontologies are defined here as those that do not make explicit to which aspects of the geographical world they refer, and therefore, are presumed to be *aspatial* or *ageographical*; they imply universality wherever they occur. Where statements make specific reference to the geographical world (such as countries, regions, places), then they are contingent upon the use of geographical boundary conditions, and are considered geographical ontological, or *geo-ontological* in their context.

The following sections explore some of the implications for considering geo-ontological boundary conditions in analyzing and mapping wellbeing indicators. The approach taken here explores these five types of boundary conditions in two ways as *internal* and *external* conditions:

1) **Internal Boundary Conditions**. The first approach illustrates how subtle variations in ontological relations result in noticeable differences when projected geographically. In this case, the geographical framework

(representing external boundary conditions) is kept constant, and three alternative ontological models (internal boundary conditions) are compared.

2) **<u>External Boundary Conditions</u>**. In the second approach, a limited number of indicators are explored using different geographical frameworks across the local-global continuum. Here, aspects of internal boundary conditions are kept constant, and alternative geographical frameworks (external boundary conditions) are compared.

Before presenting the details of the analysis, it is first necessary to describe a qualitative indicator mapping methodology that is used to more adequately accommodate some of the qualitative issues involved in looking at ontological differences in the WoN-IFM.

Mapping Qualitative Difference

Among the five boundary conditions described above, one of the more contentious areas to reconcile is the manner in which qualitative boundaries are used within the overall framework, and how they influence the processing of quantitative data. As described above, the qualitative scale that the WoN uses is a five class categorical scale that ranges from 'good' to 'bad', with 'fair', 'medium' and 'poor' representing intermediary conditions. The WA method uses a numerical index in the 0-100 range with 20 point intervals to represent these five qualitative classes for each indicator as described in Table D-1. An important element to consider in a multi-authoring environment are the binary opposite terms used in qualitative scales, and the number of intervals used as these pertain to the granularity of qualitative judgements. Value judgements may be expressed on a 'good-bad' continuum, and there may be more subtle qualitative judgements, such as 'is sustainable' to 'is not sustainable', or 'meeting goals/objectives' to 'not meeting goals/objectives'. In each case, the qualitative scale is a gradational evaluation between binary opposites of desirable and not desirable conditions, and authors may have different intentions or contexts in their use, wherein the choice of terms can have different emotional implications for readers.

Patterns seen in the indicator maps with qualitative scales have the potential for transmitting strong messages that entice readers to (either consciously or sub-consciously) form qualitative judgements about specific regions or places, and along certain dimensions. It is argued here that it is the *qualitative transformation* level of information processing that incites many contentious debates about wellbeing. Qualitative scales may be used more subjectively depending on how readers interpret and apply value-based judgements such as 'good' or 'bad', or 'is sustainable' or 'is not sustainable'. The desire for openness and transparency in information processing (e.g following guidelines such as the Bellagio Principles (IISD, 1997)) would require authors to fully communicate their lines of reasoning for such value judgements, and make readers aware of the *uncertainties* in their analysis.

Providing authors the ability to be honest about the uncertainties in their analyses, while simultaneously presenting results in a concise reader-friendly presentation style, has several challenges. There may be numerous sources of uncertainty in information processing (MacEachren, et. al. (2005)), and for illustration, three sources of uncertainty in mapping indicators are considered here:

1. First, is uncertainty about the *accuracy or correctness of primary data*, as well as its completeness. It is not uncommon to have to deal with the problem of missing data, especially for a comprehensive subject such as wellbeing.
2. Second, there may also be some degree of uncertainty with respect to *the manner in which lower level indicators are combined* to form higher level compound indicators. Mathematical functions, such as taking the minimum or average of two or more sub-indicators, may or may not be adequate for representing higher level indicators in some cases, because they may not adequately reflect the context in which terms are defined.
3. A third source of uncertainty pertains to the accuracy or appropriateness of the *performance criteria* that are applied to primary data during the qualitative transformation process. For example, knowing that a given watershed is showing repeated measurements of 30 ppb Hg is relatively straight forward (i.e. 'what there is'); it is knowing the *significance* of this level in terms of its potential risk to humans, other species and ecosystem functioning that is often more difficult to discern (i.e. 'how it might be'). Establishing performance criteria for many human indicators is also challenging in this respect. In any case, authors would need to make clear the basis of their judgements, as well as their assumptions and limitations.

An alternative to the WA numerical qualitative index method that can more easily accommodate these sources of uncertainty would be beneficial in this respect. The alternative used here is a modified Fuzzy Logic method (FLM) based on Eddy, et. al. (2006). The FLM addresses these sources of uncertainty in three ways:

1) the use of *fuzzy membership values* as an alternative qualitative numerical index,

2) the use of *fuzzy inference functions* as a more flexible approach for combining multiple factors and information sources in an analysis, and

3) the ability to adjust or accommodate *multiple propositional statements* in relation to alternative qualitative scales.

In contrast to a 0-100 numerical scale, a fuzzy logic scale uses values in the [0,1] range, where a value of 0 represents 'no' or 'is not', and a value of 1 represents 'yes' or 'is' in relation to a propositional statement. In the case of the WoN, propositional statements can be represented by the goals and objectives set for the dimensions and sub-elements of the WA framework. With the use of qualitative binary scales, such as 'good' or 'bad', 'yes' or 'no', 'favourable' or 'not favourable', or 'meeting goals' or 'not meeting goals', intermediate values in the [0,1] range can be used in the fuzzy logic approach to represent varying degrees of qualitative uncertainty between the two extremes. Formal fuzzy theory terminology refers to varying degrees of 'membership' (1) and 'non-membership'

(0). In the modified fuzzy logic method (FLM), the value of 0.5 is used to represent *complete uncertainty* in relation to a proposition.

Although the application presented in Eddy et. al. (2006) illustrates uncertainty about mineral resource potential in relation to geographical scale, the same approach is used here to represent uncertainty in relation to a qualitative value scale. It represents uncertainty in answering questions of the type “Is the situation good or bad?”, or “Is Country X meeting its goals or not?”, or “Are conditions sustainable or not sustainable?”. As is the case with many real life situations, answers to these questions are often not crisp answers. They are usually conditional upon details in the sub-dimensions, such that, for aggregate statements about places or countries, the totality of statements often fall somewhere in the middle.

The modified FLM uses the term *aporia* as the mid-point in the fuzzy membership scale (at 0.5, complete uncertainty), and *aporia* is also used as the starting point of the general *approach* to answering a question. That is, the starting point in any proposition is to first assume *aporia* until sufficient evidence can be provided as a basis for a value judgement toward either end of the scale. This is similar to an ‘innocent until proven guilty’ approach; or, in other words, ‘unknown until sufficiently known’.

Another component of the FLM is the flexibility it provides in *inference modelling*. An inference model describes how various information elements are combined to construct a propositional statement. As described above, the WoN-IFM is a type of inference model that shows a synthesis of over three hundred variables to produce more than one hundred qualitative indicator maps representing the human and ecosystem dimensions of wellbeing at a global level. At each node in the WoN model, a mathematical operation is applied to the variables combined; such as a *min* or an *average* of the values of combined sub-elements. One advantage the FLM has over these inference modelling techniques is that it provides both simple mathematical operations, as well as more advanced functions for more complex thought processes – such as the need to reconcile conflicting information sources. These functions are known as *combination rules* in formal fuzzy theory. Table D-3 summarizes five rules used in Eddy, et. al. (2006) and are described briefly here.

Table D-3. Five fuzzy combination rules used in fuzzy inference modelling.

Rule	Formula
AND	$\mu_c = \mathrm{Min}(\mu_i)$
OR	$\mu_c = \mathrm{Max}(\mu_i)$
PRODUCT	$\mu_c = \prod(\mu_i)$
SUM	$\mu_c = 1 - \prod(1 - \mu_i)$
GAMMA	$\mu_c = 1 - \prod(1 - \mu_i)^{\gamma} * \prod(\mu_i)^{1-\gamma}$

The fuzzy AND and OR functions are the simplest rules that are equivalent with standard *min* and *max* functions. The AND rule is applied in situations where the minimum of values is taken as a base measure of a situation, such as the need to have two or more preferential circumstances co-existing simultaneously. For example, in situations where both human AND environmental conditions need to be favourable, the indicator would take the value of the minimum of these two dimensions as a measure of the overall state of conditions. The OR function is applied in situations where the conditions of two or more variables are not contingent; such as taking the better value of human and environmental indicators to assess if there are favourable conditions for either indicator.

The fuzzy PRODUCT and SUM functions, in effect, stretch the AND and OR functions to lower and higher values than the minimum and maximum input values. The PRODUCT has a decreasive effect on a combination of a set of values, where the net value is always less than the minimum of the set. It is used in situations where a combination of factors has greater negative consequences when two or more conditions are not favourable. For example, if there is both war and a natural disaster in a given country, the net conditions would be regarded as lower than other places where there was only either a war or a natural disaster. The SUM function has the opposite affect. It increases the net value for situations where the combined affect is more favourable than either condition independently. For example, if both the economy and the environment are healthy, the net indicator value is calculated as being higher than either indicator individually.

The PRODUCT and SUM functions are not used explicitly in the examples that follow, however the GAMMA function is used, and its formula is a function that combines PRODUCT and SUM operations. The GAMMA is a type of averaging function and is mathematically a sliding scale that combines the PRODUCT and SUM functions. The GAMMA value is set within the [0,1] range, and determines the degree to which the PRODUCT or the SUM functions operate on the input values. A lower GAMMA value has an overall decreasive effect on the input values, and higher GAMMA values have an overall increasive effect.

Middle values (e.g. 0.4-0.6) operate similar to a standard mathematical averaging function. The GAMMA function is applied in cases where a strict mathematical average function may not seem appropriate; it is used in situations where authors may need to accommodate conflicting information in an alternative way. It is sometimes used as a basis to express a general feeling or a 'hunch', and is often used experimentally to visualize the effects of ambiguous judgements.

Fuzzy membership values can be treated as equivalent to WoN index values, and when used with simple mathematical operations (e.g. min, max and average), the FLM will produce identical results; the only difference being that the numeric values will be in a [0,1] range instead of a [0-100] range. In this way, it can be used as a direct substitute for the index method used in the WA framework, and it provides additional flexibility for dealing with missing data and more complex inference modelling. Qualitative descriptions associated with various intervals may be changed or modified depending on the author's preference and suitability for the type of qualitative judgement being applied. The following section presents several illustrations of the effect of examining internal and external boundary conditions using the FLM as an alternative to the standard WA index.

Illustrative Examples

Internal Boundary Conditions

Three models of internal boundary conditions are presented here for comparison with the WoN model, wherein the information elements used from the WoN data are restricted to the indicator level in the WoN-IFM. This scenario demonstrates how different maps and statements about the world can be made strictly on an indicator level, and it assumes that authors are satisfied with both the data and knowledge sources used on the primary and secondary levels of the model. The three models illustrate the effect of changing the internal boundary conditions in the model in three ways. Models 1 and 2 look at two ways of considering the data boundary conditions (exclusion/inclusion), and Model 3 looks at changing the dimension's boundaries. Inference maps for each of the three models are presented in Figures 11 to 13, and are described as follows:

- Model 1 (Figure D-11) – Model 1 uses the same indicators as the WoN-IFM except missing data is explicitly included in the analysis. The sub-elements for which there is missing data are indicated by the fuzzy nodes in Figure D-11. Some dimensions have missing data for more than fifty of the one-hundred and eighty countries (e.g. Community Index). Prescott-Allen addressed this problem by lowering the resulting index score for these countries. In the FLM approach, countries with missing data can be assigned a value of '0.50', which represents complete uncertainty, and can be included in the calculation of indicator scores. This way, the uncertainty value has an influence on the net calculation of the indicator score.

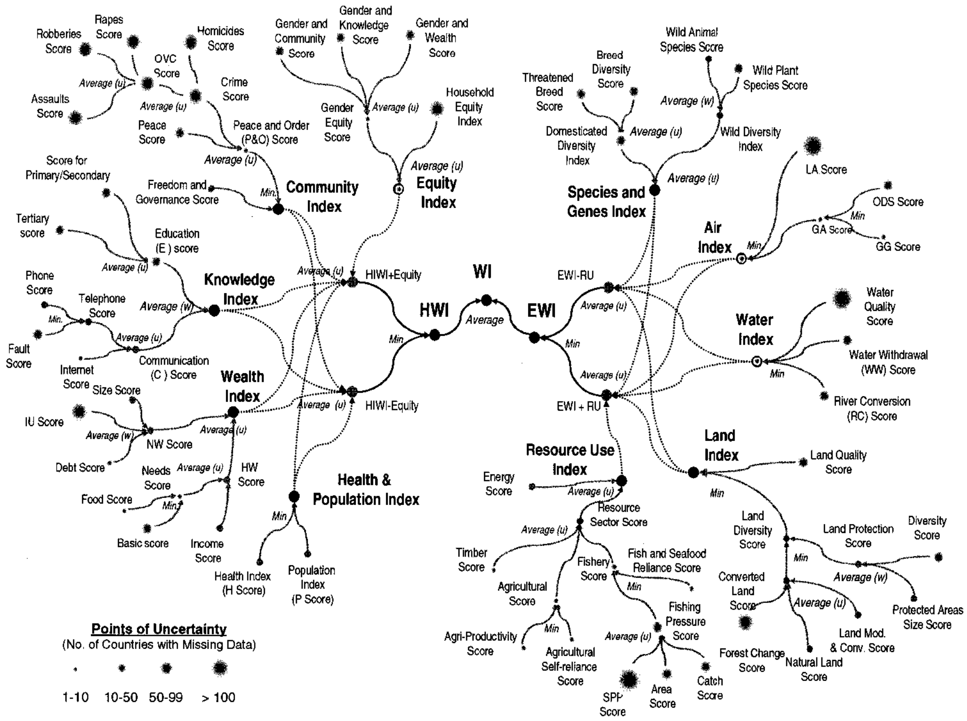


Figure D-11. Alternative Model 1 of the WoN-IFM. All indicators remain the same except missing data is included in calculations.

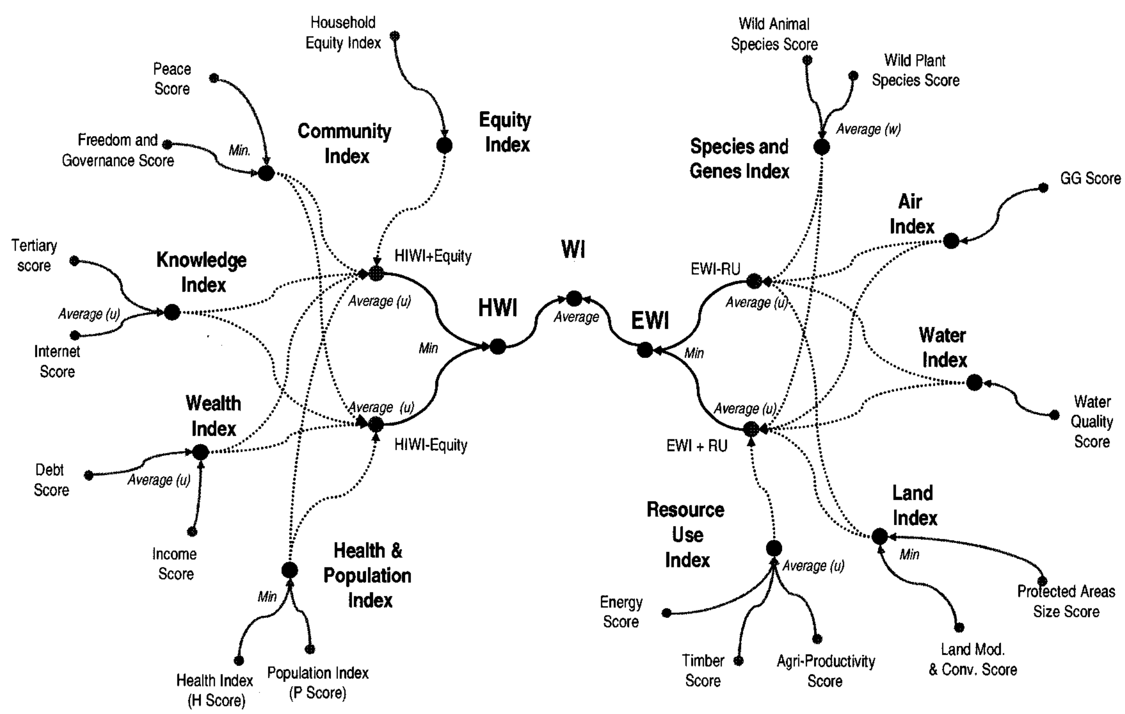


Figure D-12. Alternative Model 2 of the WoN-IFM model.

- Model 2 – Figure D-12 – Model 2 looks at a scenario whereby the number of data and knowledge sources may be limited, and therefore only a more limited number of indicators are used (Figure D-12). This scenario may be realistic for several reasons. First, if the system is used to monitor progress over time, it may not be feasible to maintain all of the primary data sources used in the WoN model. Second, some authors may not be satisfied with the problem of missing data as treated in Model 1, and may prefer to only use indicators for which there is complete representation. A third reason may be that some modellers may feel the current WoN-IFM is too complex for the public, laypeople or even experts to fully comprehend. In this view, indicators are viewed less as comprehensive measures of all of the complexities of wellbeing. A more limited number of indicators are easier to manage (e.g. such as the limited number of indicators selected for Canada by NRTEE, 2003). This option would be taken at the expense of the ability to disaggregate deeper into sub-dimensions and sub-elements when exploring dimensions that are not performing as desired.

- Model 3 – Figure D-13 – In Models 1 and 2, the dimensions and the general inference structure of the WoN model is maintained. That is, the overall *ontological structure* is unchanged, and the differences consider alternatives for more explicitly including missing data (Model 1), or limiting the number of indicators used (Model 2). Model 3 (Figure D-13) provides a different ontology wherein the main dimensions and their respective sub-dimensions and elements are different terms and concepts, and can also represent a different perspective on various fields or areas of study. Additionally, the inference logic for each dimension is also different from Models 1 and 2, whereby the scores for a subset of indicators used in Models 1 and 2 are combined differently to define the alternative dimensions. Model 3 mimics a scenario whereby the definition of wellbeing is different from that of the WoN model, and the main dimensions represent a number of alternative issues such as Peace and Justice, Biodiversity, Quality of Life, etc.

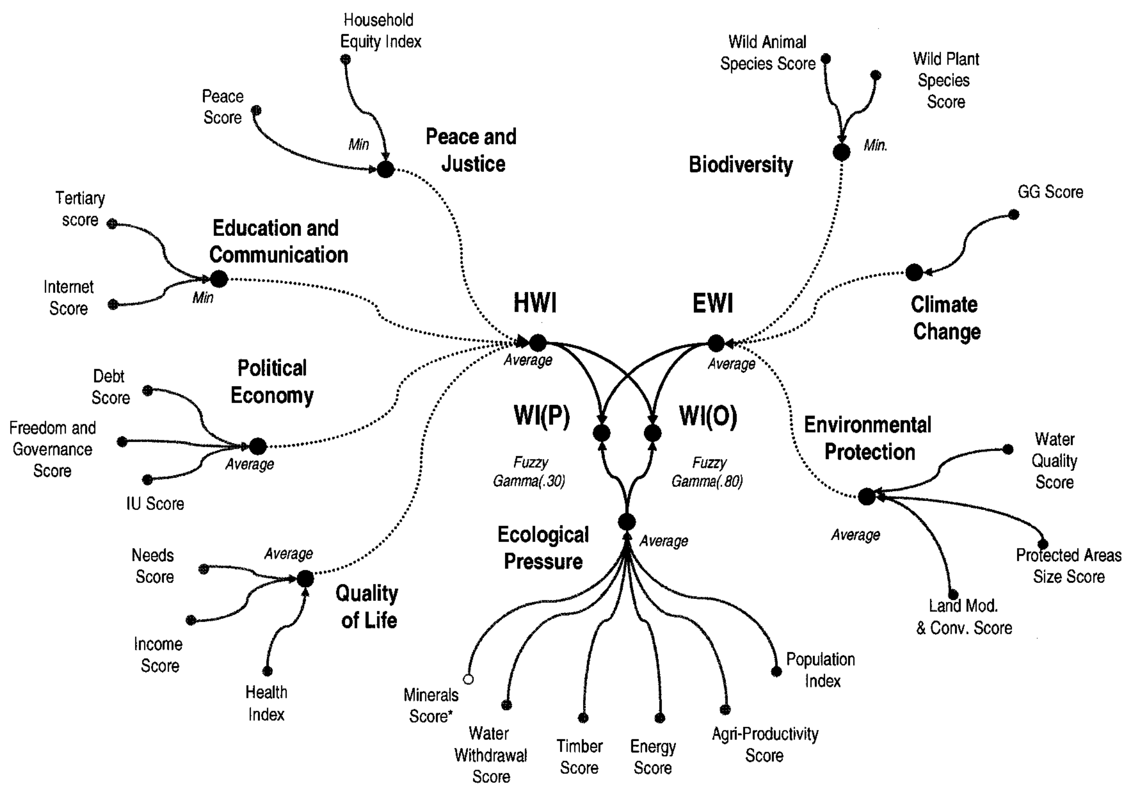


Figure D-13. Alternative Model 3 of the WoN-IFM model.

Model 3 uses three sub-systems that include human (HWI) and ecosystem (EWI) wellbeing indicators (which are defined differently than in Models 1 and 2), and an interface between the two (Ecological Pressure Index). Ecological Pressure is similar to the Resource Use dimension in the WoN model and alternative Models 1 and 2, but is separated from the calculation of the EWI. It is viewed in terms of a human-environment interface dimension that is not exclusive to either, but is included in the calculation of an overall Wellbeing Index (WI).

The two WI values represent hypothetical 'pessimistic' (WI(P)) and 'optimistic' (WI(O)) views. Here, the Fuzzy Gamma function is used with a lower gamma value (0.30) to represent a pessimistic view, and a higher gamma value (0.80) to represent an optimistic view. The gamma function could be used to compare a range of overall perceptions from a variety of authors. Some authors may view the sub-dimensions of the ecological pressure index in relation to its resource supply for human use, whereas others may take the view that these illustrate the detrimental affects on the environment. Implications for condensing an overall statement about the state of the world in this regard are discussed further below in conjunction with the maps presented in Figure D-18.

Figures D-11 to D-13 represent the three alternative models for constructing indicators of human and ecosystem wellbeing, and an overall wellbeing index. In presenting these three alternative models, the focus is not the degree of truth or correctness of one model over another. The emphasis is on demonstrating how changes in assumptions, definitions, the treatment of missing data, and the *inference logic* influence the results. The three models, as map metaphors, may be regarded as examples of the 'inner space', or human mental models for discerning the state of the world.

The results of the three models presented in the maps and graphs in Figures D-14 through D-17 illustrate several issues. Figure D-14 presents the results for the HWI and EWI in comparison with the original WoN model. Although there are differences and similarities among the four maps for each indicator, some of these differences paint noticeably different pictures of the world. The most notable differences occur not so much at the HWI and EWI indicator level. The maps in Figure D-15 show four selected indicators from within both the HWI and EWI sub-systems for Models 1 and 2 in comparison with the WoN results.

First, the results for the Health and Population Index illustrate how the FLM produces identical results in cases where there are no missing data and the same inference rules are applied. The three maps are identical because the same indicators are used in all three maps. This is illustrated also in Figure D-16 as a perfect correlation between the results from Model 1 with the fuzzy equivalent values of the WoN model.

The Community Index shows significantly different results than the Health and Population Index. Model 2 paints a somewhat more polarized view of the world, whereas Model 1, which more explicitly includes *uncertainty* among a greater number of sub-elements, paints a less polarized view of the world; one in which the values for many countries fall within the mid-range of the value scale and centre around *aporia*. The correlation between Model 1 and the WoN model remains very high in Figure D-16, but the patterns that are revealed in the map have noticeable differences.

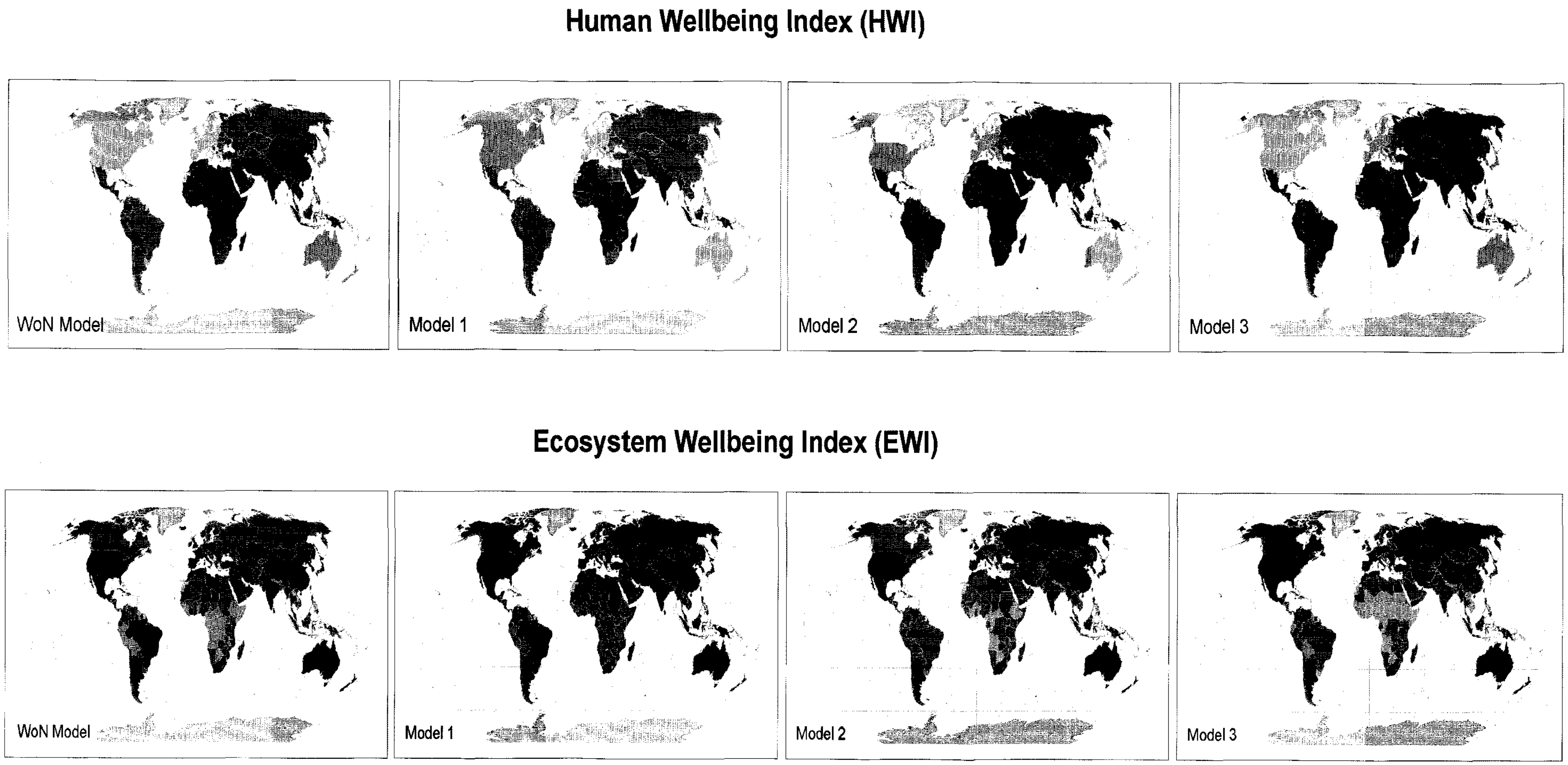
Differences in results are more significant for two sub-dimensions of the EWI; the Species and Genes Index, and the Water Index, even though the values are highly correlated (Figure D-17). In the Species and Genes Index, the change in map pattern is due to a 15-25 percent variation in values along the correlation line in Figure D-17. Such subtle differences have a noticeable affect on the map result, which cannot be visualized from a correlation chart used on its own.

The results for the Water Index illustrate a noticeable difference in the map pattern that results when missing data is explicitly included. This is because the index is calculated as a minimum of values from the three sub-elements, one of which includes missing data on Water Quality for more than one hundred countries (Figure D-11). The inclusion of missing data in this way produces a downgrading Effect on the index scores for many African countries.

One aspect of all maps that remains relatively consistent is a general inverse relation between the values of the HWI and EWI. Countries that score higher in one index tend to score lower in the other. This relation implies that HWI increases at the expense of EWI, and any overall Wellbeing Index (WI) is likely to result in mid-range values rather than overall high or low values if both HWI and EWI scores are considered equally (i.e. such as taking the average of the two).

There's so many different worlds,
So many different Suns,
And we have just one world,
But we live in different ones.

Mark Knopfler
Brothers in Arms



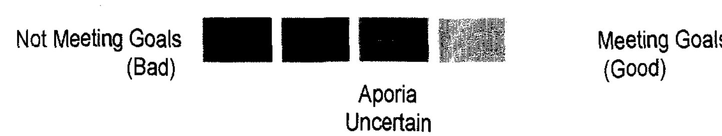


Figure D-14. Model Comparisons for the Human Wellbeing Index (HWI) and Ecosystem Wellbeing Index (EWI)

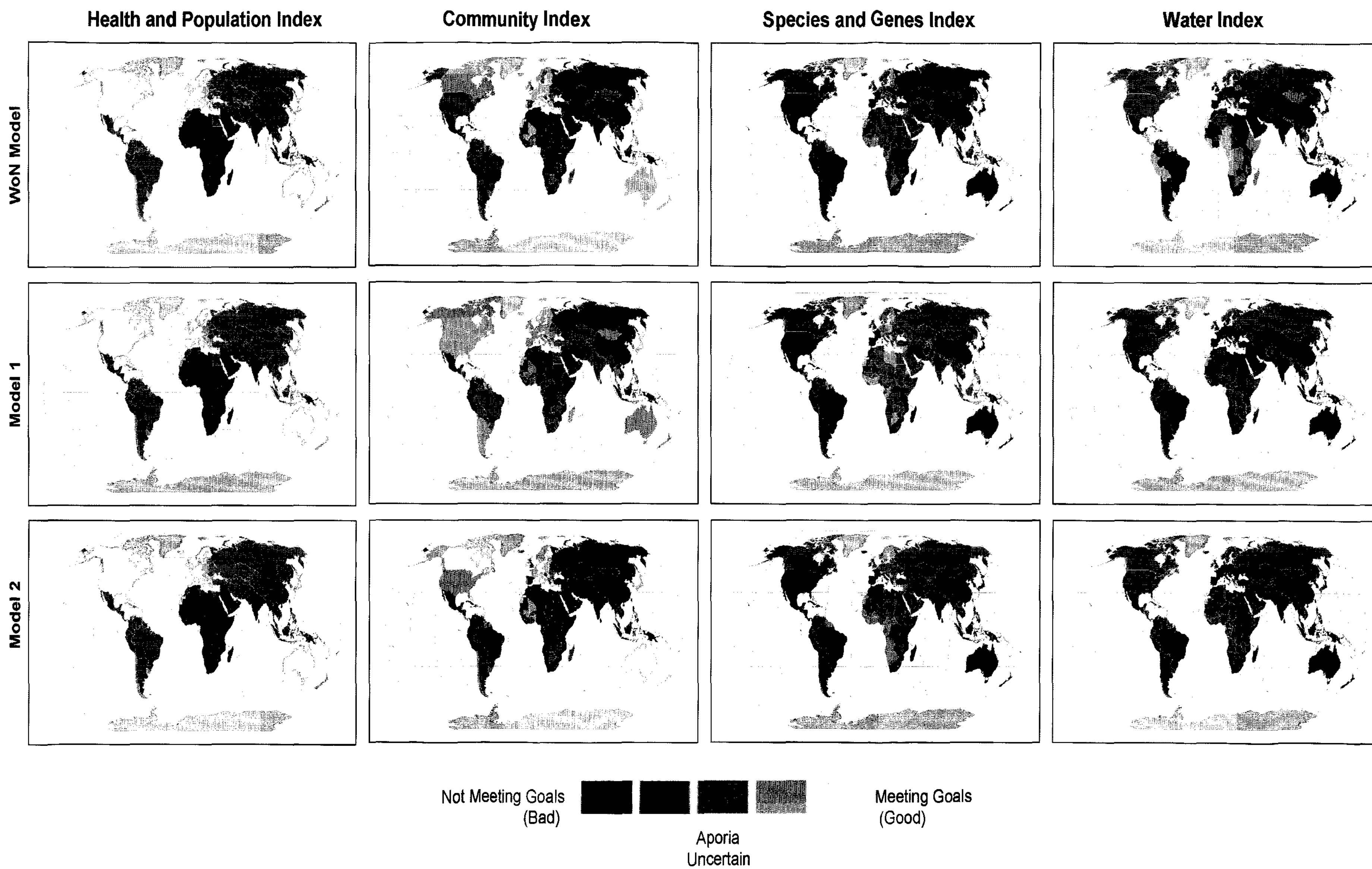
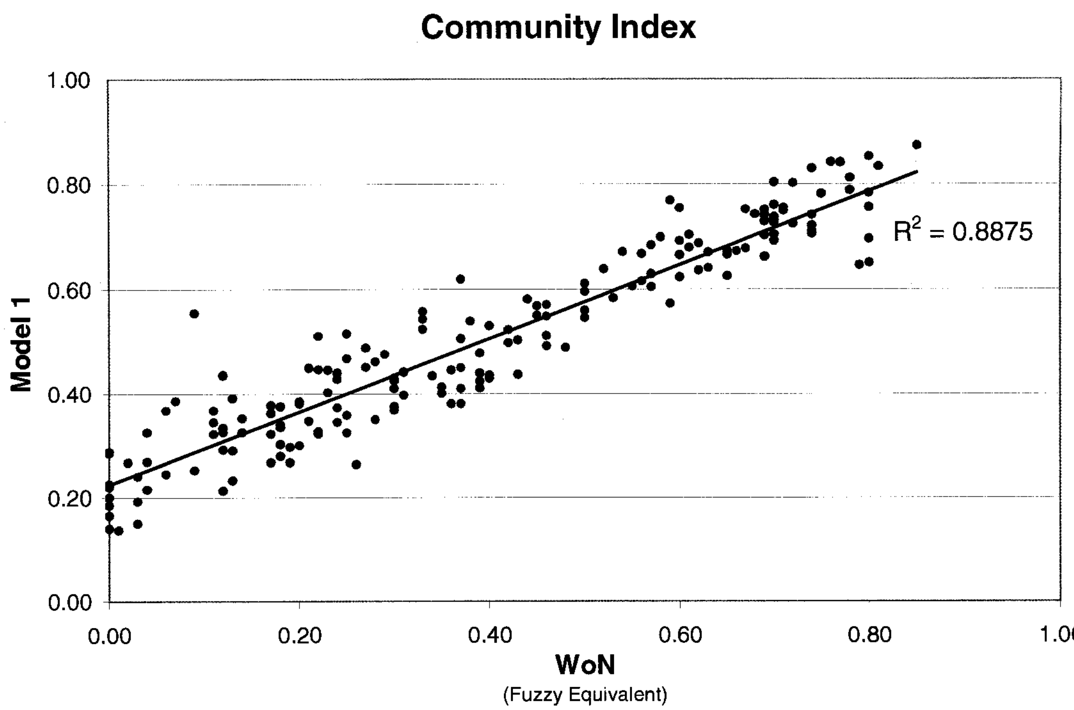


Figure D-15 Model Comparisons for Selected Dimensions.



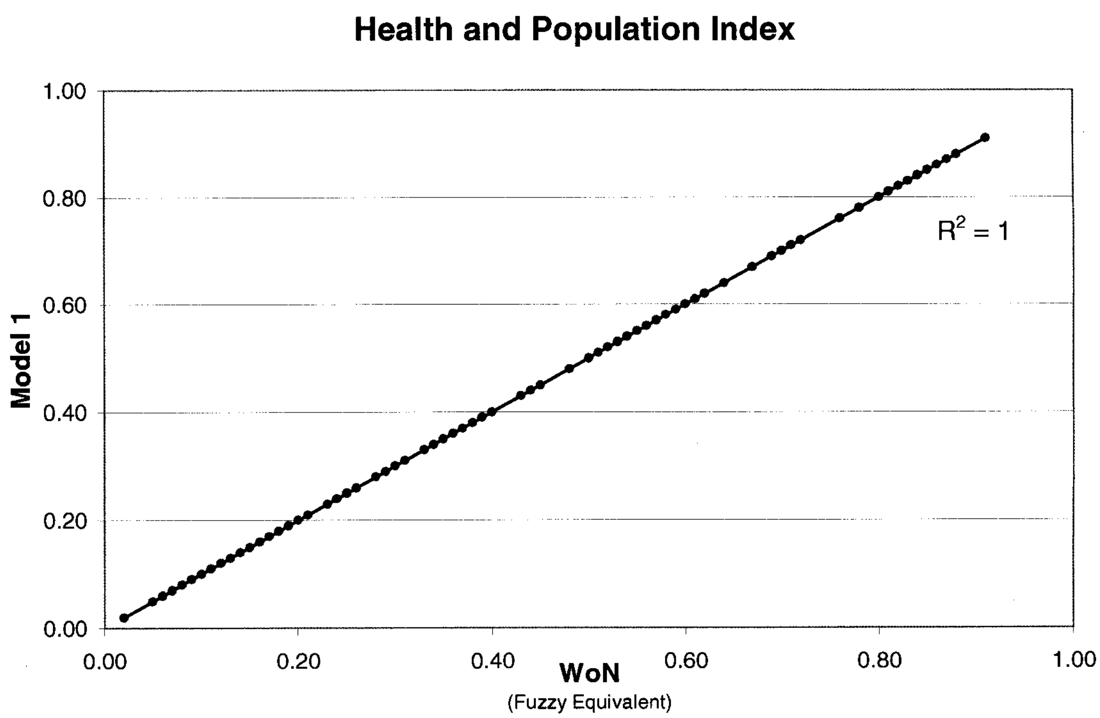
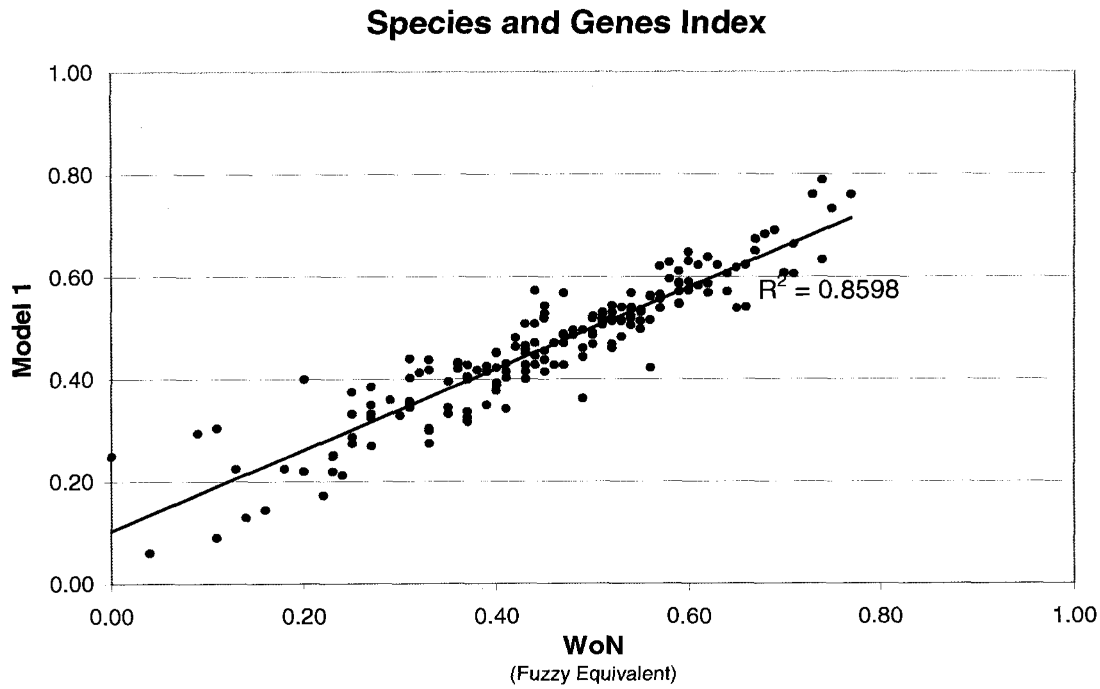


Figure D-16. Correlation of selected index values between the WoN model and Model 1: Community Index and Health and Population Index.



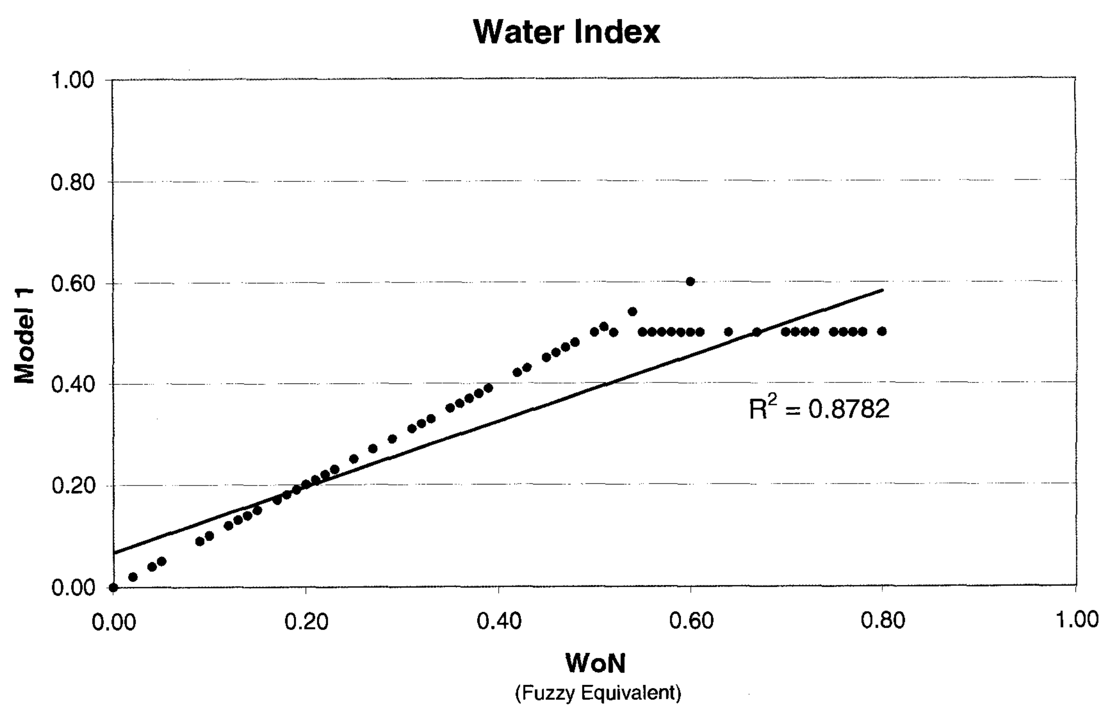


Figure D-17. Correlation of selected index values between the WoN model and Model 1: Species and Genes Index and Water Index.

This effect is illustrated in the maps shown in Figure D-18 which presents the results of two approaches to calculating a WI in Model 3. The HWI and EWI input maps for the calculations (Figure D-14) show wide variation across regions, whereas Figure D-18 shows significantly less variation when a GAMMA function is applied to simulate optimistic (WI(O)) and pessimistic (WI(P)) perspectives.

The cognitive map metaphors and the geopolitical maps presented here are examples of numerous possible ways to model and experiment with qualitative judgments. Other inference modelling, statistical analyses, and mapping methods may be applied within the fuzzy logic modelling process. These illustrations are not exhaustive, rather they are intended simply to reveal several aspects in using map metaphors to make value-based statements about the world.

Higher level compound indicators (HWI, EWI, WI) tend to reveal more ambiguity (patterns closer to *aporia*), whereas the lower level indicators (dimensions and sub-elements) tend to reveal more variation. The correlation charts presented in Figures D-16 and D-17 illustrate that although two or more models may be statistically similar, the presentation of results in map form may reveal significant differences. The map used as a medium for presenting this information is irreplaceable in this regard. The three models presented here use the same primary data and secondary knowledge sources, and substituting alternative primary data and secondary knowledge sources will produce other differences in results.

Wellbeing Index – Model 3

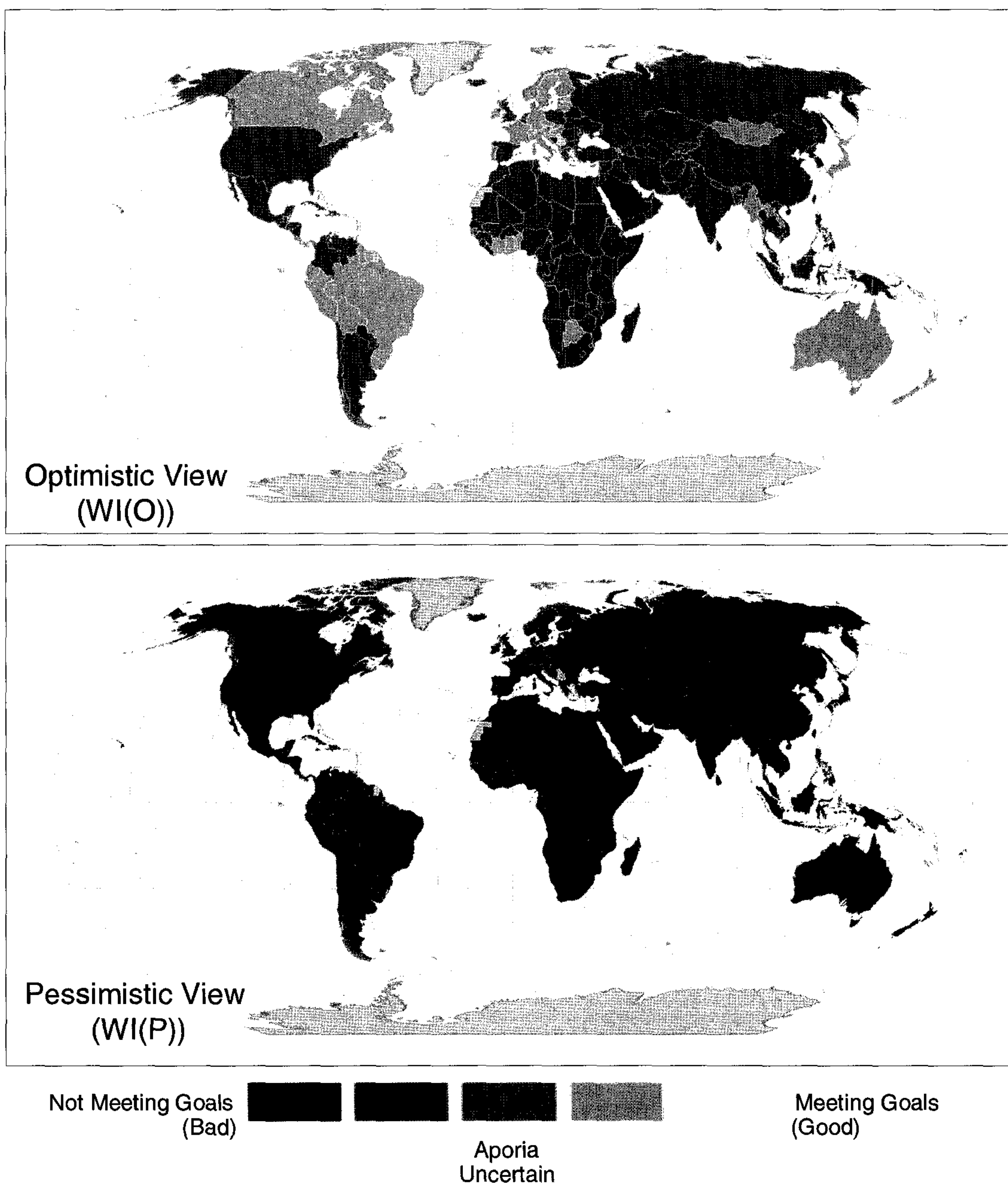


Figure D-18. Two example calculations of an overall Wellbeing Index (WI) based on an Optimistic and Pessimistic views on combining HWI and EWI values in Model 3.

These examples highlight important aspects of using maps as a *medium* for making value statements about the world. Statements made with words alone (linguistic, narrative, textual) or with numbers alone (tables, statistics) are incomplete, and can be misleading in the impressions they impose on readers. The use of maps in combination with words and numbers illustrates the necessity in making visible the *spatiality intrinsic in human thought* and its Effect on projected views of the world. An emphasis must remain on the *combined value* of maps, words and numbers, because it is important to provide readers with transparency about the mental models and the data used to express and support specific value judgments, as well as to include visualizations of what the world looks like when numbers and words are combined in different ways. It is the *spatiality* and topological relations in human thought that are rendered in these visualizations.

With respect to making qualitative value statements about the world as a whole, the WoN maps may be regarded as a 'view from the moon'. As with any geographical mapping process that is limited to a particular geographical scale, it is important to be cognizant of the potential for committing two types of fallacies:

1. First, is a fallacy of *over-generalization*; which is a tendency to make over-generalizing statements about the world, or regions as a whole.
2. The second type of fallacy is an *ecological fallacy* wherein values for specific countries or regions are ascribed equivalently to places 'within' those countries or regions.

The following section explores some of the implications of these fallacies when *external boundary conditions* are explored in relation to geographical scale.

Now watch what you say,
Or they'll be calling you a Radical,
A Liberal,
Fanatical,
Criminal.

Won't you sign up your name?
We'd like to feel you're Acceptable
Respectable,
Presentable,
A Vegetable!

Supertramp
The Logical Song

External Boundary Conditions

The WoN report is a useful reference for people and organizations working on an international level (e.g. the United Nations). It provides a means for monitoring how countries are performing in any number of dimensions or issues. There are a number of additional issues that need to be addressed if the WoN-IFM is to be used as metaphor or an interface for a wellbeing assessment atlas or web-portal wherein maps are multi-authored and present indicators on other geographical scales. A critical issue covered in this section is not aimed at the WoN report or the WA methodology directly, but more so at the assumptions and implications of the use of *choropleth maps* for this purpose; and in particular the use of various types and levels of *spatial data frameworks* for indicator mapping. This aspect explores how maps may at times be detrimental depending on how they are used.

Slocum, et. al. (2005) explain that choropleth mapping is intended for "phenomenon that is uniformly distributed within each enumeration unit, changing only at enumeration unit boundaries" (ibid., p. 251). They caution that the choropleth map is "arguably the most commonly used (and abused) method of thematic mapping", and that "data values depicted for enumeration units must be viewed as '*typical*'', as opposed to being uniform throughout enumeration units" (ibid., p 250). In using country boundaries as enumeration units in the WoN maps, a most appropriate data variable might be the form of government because this is determined in relation to the political entity represented by the enumeration unit. Other variables that are not so intrinsically related to political or administrative units can be more problematic; particularly phenomena with behaviours that do not follow political or administrative boundaries (e.g. water quality, species at risk).

Given these precautionary principles in choropleth mapping, it is important for readers of WoN maps to be able to interpret them appropriately, but this is often not the case. As Slocum emphasizes, the choropleth map is the most 'commonly used and abused' method of mapping, and many of these types of maps are not created under the more careful judgement of professional cartographers. Impressions that form in the mental models of the readers can, and often do, have social, economic, political and cultural implications. This is raised as a critical issue because in order to provide flexibility and transparency in a multi-authored mapping environment, a comprehensive subject such as wellbeing necessarily requires working across geographical scales, whereby more detailed data sources need to be included and the geospatial frameworks associated with local sources may differ significantly from the geospatial frameworks used at other scales.

The examples presented in the previous section experimented with indicator level information in the WoN model, wherein the spatial data framework (country boundaries) and the geographical scale (global) were kept constant. This section explores external boundary conditions in terms of alternative spatial data frameworks and their influence on the indicator map patterns.

The first illustration is presented in Figure D-19 which shows representations of Canada at three nested scales: A) Global, using an international-political framework (the WoN model), B) National, using provincial-territorial framework, and C) regional, using Census Divisions. The indicator shown is an Unemployment Index, which uses the same performance criteria (legend intervals) as used in the WoN. In the WoN report, Canada's unemployment rate is reported as 8.3 % for the year 2000, which falls within the 'fair' interval on the WoN scale. Figure D-19 shows this variable disaggregated into provinces and territories, and further into census divisions.

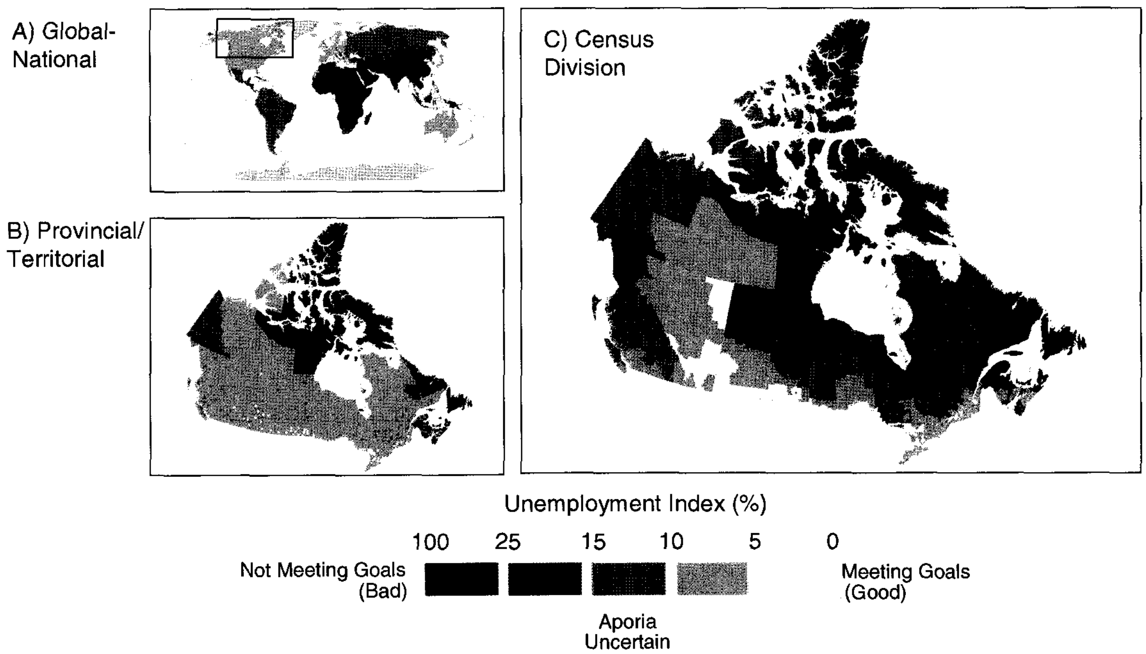


Figure D-19. Illustration of the influence of spatial data frameworks on map patterns across geographical scale. (Data Source for B and C: 2001 Census, Statistics Canada)

With each level of disaggregation, there is a an increase in regional variation. At the census division level, a significant number of areas have values greater than 15 %. It is necessary for both experts and laypeople to understand that statistical values reported or analysed at a specific framework level are always aggregated from data collected on lower level units of the framework. At each level of deeper disaggregation, the greater the variation relative to the higher level aggregated value; and therefore, the less the aggregated value is capable of adequately representing all lower level units equally in the framework.

The statement that "Canada's Unemployment Index is fair" can only be made in comparative relation to other countries around the world (and only at a 'country' level). The potential ecological fallacy in such a statement is the implied message that all regions 'within' Canada are also 'fair' (between 5-10%). The maps in Figure D-19 illustrate this is not the case. In order to better appreciate a variable and its behaviour across scales, it is useful to look at cartographic representations that show *multi-level* variation. In this context, the map is used not so much for the presentation of facts or conclusions, but to foster the discovery of patterns in geoinformation (DiBiase, 1994).

One method of cartographic rendering is presented here in the form of a *Domino Map* as shown Figure D-20. A Domino Map uses an area background theme and a point foreground theme, whereby the area theme is the higher level framework (here, census divisions), and the point theme are the centroids of the next lower level framework (here, census sub-divisions). The variable is the same for both themes, and the legend intervals are also the same. What it reveals are locations where the values for census sub-divisions differ from higher level framework (census division) values.

A Domino Map is the proposed term for this type of map for two reasons. First, the point/area overlay symbolization in black-grey-white provides visual resemblance of a domino chip. Second, the degree to which sub-division values differ from the division values disturbs the 'dominating' affect that aggregated values have over their disaggregated values. The intensity of contrast among the multiple possible combinations of shades of black, white and grey illustrates the degree of deviation from the aggregated values. The greater the degree of variation, the more intense and 'disturbing' the map appears. This can be seen in contrast to the crisp and smooth tones of the map presented in Figure D-19 (c) that shows the same aggregated values without the values of the census sub-division centroids.

Domino Maps can also be used to augment or extend taking a Domino Theory (Knox, et. al. 2004) approach to analysing domestic or foreign policies, in particular how policy objectives (such as setting specific performance criteria for particular places and regions) may differ; or influence the perception of places as they may differ from the benchmarks set within policy objectives. The Domino Map shown in Figure D-20 illustrates its use on a sub-national level that looks at individual communities in relation to regionalized variables, but may be theoretically applied at any political or administrative geographical scale and associated spatial data framework.

The emphasis here is not on visual aesthetic to please the eye, or to feed the desire for simplicity and generalization. Rather, it is intended to reveal to the reader some of the map silences that are commonly left out of conventional choropleth maps; that the information being transmitted is not as simple as is often conveyed in conventional approaches to choropleth mapping. For experienced practitioners who map statistical data, this illustration is by no means a new revelation; and there are numerous alternatives for analyzing and presenting spatial statistical variance. The benefit of the Domino Map is that it reveals the *locationally explicit* variance of a location's value in relation to its higher level framework value, and its variation in relation to other locations (e.g. locations 'A' and 'B' in Figure D-20).

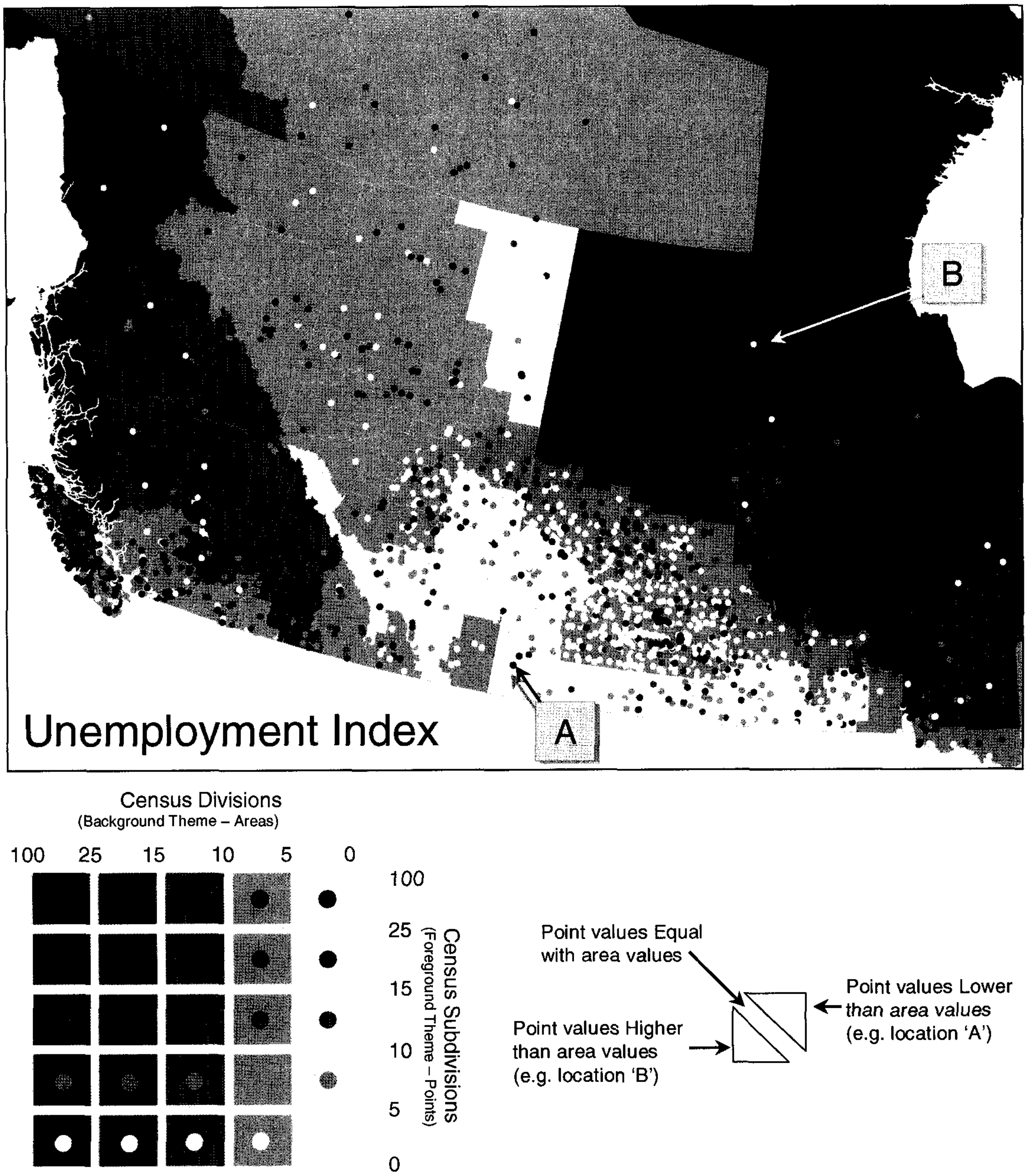


Figure D-20. Whole-part variation of data values illustrated as a 'Domino Map'. See text for elaboration. Data Source: Statistics Canada, 2001 Census.

The information provided in patterns that can be seen visually in map form cannot be represented wholly in any numerical (tabular) or textual (narrative) form. The map holds a unique place among alternative information media for conveying this information. Each place can be treated as unique, while simultaneously contrasted with its neighbours and its regional aggregate value. Figure D-20 illustrates that there can be as much variation within census divisions, as there are among provinces and territories, and on a higher framework level among countries (as shown in Figure D-19).

Exploring data in this way raises two key issues: 1) how indicator maps of this type have implications for the characterization of regions and places, and 2) issues in terms of the value judgements made about individual places in relation to normative performance criteria. In many cases, there may be little dispute over some types of performance criteria such as those applied to crime rates or income equity. A target of '0' for crime rates, and '1' for income equity between genders are reasonable judgements. However, there are other cases where performance criteria may be more ambiguous, especially when applied to local areas where the data used do not adequately represent the complexities or uniqueness of conditions at a local level.

For example, some communities may stagnate for decades at high 'official' unemployment rates, and are therefore be seen as 'poor' or 'bad' on a national or global qualitative scale. This does not suggest that it is acceptable to allow high unemployment rates to be sustained; rather, alternative metrics for employment and participation in the local economy – both formally and informally - might also need to be considered. Official employment/unemployment rates do not currently take informal economies into account. This issue can be traced back to the WoN-IFM map metaphor wherein the qualitative judgements that are placed on numerical values depend on the ontological structure imposed on the data. That is, it depends on how one defines *economy*, or *unemployment*; and consequently, how definitions determine how such things are measured and valued.

With respect to assessing the influence of an unemployment factor on the wellbeing assessment of a community, the strictly limited use of formal statistical information may not only be misleading in this regard, but detrimental to recognizing the efforts of local people who may have developed alternatives to formal modern economic means of livelihood and sustainability. This is particularly true for many communities in Canada's northern, coastal, rural and frontier communities; but may also be true for individuals and sub-communities within larger metropolitan cities (which may be shown with data mapped to a more local level in urban environments). Around the world, it may also be true for places, regions, or countries that have economies and livelihoods that deviate from modern, western economic models.

Choropleth maps that do not provide sufficient transparency on these critical elements may potentially reinforce both the over-generalization fallacy and the ecological fallacy; which are often pervasive in political rhetoric wherever references to places, regions, cultures and identities are mentioned. The uniqueness of the 'local', and especially the 'individual', is often obliterated by such overgeneralization. Conventionally, choropleth maps like the WoN indicator maps, or those presented in Figure D-19, are usually intended to *augment statistical tables* more so than to make accurate statements about places they aim to represent. In this context of use, the map or 'space' and 'place' is not the focal point, rather it is the 'statistic', and the map is provided for additional reference. However, such maps are often not read or interpreted in the manner in which geostatisticians intend.

What is needed to address these issues is a reflexive mapping environment that allows readers to explore the world from multiple perspectives, and across geographical scales and frameworks, issues/themes and data sources. This will likely involve the need to develop new cartographic methods for representing phenomena, beyond those that are conventionally used in modern analytical cartography and GIS. The Domino Map presented above is just one example of an alternative visualization. Considering multiplicities in scale, authorship, themes and issues, data sources, temporal and spatial frameworks, and visualization methods – taken in combination – is no small task. Cartography and Geographic Information (GI) Science, as a body of theory and practice, now faces this challenge, and the circumstances in which the field finds itself are not trivial. Maps and mapping will be increasingly used to convey information about life conditions and a plurality of circumstances across a full range of geographical scales. There are important political, social, cultural, economic and even personal implications for how geographical information will be used under varying circumstances. The concept of *Cybercartography* has only just begun to address some of these issues, and significantly more work is needed in this area (Taylor, 2005).

One means of approach may be to reverse a dominating 'tendency' in the practice of cartography and geographical information processing. The WoN maps, and the statistical enumerative area maps shown in Figures 19 and 20 may be regarded as 'top-down' impositions of frameworks and ontologies that are imposed upon the data, and therefore set constraints on the number of perspectives that are possible. An alternative is to take a 'bottom-up' approach, starting with individuals and their communities, and in effect, 'zoom out' to regional, national and global levels of information processing. Identification of alternative patterns will likely emerge at various scales from bottom-up processing. A variety of spatial frameworks and forms of spatial representation may emerge in time through this alternative approach.

Figure D-21 provides one alternative spatial framework for visualizing indicator patterns. It is a composite indicator map of socio-economic conditions as viewed through a *surface model* using the centroids of census sub-divisions as the spatial unit of analysis. This indicator map was calculated using the FLM method by combining four indicators including Unemployment Index, Primary Education Index, Equity Index and Employment Diversity Index derived from census data at the level of the census sub-division.

The compound socio-economic index was calculated first for each individual place (as represented by centroids of census sub-divisions). The surface model was calculated from an interpolation of values between places using an inverse distance weighting (IDW) method. There are many alternatives for generating surface models of this type, such as kriging, and there are other technical issues to consider in terms of the accuracy and appropriateness of a map of this type. The positional accuracy of census sub-division centroids as the spatial unit of analysis, and their suitability for spatial representation of the communities, may be improved by using centroid locations of actual communities. In this particular map, the patterns that are interpolated between centroids may not accurately reflect conditions in the vicinity of where communities actually exist.

In this sense, this particular model does not quite 'touch ground' as well as it should, and readers must treat it with caution.

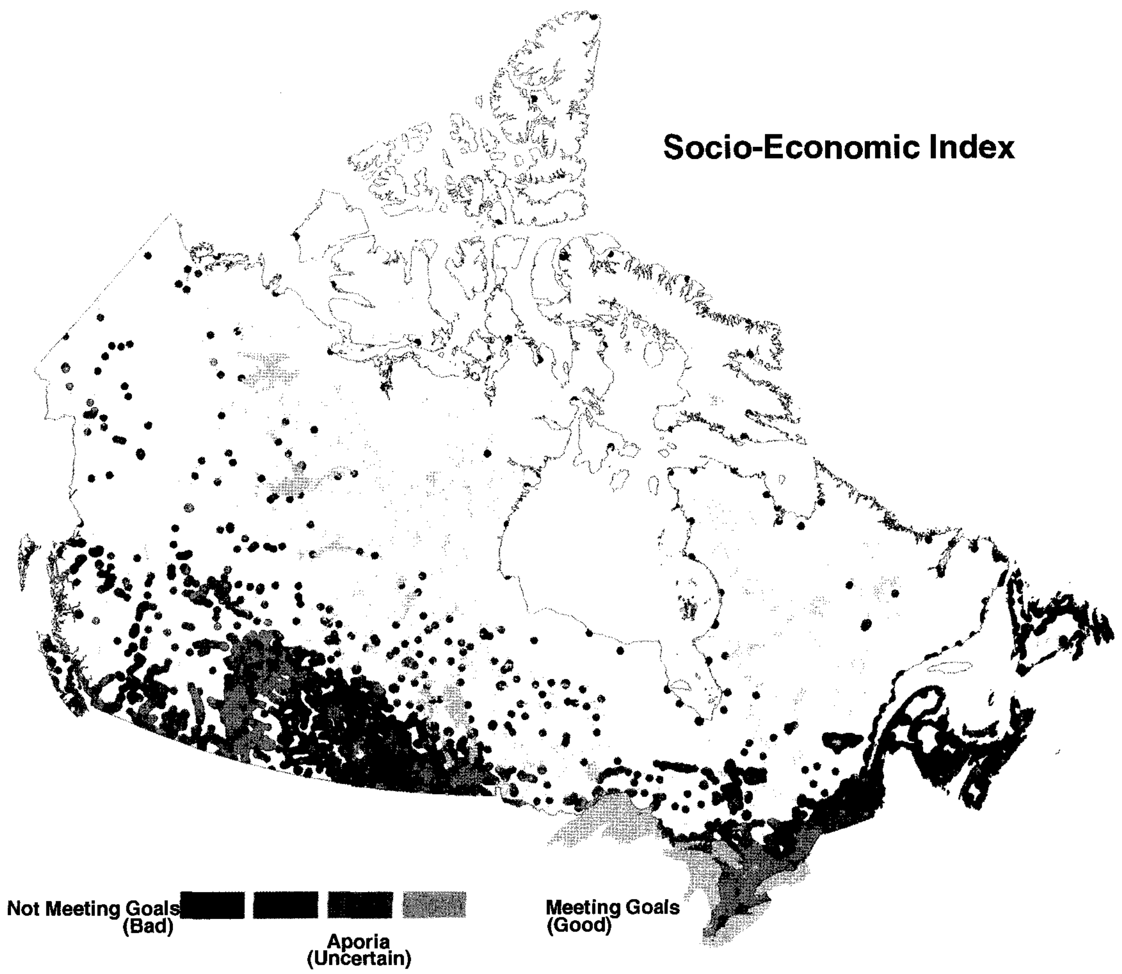


Figure D-21. Example surface model of socio-economic conditions across Canada.

These technical issues aside, the main argument for this illustration focuses on the alternative form of representation of conditions across Canada as a 'community of communities' presented independently of political, administrative or enumeration boundaries. As an alternative to conventional choropleth mapping, surface models of this type may bring into question inferences made about places (such as notions of 'have' and 'have-not' provinces). It reveals from a local (bottom-up) perspective a different reality wherein crisp notions and overgeneralizations of regions come into question. One message that the map in Figure D-21 conveys is that conditions can vary significantly over relatively short geographical distances. If similar models were presented for more local scales (i.e. within communities and neighbourhoods), it could be shown how conditions can also vary significantly down to the level of the household, and perhaps further, for individuals within each household. Given these illustrative examples, the implications of internal and external boundary conditions are summarized in terms of the theoretical framework presented in Part A.

Synopsis

The preceding sections illustrate how statements pertaining to the world are contingent upon geo-ontological boundary conditions. Both internal and external boundary conditions intersect at different scales of knowledge and representation, and any particular representation constrained by scale must be treated with caution. It is important to provide the ability for authors and readers to explore themes and variables across geographical scales, and through alternative map metaphors. Conventional or modern cartographic practices, and many GIS applications, are often constrained by scale and this presents a challenge in providing scalable mapping environments for themes as encompassing as mapping indicators of wellbeing.

The argument for considering geo-ontological contingency in subjects such as wellbeing build upon similar arguments presented by Frodeman (2003). His review of debates within the philosophy of science reveals that little attention is given to the factor of *scale* in scientific observation and measurement. Debates polarized around purely theoretical vs. empirical scientific practices neglect to account for very different approaches applied in the 'field sciences' where scale is an intrinsic factor in all forms of primary observation and measurement. Scale factors highlight the importance for considering geographical dimensions in the philosophy of science, and in contemporary debates about human knowledge about the world.

The cognitive map metaphor used in the WoN-IFM (Figure D-9) may or may not apply to local areas, or at other scales within the local to global continuum. Not only might individuals and communities use different ontologies and selections of indicators, the performance criteria applied to indicators may also need to be locally adapted. For example, a community with greater than 15 % unemployment rate may set a goal of reducing this value to 12 % over five years, and that would be a significant achievement, even if it remains significantly higher than a 7.5 % benchmark set on a national or international level. Adapting performance criteria to local conditions would significantly alter the patterns presented in the maps shown in Figure D-21.

This issue is of particular importance in more advanced geo-statistical analysis of spatial data. Classical statistical assumptions are often not rigorously questioned or adapted in many spatial analyses, and this has significant implications for statistical inference frameworks for spatial phenomena (Csillag (2005), Fotheringham (2004)). It is argued here that different ontologies, and the use of particular data and knowledge sources across various scales indicates that there are *corresponding levels of representation* that may be more adequate for different scales and specific locations, and not others. It also suggests that along any *line of reasoning* within a given sub-theme or dimension of wellbeing, there are corresponding scales to which particular types of data and knowledge are more appropriate than others. It is in considering these scale factors that both map metaphors (representing internal boundary conditions) and geographical maps (representing external boundary conditions) serve a potentially synthetic and integrative function for multi-disciplinary and collaborative enquiry.

Figure D-22 illustrates these aspects in relation to the cartographic theoretical model presented in Part A. Geographical information, in particular the use of geo-spatial data frameworks, is presented as a basis for integrative analyses across multiple scales. Here, *circumstance* is regarded as considering both internal and external boundary conditions as they interact across multiple geographical scales and levels of representation. Reality is considered to be our interaction with each other and the environment across the local-global continuum. Scale in this context is not just a *vertical hierarchy*, but also encompasses an *increasive horizontal span* across human and environmental space, from the individual to the global. For every level of reality, from the individual to the local to the global, there are not only corresponding levels of adequate knowledge, or representation, but they are *nested* and mutually influential.

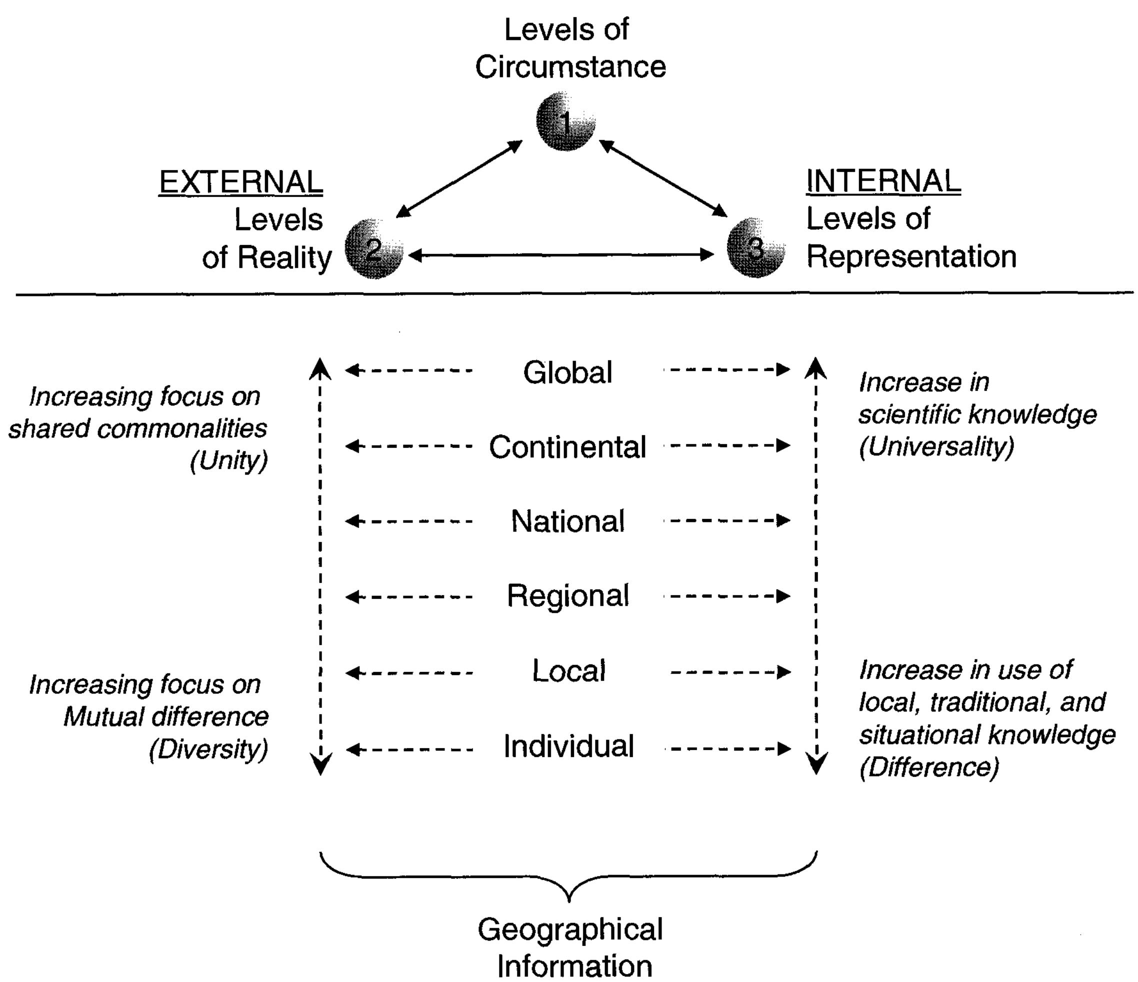


Figure D-22. Internal and external boundary conditions in relation to levels of representation and corresponding levels of reality.

This is particularly important to consider in the current era of globalization, and this aspect is discussed further in Part C. If there is one thing unique about what the discipline of geography has to offer other fields, it is its ability to emphasize the importance of *geographic scale* within which data, knowledge and meaning may be examined. The global scale raises questions about shared commonalities (a striving for greater unity) for basic human rights and freedoms, and global environmental sustainability. It is on a global scale that questions of the type "what do we all have in common?" may be asked. To consider anything less than global is to marginalize some aspect of the world. It is in looking at the world on regional to global levels wherein patterns and trends focus on commonalities using conventional scientific enquiry.

At the other end of the scale, it is increasingly important to consider local, traditional and situated forms of knowledge that highlight *difference* and *diversity* in relation to unique circumstances of individuals and communities functioning at a local level. It is within the local, more immediate space of individuals and communities where the complexities of reality tend to defy full scientific description, and often escape its normative language. The use of alternative forms of visualization, language, and communication are necessary in this regard, and may benefit further by taking the *specific circumstances of individuals and communities* into account. The principles of *unity* and *diversity*, and *universality* and *difference*, are not binary opposites, but are *realizations* that may be situated in relation to scale as a local-to-global continuum that influences our being in the world.

Conventional cartographic models, such as those presented in Figures D-4 and D-22, tend to emphasize cartography as a practice of *abstraction* of reality. MacEachren

(1994) argues that cartography serves *visualization* and *communication* purposes, wherein maps are used not so much for the presentation of truth or fact, but as aids for *visual thinking*. A post-conventional cartography might also focus on how maps (map metaphors, geographic maps, and other forms of mapping) may serve all of these purposes, but offers additional means to guide authors and readers toward *realization* and *actualization* of what they learn from maps (i.e. shifting focus back to reality from the abstract). Attention given to this dimension may help individuals and communities to more reflexively address the circumstance-reality dimension of the triadic relation shown in Figures D-3 and D-22. A means for addressing this dimension is discussed further in Part C.

In addition to knowing what is happening on the local level, people may also need to know how they affect and are affected by circumstances across geographical scales to the global level. Conversely, institutions, states, and organizations operating on regional to global levels need to know more about the *unique conditions* and circumstances on local levels. Arguments for considering unique conditions as they apply across scales have been made as far back as Hartshorne (1939) and as recently as Gregory (2000), and are illustrated in GIS-based model in Eddy (2005). Ideally, an integrative cartography is not constrained by scale, medium or style; it is intrinsically a multi-scalar, multi-thematic, multi-modal, multi-sensory, and multi-authored environment. These are the key elements in the concept of *cybercartography* (Taylor, 2003).

At each scale level, there are both individual and collective interests that span the human and environmental dimensions that need to be taken into account. Providing map metaphors of the type presented in Figure D-9 may seem a bit daunting if applied across geographical scales with alternative geo-spatial frameworks and localized data sources. The examples provided in this section illustrate how knowledge about the world, in any dimension and any perspective, is contingent upon the internal and external boundary conditions described above.

The arguments presented here support taking a 'de-centering' perspective on the world. It is argued that any given statement or truth-claim about the world is set within a context of geo-ontological boundary conditions; and that even relatively minor changes in these conditions can result in painting very different pictures of the world. Although there may not be any one singular truth-claim; it is *equally important to acknowledge that there can be many wrong ones*, and providing both authors and readers with an open and flexible mapping environment should at least help mitigate the possibilities of mis-representation and the propagation of false information.

This raises the question of what kind of approach or framework can adequately address circumstances in this manner? How can individual and collective circumstances across the local to global continuum be reconciled; and with respect to both human and environmental wellbeing, especially when any picture or statement about the world (at any given scale) is contingent upon geo-ontological boundary conditions? Part C presents an alternative map metaphor that explores these challenges.

There are times,
when all the world's asleep
the questions run so deep
for such a simple man.

Won't you please,
please tell me what we've learned?
I know it sounds absurd....
But please tell me...

...Who I Am?

Supertramp
The Logical Song

Part C – Praxis

Introduction

Part A presented a theoretical framework for considering the use of map metaphors as an aid for multi-disciplinary integration and collaborative work in GES. Part B explored a practical application of a map metaphor on the subject of wellbeing as an example that requires integration across disciplines and geographical scales. In the context of any endeavour to make statements about the world, it is argued that such statements are contingent upon *geo-ontological boundary conditions* in discerning not only 'what there is', but also in discerning 'how it might be'. Subtle differences in either internal boundary conditions (how we think about the world) or external boundary conditions (scale and geographical representation) can radically alter the assumptions, perspectives and actions taken in the world. It is argued that geography and cartography serve an important synthetic and integrative function in this regard by providing expertise in situating data, knowledge and meaning in relation to the important aspect of *geographical scale*.

This analysis is presented in the context of how geoinformation is finding increasing use at the dawn of an *information era*, and maps and mapping are increasingly becoming more mainstream and diverse in their use (Taylor, 2003). From the viewpoint that globalization is more about interactions across *multiple scales* of the local-global continuum than it is about any particular phenomenon happening *at* a global scale, it is important that the infrastructure for this information era provide adequate representation and contextualization of information across the local-global continuum. One of the key challenges is finding the means for situating individuals and communities across these scales within a *nested local-global* context.

Humans occupy a relatively small physical space of actualization; in most cases, within the range of several metres to a few kilometres. We cannot be in all places at all times, nor experience directly the uniqueness of circumstances of people and communities at other locales around the globe. Cybercartographic technologies, such as those presently emerging in internet-mapping, are providing an infrastructure to allow individuals to 'see over their own horizons'; even if such information is in a reduced, abstracted form. It provides the possibilities for people to re-vision their own circumstances in new contexts, in comparison with other individuals and places, and in relation to their own realization and actualization processes.

Mapping infrastructures and technologies that break through the *scale constraint* barrier, and provide greater flexibility in visualization, abstraction and communication capacities are important in this regard. A recent example is provided by the OpenGL advanced graphics environment (opengl.org) used in Google Earth (earth.google.com) and NASA's World Wind (worldwind.arc.nasa.gov) technologies. OpenGL-based mapping environments shatter the scale constraint barrier in the manner in which geoinformation is presented in a dynamically scaleable interactive environment. These types of technologies have the potential to significantly impact how people view the world, and how information is shared, communicated and brought into actualization processes.

With all of the promises that these recent advances in mapping technologies bring, they ultimately only represent *potentialities.* The provision of rich, diverse, data and knowledge, as exemplified by the WoN report, is by no means a trivial process. The state of Spatial Data Infrastructures (SDIs) for many countries is barely entering into early phases of development (Crompvoets, 2004), and the most significant challenges are not so much technological or informational, but organizational, legal and institutional (Onsrud (1998), Taylor, (1998)). Long-term systems development programs such as the Global Earth Observation Systems of Systems (GEOSS) (GEO, 2005) may address many of these challenges, but will still only fulfill a portion of the requirements across the local-global continuum. What is partly illustrated in the arguments presented in Part B is that the provision of open data sources, spatial data frameworks and infrastructures that cut across all scales is only a starting point. The most significant challenges lie in addressing how individuals and communities will make *meaningful use* of such information.

This is exemplified by the potential diversity of geo-ontological models that may be imposed upon primary data and spatial data frameworks. While there may be many debates how best to cartographically represent 'what there is' at various scales, it is the *qualitative transformation* of primary and secondary data and knowledge sources into meaningful *tertiary level* information that presents the biggest challenge. The meaning-making process of geoinformation is most immediately relevant to the *realization* and *actualization* aspects of the circumstance-reality dimension of the model shown in Figures D-4 and D-22.

One of the core issues to be addressed is how to reconcile different perspectives, desires, needs, and visions among people and communities that have both their own interests, and need to interact across geographical scales. At each geographical scale, there are different goals, objectives, needs and forms of representation, and it would be naive to think that agreeing upon common performance criteria will be an easy task. The WoN-IFM exemplifies the potential scope and level of effort involved. If applied across geographical scales, and opened up to both experts and laypeople for use, such as in a cybercartographic environment, it is likely that such a model would result in as many debates, disagreements and misuse of information as it might foster healthy realization and actualization of *being*.

A framework within which these multiplicities and binary opposites may be mediated would be useful in this regard. The map metaphor presented here in Part C is based on the scientific and philosophical perspectives of Ken Wilber's *Integral Theory* (Wilber, 1995, 1999, 2000a, 2000b, 2002a, 2000b), and serves to augment a perspective on how this philosophy may be applied to the discipline of geography in the concept of *Integral Geography* (Eddy, 2005). The significance and potential use of Wilber's work for the field of GES is discussed in more detail in the following sections. What follows is a set of theoretical and practical elements that provide an alternative *visual form of thinking* about the geo-ontological boundary conditions described in Part B. As stated earlier, although there may not be any singular 'truth' when looking at the world or exploring multiple representations, there are ways of working with multiple perspectives in an integral fashion. An *integral approach* does not leave readers sliding down a slippery slope of geo-ontological contingency; it provides a *map* to help navigate one's way through a universe of relativistic information. Such a map provides a framework within which to situate a number of important whole-part relationships in terms of the concept of *holons* and *holarchies* (as is explained in more detail in the following sections).

First, a brief overview of the *Holonic Tenets* that form the foundation of Wilber's philosophy is provided, which are also presented in Eddy and Taylor (2005b) as a basis for the development of the CHI model. Functional aspects of the holonic tenets are explained using the mapping examples presented in Part B. Second, different *types* of holons are discussed and help reveal important domains of *differentiation* of reality for which multi-disciplinarity and specialization is a prerequisite for *integration*. Third, this integrative theoretical framework is applied metaphorically in an alternative map metaphor of a wellbeing assessment framework. Part C closes with a review of several potential implications for using integral theory in GES with ideas for further research.

The Holonic Tenets

To say that statements about the world are geo-ontologically contingent may seem somewhat unsettling; especially in cases where the geographical dimension of phenomena is taken for granted. One way of looking at the geo-ontological contingencies is to examine more closely, and explicitly, the relationship between *parts* and *wholes*. In the WoN-IFM and the alternative models, and in each of the geographical maps presented in Part B, there are *parts* that comprised a *whole* map or statement. Insofar as any of these maps aim to represent reality, the whole-part relationships aim to represent similar whole-part relations as observed (or perceived) in reality. Both interior (how we think about the world) and exterior boundary conditions (to what aspect of the world our thinking applies) can be looked at through whole-part relationships.

The WA framework exemplifies a whole-part structure. In terms of internal boundary conditions, whole statements about wellbeing are broken down into many parts, which in turn are sub-divided into sub-elements. Each indicator stream of the WoN-IFM is also a whole-part structure, which successively feeds higher level whole-part structures from primary data sources, through the assignment of performance criteria, to the aggregation of higher level indicators of wellbeing. For external boundary conditions, the geographical maps showing indicators from global to national to regional-local levels also contain nested whole-part relationships. A map of the world (a whole) is comprised of indicators for each country (the parts). The maps shown for Canada (a whole that is simultaneously a part of the world) illustrate further sub-divisions into parts of Canada using Provincial-Territorial, Census-Divisions and a surface model based on community-level statistics. The domino map shown in Figure D-20 also exemplifies whole-part relations showing the degree to which values at a community level (parts) differ from those of higher level aggregated values (wholes).

In all of these examples, the 'whole' provides a context in which the 'parts' are presented. With the interior boundary conditions, the ontological structure imposed upon the bottom-up processing sets the context for each element in the processing stream. With reference to the geographical maps, statements such as "Canada's employment index is fair" is set within the context that it is fair in relation to other countries around the world at a global scale (and the performance criteria derived from a global distribution of values). The relevance of values for individual communities shown in the domino map in Figure D-20 is set in relation to the higher level aggregated values of the census sub-division of which the community is a part. A community displayed against a census sub-division with a different aggregated value appears differently. In essence, in order to appreciate the meaning of any information element, it is necessary to situate it in relation to a broader or background context.

There is growing interest in using formal theories of whole-part relations as a basis for better understanding complexity of phenomena, and in particular its application to geo-ontological and ecological analysis and modelling. Much of this work is traced back to Koestler (1967) with his ideas surrounding the concept of *holons* and *holarchies*. A holon is a *whole-part*; a whole which is simultaneously a part of something else. A letter in a word, is both a whole unto itself, and simultaneously a part of the word. The same is true for the relations of words to sentences, and sentences to paragraphs, and so on. A *holarchy* is a collective system of holonic relations comprising some aspect of reality. Holons and holarchies have been applied in a variety of ways in geography, sustainability and ecological modelling (Dale (2001), Eagleson (2003), Favis-Mortlock (2005), Kay (2000)). These efforts have not given as thorough a treatment to the concept of holons and holarchy as has Wilber in his integral approach. It is worth taking a more formal look at some fundamental principles of holonic relations.

In his development of the concept of holons and holarchies, Koestler identified over sixty general axioms or rules that pattern holonic relations. Wilber (1995) distilled a synthetic version of Koestler's original ideas into a set of 'Holonic Tenets', and these are listed in Table D-4 in conjunction with a graphical illustration in Figure D-23. The holonic tenets are examined here as a basis for addressing the geo-ontological contingencies described in Part B.

Reality as Holonic

The holonic tenets offer an invitation to radically shift our mental models to looking at reality in terms of holons, and not just 'wholes' and/or 'parts'. This is listed as Tenet 1 that states reality, is *not* composed of either wholes or parts, but *holons*. As illustrated with the WoN-IFM and in the geographical indicator maps, the danger in not looking at information in holonic terms inevitably results in the commission of either the fallacy of *overgeneralization* (to ascribe to the whole a quality or characteristic of some part), or the *ecological fallacy* (to ascribe to a part, a quality or characteristic of the whole). There are several other common fallacies that may be revealed in using the holonic tenets and these are described in the following sections.

The Four Tendencies

Four tendencies of holons stated in Tenet 2 illustrate their basic whole-part relational dependencies. All holons must maintain some aspect of autonomy or identity (agency) in that they must *self-preserve*; but to do so, they must also *adapt* to the conditions of other holons and their environment (communion); they must *self-adapt*. Taken together, Wilber refers to these dependencies as 'agency-in-communion'; highlighting a basic premise of the necessity for considering both masculine and feminine principles in all things. Both individuals and collectives are co-emergent (Tenet 3); and they emerge holarchically (Tenet 4).

Additionally, all holons must *transcend and include* junior holons (Tenet 5), for example, the manner in which words transcend and include letters. Holons are transcendent by nature and do so by *successively including junior holons* in their pattern or regime. What is discernable in phenomena is the *pattern* or *regime* of a holon (such as a word or a molecule), and the number of holons contained within them determines the number of 'levels' (Figure D-23a). For example, the pattern or regime of a molecule transcends and includes the patterns and regimes of the atoms that make up the molecule. The transcending and inclusive dependencies describe the mutual relation between *transcendence* and *immanence* in all things. Wilber sometimes uses the terms *agape* and *eros* to describe these elements, and to interface some aspects of integral theory with evolutionary theory and other esoteric literature. Each stage or level of *evolution* involves simultaneously a process of *involution* (Figure D-23b). Eros and evolution constitute the *immanent drive* in nature toward greater complexity and expression; and Agape and involution, constitute the *embracing* of lower level holons by higher level holons (e.g. molecules embrace atoms, and cells embrace molecules; regions embrace communities, and nations embrace regions).

Fully elaborating some of these concepts requires exploring a more advanced application of the holonic tenets, and is beyond the scope of this thesis; but it is important to note that the use of these terms takes on *different meanings* depending on what *type* of holonic activity is under consideration. Some of these concepts are explored in later sections in expanding upon their potential relevance to a number of contemporary issues relevant to GES.

Table D-4. The Holonic Tenets (after Wilber, 1995, and 2001)

1. Reality is composed, not of 'parts', nor of 'wholes', but of holons (whole/parts).
2. Holons display 4 fundamental capacities:
    (a) self-preservation (wholeness / agency)
    (b) self-adaptation (partness / communion)
    (c) self-transcendence (agape)
    (d) self-immanence (eros)
3. Holons emerge.
4. Holons emerge holarchically.
5. Each emergent holon transcends but includes its predecessors.
6. The lower sets the possibilities of the higher; the higher sets the probabilities of the lower.
7. The number of levels which a hierarchy comprises determines whether it is 'shallow' or 'deep'; and the number of holons on any given level we shall call its span.
8. Each successive level of evolution produces greater depth and less span.
9. Destroy any type of holon, and you will destroy all of the holons above it and none of the holons below it.
10. Holarchies co-evolve.
11. The micro is in relational exchange with the macro at all levels of its depth.
12. Evolution has directionality:
    (a) Increasing complexity
    (b) Increasing differentiation/integration
    (c) Increasing organization/structuration
    (d) Increasing relative autonomy
    (e) Increasing telos

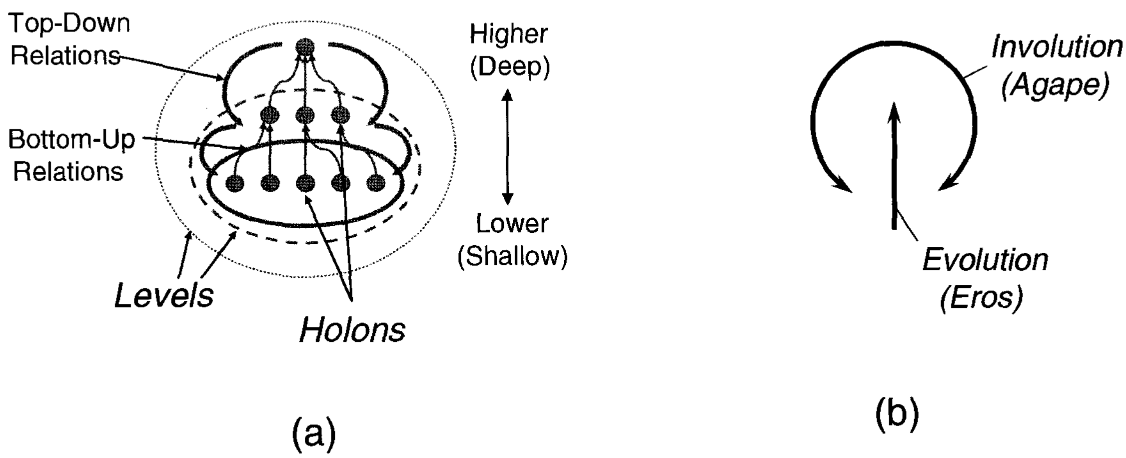


Figure D-23. Two graphical illustrations of basic holonic (whole-part) relations (see text for elaboration on terms).

Lower and Higher

Tenets 3 through 12e build upon the principles of Tenets 1 and 2. They may be applied in a variety of contexts wherever whole-part relations are under consideration. In essence, everything is a holon, and every process is said to be a *holonic process* that takes place within the context of an emerging holarchy. Several holonic tenets provide a means for further exploring the geo-ontological contingencies illustrated in Part B.

The principles in Tenets 5 and 6 may be combined when looking at internal and external boundary conditions. Where each holon *transcends and includes* its predecessors, the lower (or predecessor) sets the *possibilities* for the higher (or successor), and the higher sets the *probabilities* of the lower. In a similar way that a molecule of water has characteristics that combine the properties of hydrogen and oxygen, an indicator of wellbeing (e.g. Community Index) is defined in terms of its sub-elements. The availability of particular data sources will set the possibilities for constructing a higher level index that uses the available source data. The actual values of the sub-elements will set the range of possible values of the higher level indicators.

In considering these tenets, it is also important to consider Tenets 3 and 4 that state that holons emerge holarchically. The existence of a set of primary holons does not guarantee the creation or emergence of higher level holons. For example, the provision of numerous primary data sources does not guarantee the development of indicators that use such sources, but primary data sources set the *possibility* for higher level indicators to be developed. Where indicators do exist, or wherever statements are made about the world in general, it is suggested that such indicators or statements set a *probability* that there is supporting evidence (lower level holons), but this may not always be the case.

Another example of Tenet 6 is illustrated by the domino map in Figure D-20. The higher level holons in this case are the census sub-divisions (areas), and the lower level holons are the centroids representing the communities that comprise each census sub-division. The delineation of higher level spatial frameworks in this case was made for statistical survey purposes; and alternative frameworks may be used that are derived from other geo-political or physiographic boundaries. When performing statistical analyses using spatial frameworks, it is the framework that sets the *probabilities* of the lower (actual data counts) because they determine the number of events included within the boundary of each framework unit. Changing the framework inevitably results in changing the selection of primary data elements, and subsequently, any statistics derived from them. This is illustrated in detail in Eddy, et. al. (2006) in the calculation of probability statistics using three spatial frameworks representing three geographic scales.

Depth and Span

Tenets 7 and 8 provide further insights in an information processing context. The range of 'depth' and 'span' cover the primary, secondary, and tertiary levels of information processing in the CHI model (Eddy and Taylor, 2005) (Figure D-10). Depth, in this context, refers to the *number of levels* of information processing, and span the *number of information elements* on any given level. Tertiary level information (e.g. a Human Wellbeing Index) has greater depth and less span than the primary data from which it is calculated. Conversely, there is less depth and greater span of information elements on a primary data level.

Tertiary level information has less span because it is more synthetic; it is summary level information in which the volume of the content is significantly reduced relative to the volume of the primary source elements. This is illustrated by the WoN-IFM in terms of a statistical count on the information elements on each level in the model (Table D-5). There is a general 'many-to-fewer' relationship among information elements along each processing stream, and depending on how one draws conclusions at the highest level in the framework (i.e. as in discerning dimension indices or an overall Wellbeing Index), it is possible to say that these relations show a 'many-to-one' processing tendency. The overarching context of the model is the subject of *wellbeing*; and this sets the context (and the probabilities) for the information elements and their processing within the model.

Table D-5. Statistical count of information processing elements in the WoN-IFM model shown in Figure D-9.

Dimension	Data Sources {External}	Data Variables {Primary}	Knowledge Elements {Secondary}	Dimension Indicators {Tertiary 1}	Compound Indicators {Tertiary 2}
Human Dimensions					
Equity	7	9	4	5	1
Community	8	14	12	9	1
Knowledge	6	8	6	8	1
Wealth	18	14	13	9	1
Health	4	15	2	2	1
Sub-Total	**43**	**60**	**37**	**33**	**5**
Ecosystem Dimensions					
Species	8	33	4	7	1
Air	6	15	3	4	1
Water	20	26	3	3	1
Land	35	38	6	9	1
Resources	12	38	11	14	1
Sub-Total	**81**	**150**	**27**	**37**	**5**
Wellbeing Indicators	**13**	**2**	**2**	**24**	**3**
Total	**137**	**212**	**66**	**94**	**13**

The relation between depth and span also indicates another means for situating content-context relations in holonic terms. Information processing elements shown in Figures D-9 and D-10 are symbolized by a holonic content-context relation as described in Eddy and Taylor (2005b) (Figure D-24). In the CHI model, content is defined as the information that is actually transmitted; it is bounded, and can be picked up directly by the physical senses in some way. Context is that which is unbounded and is ephemeral; it is the *interpretive* aspect that readers must draw from their own inner knowledge, experience and perspective. All information content is context bound in some way.

The context of information content, in terms of depth and span, relates closely to the concept of *exformation* popularized by Nørretranders (1998). For Nørretranders, *exformation* pertains to the information that is *left out* of a message, and it is presumed that the receiver of the message understands and trusts the context of the message content. As an example, Nørretranders uses a very brief two-way message between Victor Hugo and his publisher. Hugo sent his publisher the following message: "?"; to which the publisher responded: "!". The message exchange was well understood by both participants, but outsiders would need more information to understand the context of the message; in this case, Hugo was asking (in an implied, codified form) about whether his book was selling well.

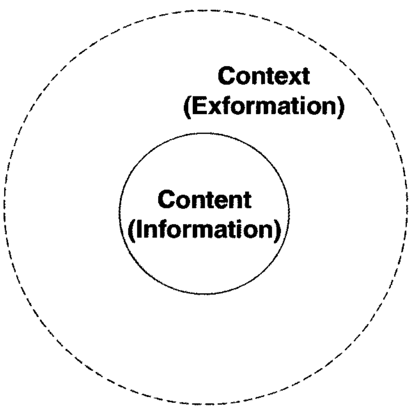


Figure D-24. Content-context as a holonic relation between information and exformation. (Modified after Eddy and Taylor, 2005).

Similar is the case with tertiary level information such as the key indicator maps in the WoN-IFM model. To the extent that such information does *not* provide access to the primary and secondary level content from which it was derived; that is, in cases where key indicator maps are used on their own, then it can be said that there is a certain amount of *exformation* associated with higher level indicators. The amount of *exformation* increases with processing depth, and it is often assumed that readers of tertiary level information understand the context of the map. This is often not the case, for either laypeople or experts. Geographical information provided in the form of static paper maps or GIS databases that are constrained by scale may carry large volumes of *exformation*, which is part of the reason why these are easy targets for critique. It is always easier to point to what information is 'left-out' of a map (*exformation*) than it is to acknowledge the context of the information that is contained in the map. The number of contexts (ways in which information may be interpreted) are increasingly boundless the higher the level of information processing with an increase in the number of readers using the information. This aspect is described in terms of *information entropy* in Eddy and Taylor (2005b).

Critical Elements

Tenets 9 through 12 provide a basis for addressing some of the more critical elements in holonic structures – be they molecules, texts, or maps. Tenet 9 states if holons on any given level in a holarchy are destroyed (or severely affected), then all higher level holonic levels will also be destroyed (or severely affected). This is most simply illustrated with the misspelling of a word (e.g. 'wrod'). A good example in the case of the WoN-IFM is the sensitivity of the Community Index maps shown in Figure D-15. The data missing for over one hundred countries at the sub-element level of the Community Index makes it relatively easier to critique than it is for the Health and Population Index for which there is no missing data.

Another basis for critique may be applied in challenging the primary data sources used in the creation of any given statement or information process. It may not be the logical inference or a definition that is weak, but the validity or authenticity of the primary inputs that may be shown to be flawed. The performance criteria applied on the secondary level may also be critiqued in a similar fashion. In this latter example, one does not necessarily reject the primary factual elements (the primary information holons remain), but in rejecting the performance criteria, all higher level holons (the derived indicators) are rejected.

Tenets 10 and 11 reinforce these critical dependencies by emphasizing that holarchies co-evolve, and their nested nature dictates that the *micro is always in relational exchange with the macro at all levels of depth.* This reinforces the content-context relational dependencies in terms of information and exformation described above. It suggests that any comprehensive and transparent statement about a subject such as wellbeing should provide full disclosure of all information elements, the processing and deductive inferences across *all levels* of primary, secondary and tertiary levels in a model – or, simply, from the micro to the macro level.

The WoN-IFM is a map metaphor for Tenets 12a-e. It is testimony to the level of *increasing complexity* and importance for *differentiating* and *integrating* information from a large number of data sources and fields of knowledge. Providing a transparent and auditable process requires increasing levels of *organization* and *structuration* of information. Here, the usefulness of the map metaphor is most vivid because as a medium, it can convey a holistic view of an overall structure and organization of a subject more so than linguistic/textual or other forms of information.

The terms *relative autonomy* and *telos* involve more advanced concepts. Briefly, *relative autonomy* refers to the degree of reflexivity of a holon to adapt and mutate under changing environmental conditions (Wilber, 1995, p. 78). An animal has greater relative autonomy than a rock, because it has greater contingency for adapting to environmental change. The metaphor in the WoN-IFM in this case would be the higher level indicators and how they are defined. Higher level referents have greater flexibility in how they are defined than do the primary level data variables. The concept of *wellbeing* has greater chances of survival since it can draw upon multiple definitions, because there are more possible ways to define a concept such as *wellbeing*, than say *air temperature*.

Higher telos, in the case of the holonic tenets, does not refer to notions of a fixed ontological goal or omega point to which everything is heading in evolution. The context in which Integral Theory uses this concept is consistent with more recent examinations in teleology (Alexander, 2002). *Telos* in this case is goal-oriented, but set within the context of a holon's *immanent* genetic make-up; an unfolding pathway through a life cycle. Wilber uses the example of an acorn's DNA code in that it has "oak written all over it" – and "Through processes of *translation, transcription,* and *transformation*, the seed unfolds into a tree, holarchically" (Wilber, 1995, 83). The adaptation of this concept to the WoN-IFM is conveyed by how all of the information elements in the WoN-IFM are directed towards an understanding of the state of wellbeing as an overarching goal, wherein *wellbeing* is the *higher telos* (the goal). As such, the model is a metaphor for the human *inner drive* for wellbeing, however it may be defined or assessed under various circumstances. Other terms, such as sustainability, development, economy, environment, human rights, etc., may provide additional referents to which the higher telos applies.

As with the terms *transcendence* and *immanence*, and *evolution* and *involution* mentioned in earlier sections, some of the advanced concepts in Tenets 12a-c (such as the term *telos*) take on different meanings depending on what aspect of holonic reality is under consideration. The application of the holonic tenets are described in this section with reference to the WoN-IFM as a map metaphor for the subject of wellbeing. Metaphorically, it illustrates how holons may be applied in exploring human mental models about wellbeing. To the extent that geographical maps are used as an information medium for wellbeing indicators, and that such maps aim to represent external reality, the holonic tenets may also be applied to physical geographical space. These two aspects cover the representational dimension of the cartographic framework presented in Figure D-4c in Part A. A question to be addressed at this point is what benefit the holonic tenets may serve in providing a more adequate metaphor for the 'reality-circumstance' dimension of the model? The following section presents a map metaphor that may be helpful in this regard.

The All-Quadrants, All-Levels (AQAL) Framework

The previous section explored the holonic tenets as they may apply to geographical information processing elements in the WoN-IFM map metaphor, and in relation to geographical maps. As mentioned above, the concept of a holon applies to anything that is whole-part related, and is therefore, not restricted to the examples provided in the previous section. One of the essential elements in integral theory is that any kind of *integration* process first requires adequate *differentiation* of that which is being integrated. With holons, it is important to differentiate among different *types* of holons, and this provides a basis for differentiating fields of knowledge and methodologies associated with various phenomena.

Types of Holons

Wilber discerns among three broad sets or types of holons, and these were introduced in Eddy and Taylor (2005b) as part of the development of the CHI model. Briefly, holonic typology considers the following types:

1. Individual and Social (or Collective)
2. Sentient and Non-Sentient
3. Artefact and Heap

In differentiating these types of holons, Wilber (2002b) emphasizes that with each type, the *definitions* of *whole* and *part* are different; and have different implications for how the holonic tenets are applied. The holonic tenets apply fully for individual, social and sentient holons (in their individual and collective capacities), but do *not* fully apply to artefacts and heaps. In reality, all holons co-evolve. For example, a spider, as a sentient individual holon, creates a web which is a non-sentient artefact. The spider's existence (and drive for higher telos) follows the holonic tenets, but the spider's web does not. It is therefore useful to situate holons within a framework that adequately differentiates these various types, while simultaneously situating their inter-relationships.

The AQAL Map

Figure D-25 provides a generalized adaptation of Wilber's original model (Wilber, 1995). It is referred to as an *AQAL Map* wherein *AQAL* is an acronym for *All Quadrants*, *All Levels*. There are three other elements to the AQAL map that refer to *lines*, *states* and *types* that are explored in later sections upon taking a closer look at the circumstance-reality dimension of the cartographic model.

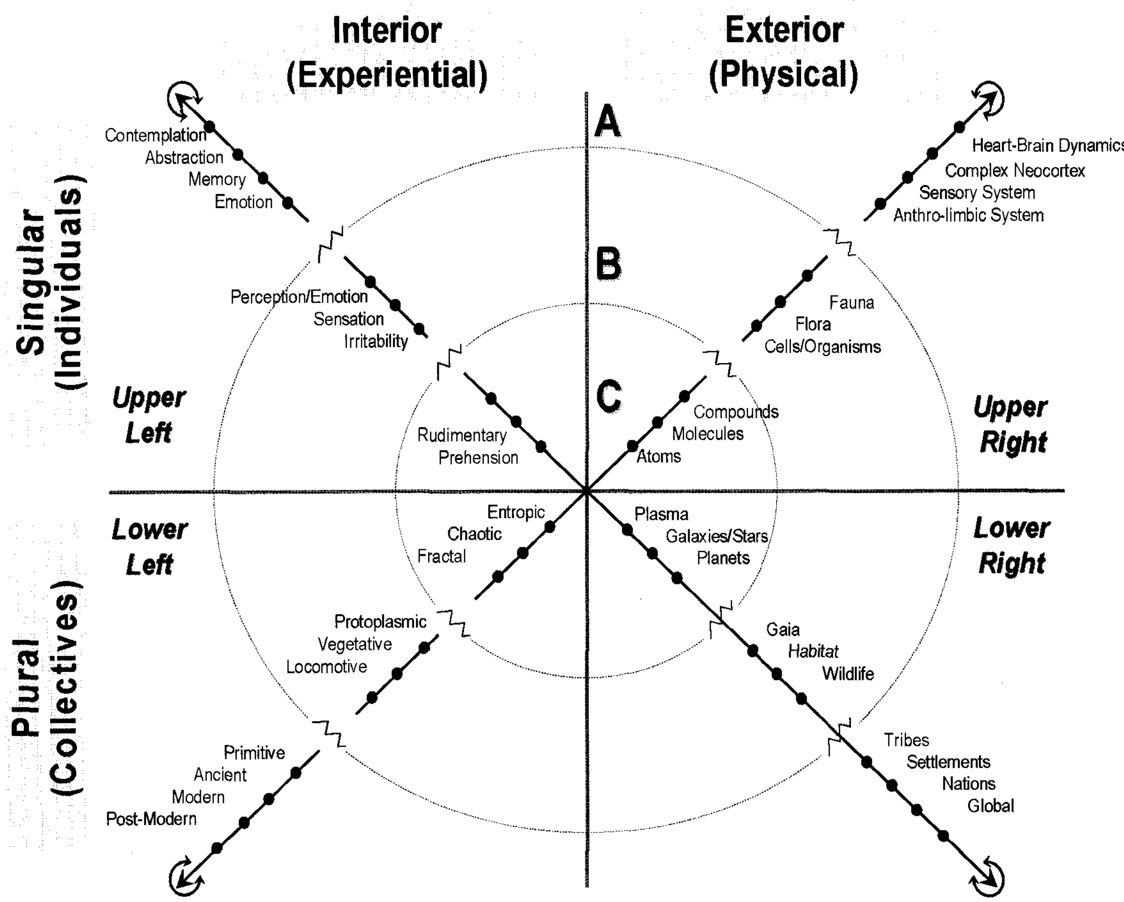


Figure D-25. Basic All Quadrants, All Levels (AQAL) Map used in Integral Theory (modified after Wilber, 1995).

The Quadrants are defined in terms of differentiating *individuals* and *collectives* against *interior* and *exterior* dimensions. of reality. For Wilber, the quadrants refer to a minimum number of aspects of our perceived reality that must be taken under consideration in any circumstance. Failure to acknowledge or account for any of these quadrants results in the failure of a holon to survive an adaptation process; and this includes humans in all aspects. In brief, the right and left quadrants represent the ex*terior* and *interior* aspects of reality; or respectively, that which we see, touch, or sense in any form 'out there' (exterior); and the 'inner' aspect of reality from where we experience and perceive what we sense in the exterior world (interior). This perceived dual aspect of reality is combined with *singular* and *plural* forms in all things, as represented in individuals and collectives by the upper and lower quadrants.

The AQAL framework emphasizes each level as characterized by relative correlates in each quadrant. Whole-part relations apply not only to how molecules form from atoms in the upper right (physical-individual) quadrant, but they co-arise, or *co-evolve* in the collective dimension as plasma and galaxies in the early stages of the universe. The *Levels* indicate increasing holonic levels within each quadrant as they emerged through space and time in evolution as we conventionally perceive it; from rudimentary particles and molecules during the beginning of the universe, through the emergence of stars, planets, and life on Earth, to the emergence of humans and societies. For example, for each level in the upper right quadrant, there are corresponding interior *experiential* phenomenon in the upper left quadrant; and because all individual holons co-evolve collectively, there are corresponding exterior and interior dimensions in the lower quadrants on each level. For Wilber, the AQAL map is a metaphor for *consciousness* expressed in its most basic dimensions and levels.

Each stage of evolution is characterized by the creation of more complex holonic structures in each of the four quadrants. A comprehensive understanding of anything requires studying the holonic correlates among all four quadrants, and at all levels involving bottom-up and top-down relational dependencies and influences (using the holonic tenets as a guide). The spheres indicated by A, B, and C approximate Anthroposphere, Biosphere and Cosmosphere as illustrated in one adaptation of the

AQAL framework for *Integral Geography* (Eddy, 2005). Other aspects of this ordering are discussed in later sections.

Integral Methodological Pluralism

A key distinction offered by the four quadrants is that Wilber insists that these are different aspects of reality that require different *modes of enquiry* (fields of knowledge with associated methodologies) for investigation. This is illustrated in Figure D-26 wherein the upper quadrants differentiate *intention* and *behaviour* among individuals, and the lower quadrants differentiate *culture* and *society* in collective dimensions. He reinforces this argument by suggesting that the quadrants represent three essential perspectives that are pervasive in all human language; the 1^{st} (I), 2^{nd} (We), and 3^{rd} (It/Its) person perspectives; which further provides a basis for cross-cultural applications.

Several closely related fields of (formal) knowledge are indicated in Figure D-26 as *methodological families*. Advanced Integral Theory refers to this type of framework as an 'Integral Methodological Pluralism (IMP)' approach to collaborative enquiry. The example spheres or families tend to draw from similar methodological principles because they are probing similar domains of reality. One of the key aspects of the AQAL framework is that it insists that adequate *integration* of knowledge and experience requires maintaining these methodological *differentiations*. It is important to not try to explain or study phenomena in any given quadrant with methods from other quadrants. Wilber argues that such attempts lead to fallacies of *reductionism* (explaining all of reality in pure physical scientific terms in the upper right quadrant), *elevationism* (reality as wholly psychoanalytic or phenomenological in the upper left quadrant), *cultural* *relativism* (reality as wholly culturally or socially constructed in the lower left quadrant), and *systemic holism* or *subtle reductionism* (when reality is explained strictly in terms of systems theory in the lower right quadrant).

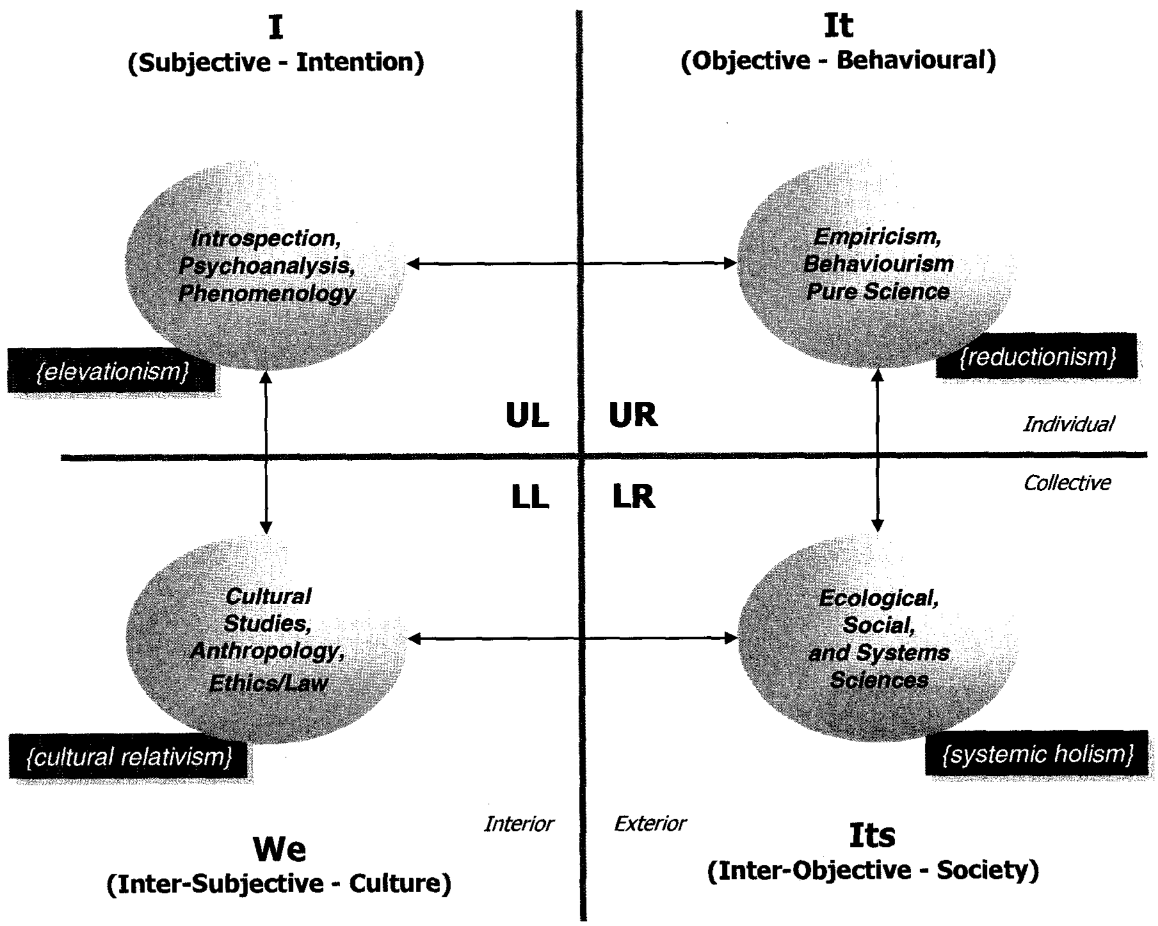


Figure D-26. AQAL framework illustrating examples of methodological families used in an Integral Methodological Pluralistic (IMP) approach.

This is to say that any mode of enquiry is appropriate only for its respective quadrant; but not appropriate for other quadrants. The fallacies described here, indicated as shadow elements in Figure D-26, apply only in situations where practitioners of any given method fail to acknowledge the partiality of the approach; or if the relevance of methods used in other quadrants is denied.

A formal *Integral Approach* insists on taking All Quadrants and All Levels into account as best as possible under any circumstance using some combination of these methodological families in a pluralistic fashion. The manner in which these methodological families may be integrated provides the possibility for using the AQAL model as a *mixed-methods* framework for integration, wherein various combinations of disciplinary, multi-disciplinary, inter-disciplinary and trans-disciplinary approaches may be taken (Wilber, pers. comm.). The emphasis of an IMP framework is in exploring the *inter-relationships* among data and knowledge disclosed by methods from all four quadrants simultaneously.

There are other aspects of holons and their inter-relationship that are discussed in more detail in the following sections. In particular, are important distinctions between *individual* and *social* holons in both *sentient* and *non-sentient* forms. Such distinctions offer a different perspective on means for approaching polarizing subjects such as individual vs. collective rights (and their social and political implications), as well as society-nature and human-environment themes. Before presenting a synopsis of these aspects, it is helpful to first look at one example application of the AQAL map as an alternative metaphor for outlining some of the basic contours of an integral perspective on *wellbeing*.

The Ecological Crisis and Wellbeing

Wilber's integral framework, and his work in general, spans many disciplines. This is true with respect to the AQAL model, first published in Wilber (1995), but was not always the case. The AQAL model is a synthesis of more than twenty years of Wilber's research and writings concerning study of *consciousness*. Reflecting an integrative ontology, much of Wilber's motive concerns not only 'what there is', but also 'how it might be'; and he approaches these questions from the perspective of consciousness studies. In this stream of thought, his writing frequently concerns the current global ecological crises for both humanity and the global ecology, and offers several arguments and perspectives on these issues that warrant some review.

Ecology, Consciousness and Spontaneous Creativity

The AQAL emerged from taking an integrative approach to human psychology by combining various schools that study different aspects of humans in the upper quadrants; for example, the integration of behavioural (e.g. Skinner), psychoanalytic (e.g. Freud) and transpersonal (e.g. Jung) levels or schools. During the 1980s, Wilber gradually integrated important aspects from the social and cultural dimensions into his model drawing from additional sources in these fields. His model argued that human psychology is not only an individualistic issue; individuals function as socio-cultural beings, and that these dimensions must also be taken into account to be more comprehensive. In essence, his work in the 1970s and 1980s increasingly spanned the four quadrants, but did not fully integrate them in a comprehensive way.

After a hiatus in the late 1980s, Wilber returned to further develop his model in the early 1990's. This later effort resulted in the voluminous *Sex, Ecology, Spirituality* (Wilber, 1995). Two aspects highlighted in this work include his use of Koestler's (1967) concept of holons and holarchy (and his own synthesis of the holonic tenets), and situating them within an evolutionary perspective drawing from various fields of cosmology, ecology, complexity and systems theory, cultural studies, post-modern philosophy, and other disciplines. The essential argument presented by the AQAL model is the perspective that *consciousness*, as best as it can be known, is intrinsically *ecological*. At every stage of evolution in the history of the universe, the emergence of holons of various types succeeded as a result of a *successful negotiation* among holons across all four quadrants and at all levels. By *negotiation*, Wilber is referring to a quadratic inter-action among holons in all four quadrants, commensurate with those that have come before (an inheritance of the past) with those that are creatively emerging at any given point in time and space (a continuously emerging present).

For Wilber, such negotiation is not always a pleasant affair. The more complex things become, the more difficult it is for holons to succeed in such negotiations. Higher level holons (e.g. animals and humans) carry more burden than lower level holons (e.g. rocks and trees) because they need to constantly maintain (and *sustain*) *more holonic depth*. The burden of having greater holonic depth (and consequently, greater depth of consciousness), for Wilber, is that there are *more things that can go wrong*. Life in general is a continuous ecological *re-creational* and *re-constructive* process at all levels of holonic depth (and not just at the level of what we perceive to be that of human affairs). It is because of these levels of increasing complexity that higher forms of life (sentient holons) increasingly complexify into more resilient, reflexive and self-adaptive creatures.

Wilber's perspective is that the universe, the planet, the biosphere, and humanity are in a constant re-negotiating situation, and each moment requires an element of *creative novelty*; while simultaneously honouring (transcending and including) all that has come before (inheritance or *kosmic karma*). Such creative novelty is not provoked by a pre-fixed, or pre-given teleological order; rather, it is guided by a *telos* that changes its goals and purpose with each turn of space, time and circumstance (the basic dimensions of *perspective*). In short, for Wilber, God or Spirit or Consciousness in general, is 'making things up as it goes along'; a sort of eternal, spontaneously creative, hyper-narration of the Kosmos.

It is important to mention that these aspects of his philosophy and theory are only *very briefly* summarized here, and readers may consult Wilber (1995) for his crediting numerous other scholars in this synthetic philosophical approach. It is introduced in this section to set a context for an integral perspective on the current global ecological crisis that humanity and the global ecology are now facing. It is from presenting this perspective that the use of maps and map metaphors is carried further in following sections.

Crisis, Neurosis, and Agreement

Two statements extracted from Wilber's work that pertain to the global ecological crisis, and in particular to themes similar to the concept of *wellbeing* as presented in Part B, include the following:

> *"Every neurosis is an ecological crisis"* (Wilber, 1996. p. 169)
>
> *"The startling fact is that ecological wisdom does not consist in how to live in accord with nature; it consists in how to get subjects to agree on how to live in accord with nature. This wisdom is an intersubjective accord in the noosphere, not an immersion in the biosphere. No representation of the biosphere whatsoever will produce this wisdom."* (Wilber, 1995, p. 293)

Wilber attributes the present global ecological crisis in the context of a widespread human neurosis on a global scale. A significant element of the crisis is not only about what is happening 'out there' with biospheric and physiospheric degradation and change in relation to both ecological change and human pressures, but that it is as much an artefact of human consciousness (in the noosphere) as it manifests in different forms and circumstances (including social, economic, political and cultural dimensions).

As a map metaphor, the WoN-IFM highlights several characteristics of this neurosis. The level in which agreements are necessary occurs in the *qualitative transform* level of information processing in discerning how things might be. A key area of contention is how to come to *collective terms of agreement* on a global scale as to how to live in accord with the biosphere. For Wilber, *no representation* (i.e. systems models, maps or texts representing 'what there is') will produce the level of wisdom required for such an agreement. Representations are important, as they make possible the availability of information about the state of human-environment conditions, but it is at a different level of *collective* information processing wherein humanity needs to decide *how things might be*.

It is argued here that one of the key difficulties in coming to such terms of agreement occurs with a neglect to recognize that statements about the world are geo-ontologically contingent. In other words, *geography matters.* Intrinsic to coming to terms of agreement is the need to reconcile the polarities of the local with the global, individual and collective interests, and our inner experiential worlds with our exterior physical world where actualization takes place. The following section presents an alternative map metaphor for wellbeing that illustrates key aspects of these dimensions.

An Integral Topology of Being

One application of the AQAL map is presented in Figure D-27. The title *Integral Topology of Being* (ITB) is used here in the following context. The AQAL framework is used in a metaphorical context to situate a number of selected indicators of wellbeing that consider the polarities and dimensions discussed in the previous section. It is presented as one way for inter-relating a number of points, lines and areas in consideration for a topology of being; but is by no means exhaustive – only illustrative. As a map metaphor, it offers a more explicit visualization of relations that are sometimes implied in texts that explore similar ideas (e.g. Maldonado-Torres, 2004).

The term *topology* is used here as a basis for inter-relating these points, lines and areas in a number of ways; and in using it metaphorically, it suggests several important factors that might be taken into account when negotiating terms of agreement. Its intention is to expand upon the elements presented in Figure D-22, with an emphasis on multiple forms of knowledge, expression and being that necessarily differ with geographical scale; such as local, traditional, folk, or 'situated' knowledge as examined by Doubleday (1993) and Dyck (2005).

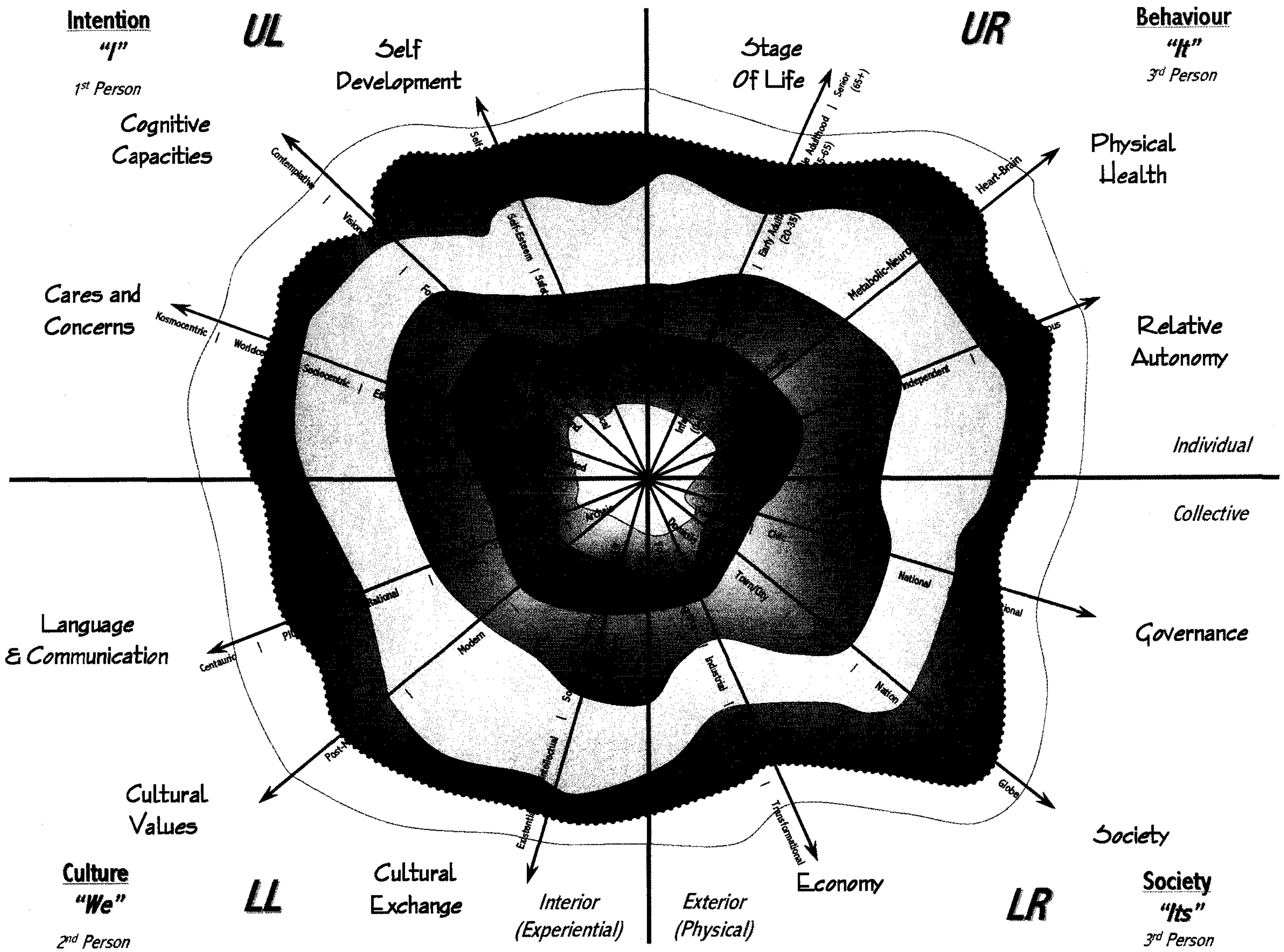


Figure D-27. An Integral Topology of Being as a Map Metaphor.

Topological Elements

The main topological elements in the ITB map consist of the *four quadrants* of the AQAL map, with a number of *developmental lines* in each quadrant. Each developmental line consists of a number of points, or stages, at which individuals and collectives may find themselves. The colour-coded contours, or *areas*, in the map approximate *background contexts* wherein which individuals and collectives may be situated. It is necessary to elaborate on some of the principles of these topological relations.

First, each line of development is set in a holonic and holarchical context. The words used to describe some of these levels are taken from Wilber's synthesis of several dozen psycho-social models of human development presented in *Integral Psychology* (Wilber, 1999). For example, from his original synthesis in the line of cognitive capacities, and building upon the work of Piaget, Wilber has illustrated that such capacities tend to develop in a stage-like sequence during a person's life-span from pre-operational (infant), to representational-mind (early childhood), to concrete-operational (childhood/adolescence), to formal-operational (early adulthood), to vision-logic (middle-adulthood), and higher (contemplative) capacities. As with other holons, by 'stage' it is not meant that one stage is better or more important than lower/prior stages; rather that they are holarchically nested, and they tend to unfold at different stages of a human life span.

What is particularly revealing about Wilber's analysis in this regard is the historical, evolutionary context in which he situates his model of human development. Cognitive capacities are only one of many lines of development that evolved over a million years of human physio-socio-cultural evolution. Other identified lines include kinesthetic, moral span, aesthetics, musical or math skills, social skills, psycho-sexual development, etc. Following the view of Gardner (1972), for Wilber, *intelligence* is best approached as a combination of these lines as they uniquely come together in each human personality (i.e. multiple intelligences). Historically, the capacities for these developmental lines emerged as a result of *creative novelty* working in response to various *crises* that occurred as humans increasingly interacted with the rest of nature and each other over broader territories of physical and human geographies.

Second, for each level or capacity in the upper left quadrant, there is a corresponding level in each of the other quadrants that can be looked at along any number of other lines of development. This emphasizes the importance of the geographical dimension in human development when looked at through the holonic relations in the AQAL map metaphor. Drawing from the work of Gebser (1985), the general sequence of rep-mind, concrete-op, formal-op, and vision-logic capacities that develop within individuals in the *upper left* quadrant has corresponding historical cultural systems of language and communication in the *lower left* quadrant associated with archaic, magic, mythic, rational and pluralistic forms of language and communication. These in turn can be mapped to approximate traditional, modern and post-modern values that emerged in correlation with foraging, agrarian, industrial and the presently emerging informational and transformational economies operating at their respective geographical scales of society and governance in the *lower right* quadrant. The model suggests that the evolution of modes of economic production correspond with fulfilling corresponding needs for cultural exchange and individual needs. Different modes of economy provide the possibility for nurturing other lines of development in individuals and collectives (e.g. self-esteem and self-actualization in the upper left; levels and forms of governance in the lower right). The application of such a map has a number of implications in approaching definitions of being and wellbeing.

Being and Wellbeing

There are several topological criteria that are important to take into consideration when applying such a model. First, Wilber emphasizes that with regard to various lines of human development, they *develop independently* from each other. For example, a middle-aged individual may have achieved relative economic autonomy and have developed an advanced vision-logic cognitive capacity, and be simultaneously centered upon an egocentric or ethno-centric stage in the line of cares and concerns while dealing with issues of safety and belonging, or self-esteem along the line of self-development. In the collective quadrants, a society may be intellectually and technologically advanced with a value structure that is also ethnocentric (i.e. concerned only for its own culture and people, and not others). This factor of line independence creates the *uniqueness of circumstances* for both individuals and collectives at different scales of interaction. Every individual has a unique profile, and every collective (community or place at some geographical scale) also has a unique profile. Some lines may reach advanced stages, while others may not; and additionally, each stage can take on a healthy or unhealthy condition. Consideration given to any number of lines as indicators, for either individuals or collectives, is characterized in Eddy (2005) as rhizomatic complex.

To illustrate these unique conditions, Figure D-28 illustrates two hypothetical indicator profiles for two individuals situated in the same place. Using the ITB map as an indicator framework in this manner is similar to the multi-level, multi-dimensional approach developed by Bossel (1999); here the dimensions and levels in this framework are based on the AQAL model.

The place, in this context (represented by the indicator lines in the lower quadrants), is a hypothetical location that is a stable nation-state with a democratic governance structure and an industrial economic base currently undergoing an informational economic transition (in the lower right quadrant). Its internal cultural lines are centered upon social/security provisions based on traditional values using a predominantly mythic-rational mode of language and communication. Individual A is a healthy, middle-aged adult who has achieved relative autonomy in her society with an advanced education, but is dealing with issues of safety and belonging and is predominantly ethnocentric in her cares and concerns. Individual B is a healthy adolescent who is dependent upon his parents, and has demonstrated an advanced level of intelligence for his age. He has a healthy self-esteem, but is egocentric in his line of cares and concerns.

In each of these cases, *wellness* of being can be discerned only in terms of the *uniqueness of circumstances* for both individuals and communities along these various lines. The ITB map does not suggest that higher level holons are 'better' than lower level holons, rather that each level is an important dimension to the overall topological structure of being; and each level, along each line can take on a *healthy* and *unhealthy* condition. Correlative elements among developmental lines are associative; not deterministic.

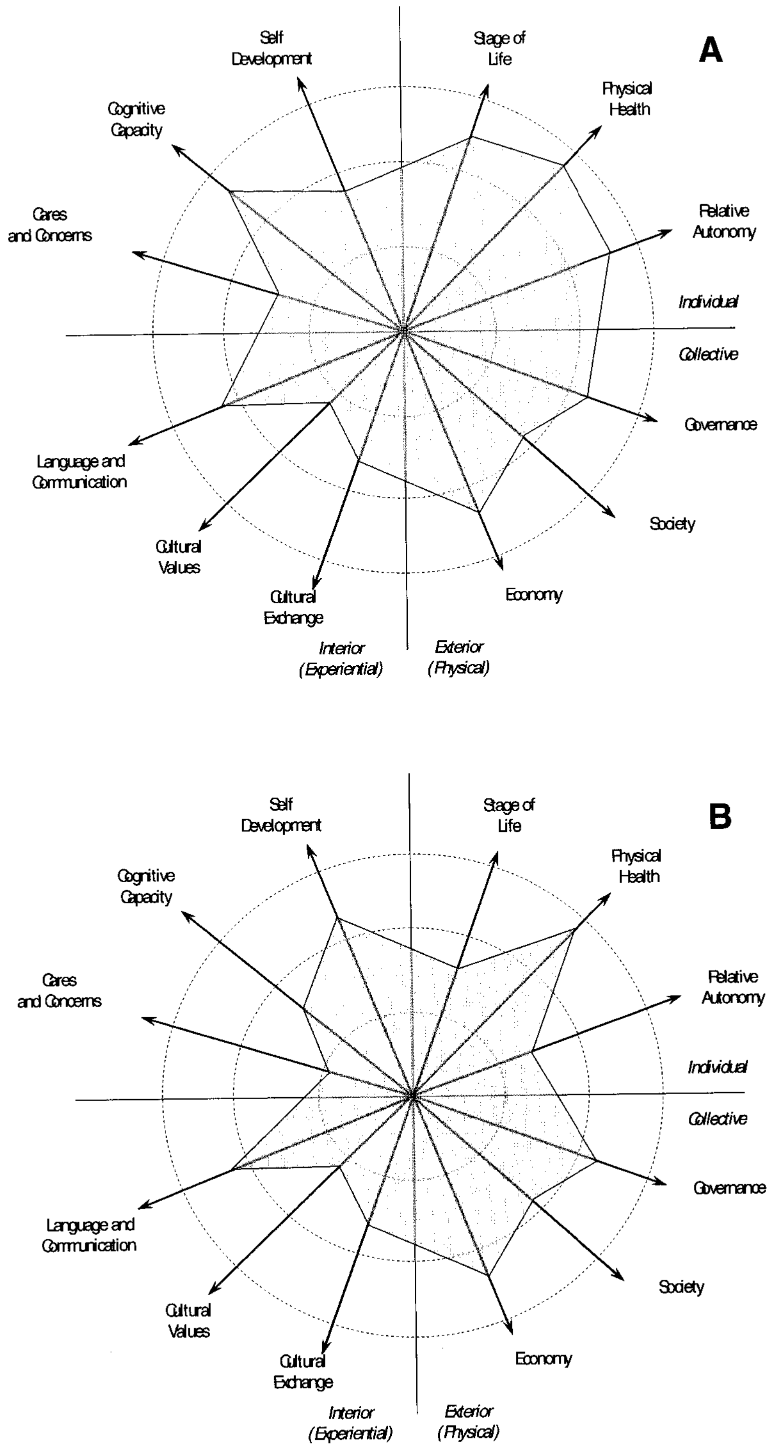


Figure D-28. ITB profiles comparing two individuals living in the same location.

Sustainability and Development

The levels along each line can be roughly correlated as indicated by the colour-coded contours in Figure D-27. The colours used here approximate the value-meme (vMeme) colour codes of the Spiral Dynamics model of psycho-social development by Beck and Cowan (1996). They approximate general correlative elements among the lines and levels across all quadrants as and are described here as *affinities*.

For example, the Green vMeme is characterized by pluralistic modes of discourse with world-centric cares and concerns based on post-modern values that are reinforced by intellectual and existential cultural exchange. In the lower right quadrant, this vMeme operates on an informational economic base on a global scale, and is working towards developing trans-national and other pluralistic modes of governance, social structures and cultural exchange. Individuals centered on Green vMeme values have likely achieved some advanced degree of relative autonomy and may frequently be observed to be in a process of self-actualization. This value system usually develops in individuals in early to mid-adulthood, but as with other lines of development, such a correlation is probabilistic, not deterministic. The other colours depict affinities in a similar way.

The uniqueness of circumstances for both individuals and collectives suggests that these contours present *scales of potentiality* within which various lines of actualization and being may take place. They are background contexts within which human development may be situated in exploring the circumstance of individuals and communities in different places and at different scales of interaction across geographical space. *Actualization* pertains to how individuals respond to AQAL pressures and asymmetries of the state of conditions along various lines (as they may be healthy or not healthy). A particular ITB profile, taking all lines and quadrants into account, would comprise an overall 'state of conditions' or circumstances that need to be addressed, and they are as likely to be as unique for individuals as they are for individual communities, or nation-states. In essence, the contours provide a scale against which qualitative assessments of wellbeing, sustainability and any number of inter-related issues may be explored.

One challenge highlighted by the ITB is that in order for individuals to achieve a healthy state at all levels and lines, each level within each line and quadrant must be *co-sustained.* This presents a different context for considering the apparent contentious relationship between sustainability and development. Here, the context for development is not focused on a modernist perspective in solely terms of nation-state and industrial economic development in the lower right (a Blue-Orange social construct), but development along multiple lines and levels in all four quadrants. Wilber describes this developmental process as being intrinsically an *envelopmental* process, whereby each level must embrace (transcend and include, or envelope) preceding levels of development, and in doing so must also sustain their health. *Sustainability*, in this context, may be defined as *development through envelopment*, which is another coinage for Wilber's concept of *evolution through involution.* Following this context builds upon a critique offered by Dobson (2000) in asking not only 'What are we sustaining?', but in also asking 'What are we developing?'.

It is from this type of framework wherein globalization may be questioned with regard to whether or not consideration is given to the health of conditions on local and individual levels, and multiple lines of development on different geographical scales of culture and society. As suggested by the broader A-B-C AQAL relations in Figure D-25 (and detailed in Eddy (2005)), the state of the environment (B-sphere and C-sphere conditions) on local to global scales, sets the *possibilities* for what humans are capable of achieving in the Anthroposphere; including global levels of governance and geopolitical organization. The reasoning behind this aspect is discussed further in the following section. It suggests that the global ecological crisis cannot be decoupled from globalization; or to put it in terms of holonic relations, the ecological crisis is *nested within* globalization. The *terms of agreement* required must be addressed not only on a global level (as exemplified by the WoN-IFM), but must be addressed at all levels, lines, and circumstances for both individuals and communities at various scales of interaction.

The ITB map complements concurrent research in applying the AQAL map in sustainability, development, ecology and environmental studies (e.g. Brown (2004), Esbjörn-Hargens (2005), Hargens (2002), Hochackha (2005, 2006), Owens (2005), and Zimmerman (2005)). The contribution that the ITB emphasizes in all of these approaches, is the overarching argument of this thesis that *geography matters*. The geo-ontological contingency intrinsic in concepts such as wellbeing and sustainability requires addressing the *unique life conditions* and circumstances of individuals and communities responding to increasingly complex forces of ecological change and globalization on local to global scales. It is to such circumstances that several implications for using map metaphors in this context, in particular the AQAL map or its ITB derivative, may have relevance to a number of contemporary debates in geography and environmental studies, and other disciplines and organizations concerned with these and related issues.

Ideas for Further Research

Multi-disciplinary Context

A number of arguments are presented throughout this thesis pertaining to the potential usefulness of maps and map metaphors for integration in the field of GES, and in particular, to multi-disciplinary and trans-disciplinary issues such as wellbeing, sustainability and development. The maps provided in Part B support the argument that statements made about the world, and in particular, value-based judgements, are geo-ontologically contingent. Geo-ontological contingency is characterized by differentiating internal boundary conditions (reflecting how we think about the world) and external boundary conditions (reflecting the scale and scope as to what parts of the geographical world to which statements pertain). Conventional geographical maps are used to visualize the latter, and map metaphors are used to visualize the former. Both types of maps used in combination provide a basis for visually thinking in a constructively critical way about circumstances and issues across geographical scales.

Recognizing geo-ontological contingency in human affairs presents a significant challenge to which integrative frameworks such as the AQAL map aim to provide one means of approach. In this regard, how maps and map metaphors may be used in this way is illustrated by the ITB map presented in the previous section. It is important to emphasize that the focus of this examination is on the use of maps and map metaphors to illustrate their potential for synthesis and integration. Integral theory is one approach, and there may be many others.

Any multi-disciplinary or trans-disciplinary integrative framework is ultimately a tool for collaborative enquiry, and therefore beyond the capacity of any individual researcher to provide all of the comprehensive details that need to be filled in. Other integrative map metaphors are likely to emerge in time, and Wilber's AQAL map, and its application to Integral Geography and the ITB map provide a starting point for further research.

It is this author's perspective that the potential usefulness of Wilber's integral philosophy, and its application to GES, is that it presents an example of one approach to synthesis and integration, with practical applications for many contemporary issues. The importance of both qualitative and geographical scaling issues in both human knowledge and the external world are emphasized in holonic theory and AQAL modelling. As a map metaphor, it provides an alternative way of visually thinking about problems and research questions, while honouring (transcending and including) many methodological families of enquiry that necessarily need to be included.

It also emphasizes a philosophy that meaningful *integration* must *maintain* important *differentiations* of methods of enquiry. This suggests that integration is not simply a matter of loosely connecting potentially disparate pieces of information from multiple disciplines or methods of enquiry, but must be situated in an integrative *context* (an integrative or integral framework) that adequately maintains and respects the important contributions that are made through various fields of specialization, while simultaneously providing a guide for collaborative integration.

This thesis presents only several introductory to intermediate level aspects of Wilber's philosophy, and readers are encouraged to explore his work further for additional details. There are several issues, however, that are worth briefly reviewing as part of this examination that are potentially relevant to a number of contemporary issues in GES. To illustrate the integrative utility of holonic theory and the AQAL model, this section discusses its potential application for a number of issues of concern to the general sub-fields of GES.

Physical Geography

Several aspects of the application of integral theory to physical geography are developed in Eddy (2005); in particular, how the A-B-C relations presented in the AQAL map in Figure D-25 may be arranged to highlight the holarchical dependencies of the physical and social sciences that study these domains. The A-B-C model makes a distinction between an Anthroposphere and the Biosphere, and arguments for this distinction are made for a number of reasons.

First, Wilber and other integral ecologists, including Zimmerman (2005) and Esbjörn-Hargens (2005), have uncovered what they believe to be a significant fallacy in conventional ecosystems modelling that pervades many assumptions and discourses concerning the place humans have in relation to the biosphere and the global ecosystem. Variations on this theme are plenty, but it is often presented in statements of the type that "Humans are a part of the biosphere".

The intention of such a message is aimed at raising awareness regarding our ecological connections to the biosphere, and to some extent, such messages serve this purpose. However, there is a shadow element that reinforces certain fallacies upon a more detailed analysis; which has implications for the setting of priorities and addressing ethical issues in human-environment relations. For Wilber, such statements are reductionistic in two ways. First, it is easy to interpret the statement in a way that denies the importance of the left-hand quadrants, and situates being human as a being a part of a kind of 'system' of parts in the lower-right quadrant. Second, it denies the difference in degree of *holonic depth* of human consciousness in relation to other species and ecosystem elements. Wilber's model does not deny consciousness to other species; in fact, it affords them significant holonic depth within which humans share similar levels (i.e. the capacity for sexual reproduction, hunger, socialization, adaptation, emotion, etc.). What differentiates humans from other species is that humans contain *at least a few more holonic levels* of depth in all four quadrants. In the upper right, humans have a complex neo-cortex brain structure that supports levels of consciousness such as logic, story-telling, building nuclear arms, and having intellectual discussions. But as emphasized in previous sections, higher levels do not necessarily mean 'better than.....', because as consciousness can take on many more forms of expression and reflexivity, *more things can also go wrong.*

As discussed in preceding sections, one aspect of this fallacy pertains to the context in which the word *part* is defined. If interpreted in the strictest or most common physical sense of what it means to be a *part of* something (a whole), it suggests that in damaging or removing the part, the whole will somehow malfunction. If humans were a 'part' of the biosphere, and if humans are removed from the planet, then it suggests the biosphere would collapse (or at least be severely affected in its structure and function). What is important in this subtle distinction is not that 'humans are a part of the biosphere', rather that 'the biosphere is a part of the anthroposphere'. If the biosphere is destroyed or affected in any way, then humanity will suffer the consequences.

This reinforces an alternative perspective on human-environment issues and society-nature concepts in that the *environment*, conventionally defined as *surroundings*, is actually *contained within* the anthroposphere when looked at through the lens of the holonic tenets and AQAL topology. An ethical imperative derived from this perspective is that all aspects of biospheric functioning and integrity must be *sustained* in order for a healthy anthroposphere to function, and the anthroposphere must learn to adapt within the carrying capacity and resource constraints of the biosphere and cosmosphere (the lower sets the possibilities for the higher, and by degrading the lower, humans may unknowingly limit their possibilities).

A third aspect of this fallacy pertains to situations that fail to distinguish between *individual* and *social* holons. To say that humans (as individuals) are a part of the biosphere is to confuse individual ecological entities with a collective systemic function. This is a subtle semantic distinction, but has significant implications if not given adequate reflection. Individual holons (as represented in the upper quadrants) are not parts, but *members* of social holons (represented by the lower quadrants). It is more correct to say that the biosphere and ecosystem functioning is a part of *humanity* (in the collective sense); and that biological structures are part of being human (in the individual sense). By removing individuals, the system does not collapse (as would be the case if they were defined as *parts*). Rather, individuals *participate in* ecological functioning through collective interaction. These distinctions are not only important to physical geographers and ecosystems modellers. The following section provides a brief review on how it may be applied to issues relating to organizational theory, geopolitics, and identity in human geography.

Human Geography

The perspective offered in the previous section concerning the holonic relations between humans and the biosphere may present an alternative framework for exploring discourses in human-nature, society-nature, and other human-environment themes in human geography. Among these, distinguishing between individual and social holons may be of particular interest from a number of vantage points. As discussed in previous sections, it is critically important to consider how the terms *whole* and *part* are defined in terms of individuals and collectives. For Wilber, these terms take on different meanings and may have implications for a number of contemporary issues and research questions.

First, individuals are differentiated from collectives in that with individuals there is a *dominant monad* (derived from the philosophy of Leibniz). From a physical standpoint, higher level holons in humans *subsume* junior holons; which means that they are physically nested (e.g. atoms, molecules, cells, and organs). When an individual decides to walk across a room, all junior holons (molecules, cells, organs) must follow. Higher level holons are in part defined by the pattern, regime or functioning of the junior holons that comprise the whole, and junior holons set the constraints (possibilities) for the capacities of an individual. For Wilber, the *mind* is not so much a structure that superimposes (transcends) the *body*; rather, that for each level of physicality in the upper right quadrant, there are corresponding *levels of mind* in the upper left quadrant. Higher level mental or experiential holons in this case pertain to individual will, desire, and deeper (higher) personal capacities; and these are physically supported by advanced neurological-emotional processing associated with heart-brain-emotional functioning (which in humans, is facilitated by a complex neocortex; see Figure D-25) .

Social holons, on the other hand, do not function according to a dominant monad. There is no 'one subject' (i.e. one will, or one desire) that decides for all members of a collective. Social holons are defined by the patterns or regimes of individual holons that intersect through *inter-subjective* and *inter-objective* interactions in space. Local to global levels of human organization are nested, and the holonic tenets may be applied (although somewhat differently than for individual holons), but each level transcends and includes the pattern or regime of the *social holonic spaces* of the lower (more local) levels. Wherein the lower sets the possibilities for the higher, wider spans of social holonic space first require healthy *local* social holons. In short, if the local is not healthy, then neither is the global; and conversely, in order for a healthy global society to emerge, healthy local societies must be developed, sustained and maintained.

Following similar arguments that humans are not a part of the biosphere, the implication for human organizational and geopolitical theory is that individuals are *not 'parts' of a state*. For Wilber, the state does not have a *locus of subjective consciousness*, which means that *social holons do not transcend and include individual holons*. Higher level social holons (e.g. countries) transcend and include junior level social holons (e.g. towns and cities), which means that they transcend and include the social holonic regimes that pattern the interactions among individuals in various inter-subjective and inter-objective spaces, and at different geographical scales (differentiated in the lower quadrants). Individuals are *members* that may or may not participate in various social patterns, affinities or regimes depending on the degree in which they share the inter-subjective and inter-objective spaces of social holons across these scales.

Cases where social holons are modelled as if they were individual holons assume a chain of command that operates like a dominant monad; exemplified by autocratic and dictatorship forms of governance. This is central to what Wilber refers to as a form of *pathological hierarchy* or *dominator social hierarchies.* The imposition of the will of a state or organization on individuals (usually argued in the interest of collective rights, and often decided by limited number of individuals who assume the locus of power) leads to various forms of oppression and limitations of human rights and freedoms. The key emphasis of the AQAL model is to not favour one aspect over another (i.e. individualism vs. collectivism), but to recognize the important distinctions among both and their AQAL relations. Applications of these holonic distinctions to geopolitical theory would be worth further examination; in particular, in the context of how various forms of governance may correlate with patterns and circumstances in other lines of being for individuals and collectives as illustrated in the ITB map in the previous section.

The distinction between individual and social holons may also find application in studies of *identity*, which may not be entirely de-coupled from geopolitical aspects of these relations. The idea that individuals are *members* of social holons suggests that individuals may take on any number of identities or affinities across geographical scales. Integral Psychology (Wilber, 1999) discusses the concept of *identity* in relation to *self development* drawing from several schools of psychology that study these lines of development in the upper-left quadrant. Further research in this area may provide an alternative means for exploring how identities may be related to individual lines of the span of *cares and concerns*, and *self development*, as they intersect or correlate with *cultural values and exchange*, and modes of *language and discourse* in the lower left quadrant. Such an analysis might benefit from interfacing with physical and social scientific investigations that provide information on upper and lower right physical and societal circumstances in which individuals are situated.

Hochachka (2006) applies the integral framework in this way in a community development project in El Salvador. Her integral approach emphasizes how *both* self-development of the people in the community *and* the self-development of the researcher or community practitioner are integrally important in development work. It is worth mentioning that the contours of identity and self-development across local-global scales present the most significant challenge in bringing forth *sustainable actualization* among people. Her account in working with the people and their circumstances in El Salvador is exemplary of the usefulness of the AQAL map and integral theory as a guide for practice, and she also illustrates its many challenges.

These are just a few suggestions for further research. The examples provided for both physical and human geography illustrate their potential for being considered in an integrative approach such as that proposed in *Integral Geography*. In light of the potential for such integration, it is worth reviewing how these aspects may be applied to Geographical Information Processing (GIP).

Geographical Information Processing

There are a number of areas in which holonic theory and the AQAL framework may apply to geographical information processing. The CHI model developed in Eddy and Taylor (2005b) provides one approach, and illustrates how the elements of the CHI model are in part derived from the holonic tenets and integral theory. This section provides a brief review of its potential application in the field of *geo-ontological modelling* in the field of GI Science. In brief, geo-ontological modelling encompasses many of the issues of data structuring and information processing presented in Part B. This area of research emerged in the late 1990s with focus on how spatially-referenced information may be modelled in different ways depending on the application and information community, and is a key area of research and development for establishing standards for inter-operability and information exchange across disparate systems and data formats (e.g. GSDI (2004), OGC (2003), Galton (2003), Smith and Mark (2001)). An in-depth review of this field is beyond the scope of this thesis, however, a potential interface with holonic theory and AQAL modelling is worth mentioning.

One area of recent focus for GI Scientists concerns the development of terminology in ontological modelling of geographical phenomena. Galton (2003) proposes a number of terms that aim to differentiate *object-based* from *field-based* views of geographical reality, and differentiating terms such as *continuants*, *fluents*, and *occurants*. His arguments for differentiating object-based and field-based views have implications for issues related to *identity* in ways similar to how questions about identity were raised in the previous section. A potential interface may surface from taking a closer look at how the terminology used in the holonic tenets and the AQAL model may be synonymous with those proposed by Galton for various geographical phenomena. His arguments for differentiating *objects* and *fields* appear similar to the Wilber's differentiation of *individual* and *social*, as may be applied across anthropospheric, biospheric and cosmospheric levels in the A-B-C model. Wilber's model emphasizes the 'interior' (subjective and inter-subjective) aspects of objects and fields, and is more comprehensive in this regard.

Such an examination may provide an important interface for other works in GI Science that are beginning to make use of holonic information processing frameworks. Eagleson, et. al. (2003) use 'hierarchical spatial reasoning' (HSR) theory to address statistical aggregation issues across different spatial data frameworks and geographical scales. Applications of the AQAL map, such as the ITB presented above, or the Eco-AQAL model presented in Eddy (2005) present possibilities for use as *geo-ontological frameworks*, within which various alternative approaches to geo-ontological modelling and analysis may take place.

Synopsis

Part A presented a theoretical framework for situating map metaphors in relation to three basic elements involved in a cartographic process (Figure D-4c). It emphasizes the utility of map metaphors which not only serve as a means for visualizing mental models or thought processes, but by rendering thought patterns in map form, map metaphors serve an additional utility potentially revealing alternative insights, thereby contributing to debates.

In Part B, this utility was illustrated by presenting arguments for how statements about the world are geo-ontologically contingent. Here, Part C presented a theoretical framework using a map metaphor as a means for navigating these contingencies (i.e. the holonic tenets and the AQAL map). Consequently, it outlined one approach for trans-disciplinary integration in GES, which highlights a need to maintain important differentiations of methodological families used in probing different aspects of reality – those being the primary dimensions of interior and exterior realities of individuals and collectives. The ITB map metaphor illustrates the importance of geography and scale in examining local-global interaction, and provides room for individuals to situate their own circumstances in relation to cultural and societal dimensions in the collective sphere. The use of map metaphors in this context may have a number of implications for cartography and geography.

First, the relation between the AQAL map and the theoretical framework outlined in Figure D-4c suggests a potential broadening of context for the role of cartography in GES, and possibly for other disciplines. Some of these aspects have been suggested in Taylor's (2003) concept of *cybercartography*. What is apparent from the examination in the preceding sections, in particular, the use of an application of the AQAL map such as in the ITB map, is its potential for allowing individuals to situate their own circumstances and physical location (personal lines in the upper quadrants), in relation to others (people, species, and places) across geographical scales and forms of representation in the lower quadrants; including the multiple forms of knowledge from local-traditional to global-scientific forms (Figure D-22).

An integral approach to addressing circumstances involves taking into consideration and reconciling both internal and external boundary conditions. This suggests that the role of cartography, although conventionally considered to be occupied with *visualization* and *abstraction* of reality (MacEachren (1994), Peterson (1995), Taylor (1994)), be expanded to include, and be tested against its utility for *realization* and *actualization*. This is illustrated in Figure D-29 in relation to the triadic elements of

Figures 4c and 22. Giving additional consideration to these functional aspects of maps and mapping reinforces the necessity and importance for *visualization* in relation to *realization* and *actualization*. As discussed in earlier sections, maps provide people a means to see over their own horizons. Not using maps is akin to dropping the third element from the model wherein the capacity for addressing geo-ontological contingency is significantly diminished, if not removed entirely. Conversely, by emphasizing the other two elements *in addition to* visualization, it serves as a basis to ensure that people do not fall into the trap of 'map fixation', (i.e. focused only on the third element as described by Muehrcke and Muehrcke, 1989).

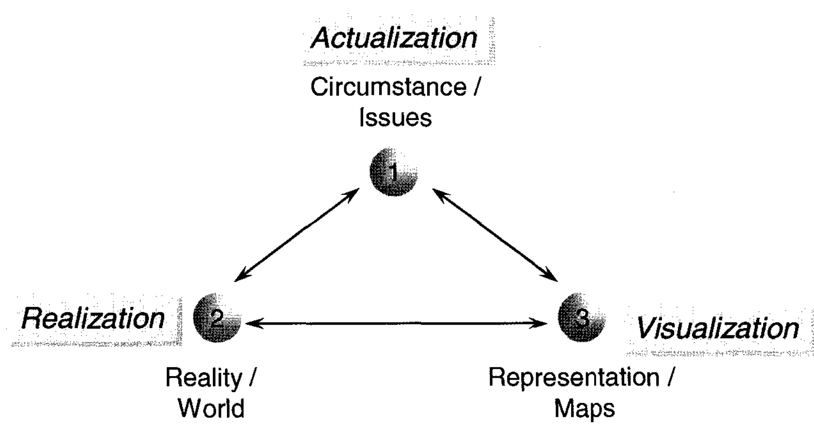


Figure D-29. The triadic cartographic framework highlighting three principal utilities for maps and mapping processes: visualization, realization and actualization.

A second implication is suggested as a possible broadening of the definition of *geographical information* (GI). Conventionally, GIS and GI Science focus on the formal spatial topological elements of spatial phenomena, as are conventionally modelled in GIS. The *information* element in GIS (i.e. the 'I' in GIS) is commonly considered to focus on the derivation of new information from combining primary map inputs; often, with a focus on formal statistical and mathematical operations applied to data. In short, it focuses primarily on scientific aspects of GI, and does not conventionally consider other forms of geographical information that may be equally useful, if not more important for some applications. As argued in Eddy and Taylor (2005b), *information* is not an intermediary 'level' of content in a processing stream, rather, all content relating to multiple forms of data, knowledge and meaning constitute various forms of *information.* Stories, videos, traditional and local knowledge, personal cartographies, news articles and research papers written about places are a few examples of additional types of information that can all be considered forms of GI under a broadened definition. Although conventional GIS and GI Science does not currently focus on these types of information, cybercartography is more accommodating. The integral framework can be used to situate three broad types of information that may be considered in a broadened definition, and these are summarized with the help of the schematic presented in Figure D-30.

This model builds upon the A-B-C model presented in Eddy (2005) and the analysis provided in Part C, and is summarized here as an 'A-B-C-/1-2-3' approach to *Integral Geography.* The A-B-C component refers to Anthropospheric, Biospheric, and Cosmospheric components, which are holarchically nested as described in Figure D-25. The 1-2-3 component refers to the three primary perspectives that the AQAL map maintains are necessary for building a comprehensive geoinformation base on a subject.

As mentioned in earlier sections, Wilber sometimes simplifies the AQAL model in terms the three primary perspectives of I, We and It. The first perspective ("I") pertains to individuals and their personal situated knowledge and perspective, and may be extended to include perspectives on aesthetic, phenomenological, psychoanalytic and other modes of enquiry associated with this domain. The second perspective ("We") pertains to the cultural and ethical domain, where people dialogue and communicate terms of agreement or sharing of perspectives, and finding mutual understanding. The third perspective ("It") pertains to information that represents the scientific study of the world, including all of the physical and social sciences and their respective contributions for providing objective-based information on A-B-C interactions. Taken as a holonic template, such a framework may serve as a cornerstone for facilitating integration in geography, while reassuring the necessity for maintaining important methodological differences in human and physical geography, and differentiating scientific, ethical and aesthetic dimensions.

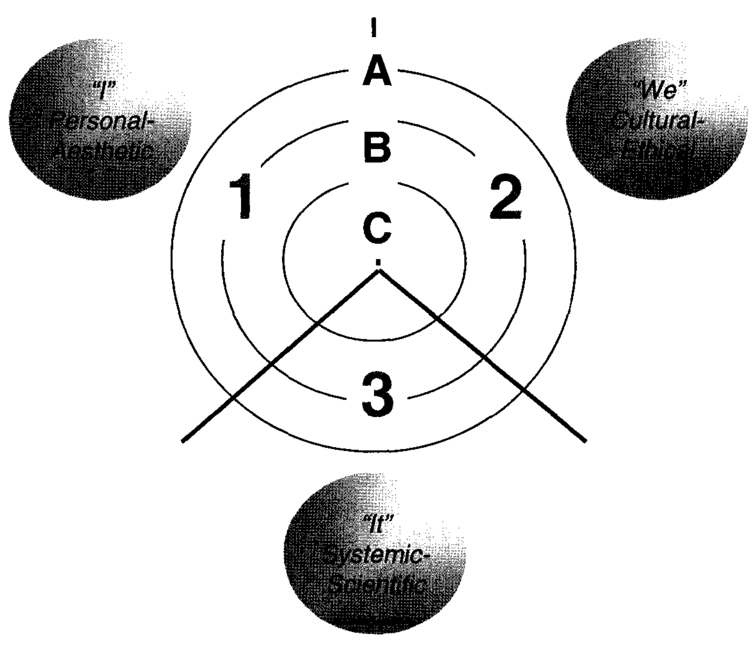


Figure D-30. A simplified A-B-C/1-2-3 schematic for *Integral Geography*.

Differentiating these elements is consistent with other integrative perspectives in geographical thought in recent years; two of which are mentioned here for illustration. Sack (2003) presents a framework that considers 'Truth, Justice and the Natural' in a moral domain of enquiry, in parallel with 'Meaning, Social Relations, and Nature' in an empirical domain of enquiry. Juxtaposing these elements parallels Wilber's association of the 1st, 2nd, and 3rd person perspectives (I, We and It) with Plato's 'beauty, goodness and truth'. The importance in differentiating these domains, as Sack demonstrates with several case studies, is that it provides a means for drawing upon insights and methods used in both human and physical geography, and contributes to the development of more comprehensive analyses to complex issues. Sack also proposes two sub-fields of inquiry of geo-psychology and geo-sociology that correspond well with individual and social quadrants of the AQAL map.

The A-B-C/1-2-3 relations may also interface closely with arguments presented by Urban and Rhoads (2005) in their perspective on what is required to pursue a more integrative approach to geography. Their perspective is similar to arguments presented by Wynn (1999), in that they attribute the division of geography into human and physical sub-disciplines as an artefact of Cartesian dualism, which is further reinforced in the dichotomous split between qualitative and quantitative research methods used in the physical and social sciences. They argue that "geographers should figure prominently in the dissolution of the human-nature dichotomy" (ibid., 224), and suggest "what is needed …is a 'multi-aspect monism' that allows for the biological basis of humanity while, at the same time, acknowledging the distinguishing traits of humans, such as a level of consciousness capable of unparalleled degree of self-awareness" (ibid., 222).

Clearly, there are parallels between this perspective and those presented with the integral framework in previous sections. *Integral Geography*, however, does not suggest a *dissolution* of boundaries (as the philosophy of 'monism' implies), rather that they be adequately *differentiated* in order to permit integration, such as illustrated in Figure D-30. Integral philosophy approaches Cartesian dualism with the concept of 'non-dual', which is significantly different from what Urban and Rhoads describe as 'monism'. Such differences aside, these examples are indicative of a shift in geographical thought towards a more integrative approach for GES, and to which the A-B-C/1-2-3 model aims to contribute. Further research into the potential interfaces among these perspectives will be useful.

How then, am I so different
from the first ones through this way?
Like them, I left a settled life -
I threw it all away.

To seek a Northwest Passage
not knowing where or when
to find there but the road back home again.

Stan Rogers
Northwest Passage

Conclusion: Thesis Statement

Integration in the fields of Geography and Environmental Studies (GES) is not only possible, but necessary for addressing practical problems on local to global scales. In the interest of pursuing such integration, maps and map metaphors provide an important role in at least three ways:

1) Map metaphors are useful as a critical analysis tool in visualizing the spatial, geographical, and topological relations intrinsic in human thought and language.
2) The combined use of conventional geographical maps and map metaphors are necessary for illustrating the long-standing arguments made by geographers that statements about the world are *geo-ontologically contingent*; or, more simply, that *geography matters*.
3) Map metaphors also provide a means for exploring topological relations among inter-disciplinary boundaries in geography and in human-environment relations.

Maps are at times *necessary* when topological relations require explicit *visualization*; at other times, they may not be necessary but are *useful* in augmenting other forms of information as an aid to *realization*; at still other times *detrimental* in cases in which they violate generally accepted cartographic practices, or fall significantly short of being able to capture human thought and expression (e.g. poetry); but at all times, they are *insufficient* in the ability to bring about human *actualization* processes.

Tiredness and excitement
Inner glow awakening
Bursts of Thunder, Sound of Rain

Rivers wash over me creating new pathways
through an ancient forest.

Voices of those who hold me
and free me
echo in my ear.

This moment
and the next
and the one before

All Melt into One.

Here. There. Everywhere.

Brian Eddy
Integral Life Practice (ILP) Seminar
Phoenicia, New York, May 2006

References

References for the Introduction

Castree, N., Rogers, A. and Sherman, D. (Editors) 2005. *Questioning Geography.* Blackwell Publishing: Oxford, UK. 314 p.

Eddy, B.G. 1996. *A GIS-based fuzzy logic Method for Mineral Potential Mapping: An Experiment with a Geological Map of the Parry Islands, NWT, Canada.* MSc Thesis, Dept. of Earth Sciences, University of Ottawa. 83 p.

Eddy, B. and Taylor D.R.F. 2005. *Exploring the Concept of Cybercartography Using The Holonic Tenets of Integral Theory.* In: D. R. F. Taylor (2005). (ed.), Cybercartography: Theory and Practice, Amsterdam: Elsevier. pp. 35-61.

Esbjörn-Hargens, S. 2005. *Integral Ecology: The What, Who and How of Environmental Phenomenon.* World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp. 1-49.

Gober, P. 2000. *Presidential Address: In Search of Synthesis.* Annals of the American Association of Geographers. Vol. 90(1). pp. 1-11.

MacEachren, A. 1995. *How maps work: representation, visualization, and design.* Guilford Press:New York. 526 p.

Martinez, E. and Reyes, M.D.C. 2005. *Cybercartography and Society.* In: D. R. F. Taylor (2005). (ed.), Cybercartography: Theory and Practice, Amsterdam: Elsevier. pp. 99-122.

May, T. 2005. *Gilles Deleuze: An Introduction.* Cambridge University Press, New York. 184 p.

Murphy, A. 2006. *Enhancing Geography's Role in Public Debate.* Presidential Address. Annals of the American Association of Geographers, 96(1), pp. 1-13.

Prescott-Allen, R. 2001. *The Wellbeing of Nations: A Country-by-Country Index of Quality of Life and the Environment.* Island Press / International Development Research Centre: Ottawa/Washington, D.C. 342 p.

Pulsifer, P. and Taylor D.R.F. 2005b. *The Cartographer as Mediator: Cartographic Representation from Shared Geographic Information.* In: D. R. F. Taylor (2005). (ed.), Cybercartography: Theory and Practice, Amsterdam: Elsevier. pp. 149-180.

Reyes, C., Taylor, D.R.F., Martinez, E., and Caloca, F. 2006. *Geo-Cybernetics: A New Avenue of Research in Geomatics?* Cartographica, 41(1), pp. 7-20.

Taylor, D. R. F. 2003. *The Concept of Cybercartography.* In: Maps and the Internet, M. P. Peterson (Editor), Elsevier:Cambridge, pp. 403-418.

Taylor, D. R. F. 2005. *Cybercartography: Theory and Practice.* Amsterdam: Elsevier. 454 p.

Trudgill, S. and Roy, A. (Editors) 2005. *Contemporary Meanings in Physical Geography.* Oxford University Press: New York. 292 p.

Wallace, I. 2002. *Sustaining Geography; Sustainable Geographies: The Linked Challenge.* Past-president's Address. The Canadian Geographer, 98(2). pp. 98-107.

Wilber, K. 1995. *Sex, Ecology, Spirituality: The Spirit of Evolution.* The Collected Works of Ken Wilber., 2nd Edition, Shambhala:Boston. 853 p.

Wilber, K. 1996. *A Brief History of Everything.* Shambhala: Boston. 339 p.

Wilber, K. 2000. *A Theory of Everything: An Integral Vision for Business, Politics, Science and Spirituality.* Shambhala:Boston. 189 p.

Wilber, K. 2002. *Excerpts A-G - Volume 2 of the Kosmos Trilogy.* http://wilber.shambhala.com/html/books/kosmos/index.cfm/{Last accessed June 25th, 2006}

Zimmerman, M. 2005. *Integral Ecology: A Perspectival, Developmental, and Coordinating Approach to Environmental Problems.* World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp.50-62.

References for PAPER A

An, P., Moon, W.M., and Rencz, A., 1991. *Application of Fuzzy Set Theory To Integrated Mineral Exploration.* Canadian Journal of Exploration Geophysics, Vol. 27, No. 1, p. 1-11.

Anglin, C.D. and Harrison, J.C. 1999. *Mineral and Energy Resource Assessment of Bathurst Island Area, Nunavut (Parts of NTS 68G, 68H, 69A, and 79A).* Geological Survey of Canada, Open File 3714.

Agterberg, F.P., Bonham-Carter, G.F, Cheng, Q., and Wright, D.F. 1993. *Weights of Evidence Modelling and Weighted Logistic Regression for Mineral Potential Mapping,* in *Computers in Geology: 25 Years of Progress.* Editors: J.C. Davis and U.C. Hertzfeld. Oxford University Press, New York. 298 p.

Bonham-Carter, G.F. 1994. *Geographic Information Systems for Geoscientists:Modelling with GIS.* Pergamon Press, Oxford, 398 p.

Burrough, P.A. and McDonnell, R.A. 1998. *Principles of Geographical Information Systems.* Oxford University Press. 333 p.

Cheng, Q., 1994. *Multifractal modeling and spatial analysis with GIS: gold potential estimation in the Mitchell-Sulphurets area, northwestern British Columbia.* Phd dissertation (unpublished), Dept. of Earth Sciences, University of Ottawa, 268pp.

CHPC, 1997. *National Parks System Plan.* Third Edition. Canadian Heritage Parks Canada. 106 p.

Chung, C.F. and Fabbri, A.G., 1993. *The Representation of Geoscience Information for Data Integration.* Nonrenewable Resources, Vol. 2, No. 2, p. 565-577.

Constanza, E.J.M., and Hale, M. 2001. *Geologically Constrained Fuzzy Mapping of Gold Mineralization Potential, Baguio District, Philippines.* Natural Resources Research, Vol. 10, No. 2. pp. 125-136.

Crisp, R. 1999. *The Cambridge Dictionary of Philosophy.* 2nd Edition. Cambridge University Press. p. 34.

Eckstrand, O.R., Sinclair, W.D., and Thorpe, R.I. (1995). Geology of Canadian Mineral Deposit Types. Geological Survey of Canada, Geology of Canada, no. 8. 640 p.

Eddy, B.G. 1996. *A GIS-based fuzzy logic Method for Mineral Potential Mapping: An Experiment with a Geological Map of the Parry Islands, NWT, Canada.* MSc Thesis, Dept. of Earth Sciences, University of Ottawa. 83 p.

Griffiths, J.C., Watson, A.T., and Menzie, W.D. 1980. *Relationship between mineral resources and geologic diversity.* In: Miall, A.D. (Ed.) Facts and Principles of World Petroleum Occurrence. Can. Soc. Petrol. Geol., Memoir 6, pp. 329-341.

Harris, J., Wilkinson, L., Heather, K., Fumerton, S., Bernier, M.A., Ayer, J., and Dahn, R. (2001). *Application of GIS Processing Techniques for Producing Mineral Prospectivity Maps-A CaseStudy: Mesothermal Au in the Swayze Greenstone Belt, Ontario, Canada.* Natural Resources Research, Vol. 10, No. 2. pp. 91-124.

Harrison, J.C. and de Freitas, T.A. 1998. *Bedrock Geology, Bathurst Island Group, District of Franklin, Northwest Territories (Nunavut) (NTS 68H,68G,69A,69B and parts of 78H and 79A).* Geological Survey of Canada, Open File 3577 (scale 1:125,000).

IAMG, 1994. *Panel discussion on qualitative vs. quantitative approaches to mineral resource assessment.* International Association for Mathematical Geology Conference, Mont Tremblant, Quebec. (participant).

Kerr, J.W., 1974. *Geology of Bathurst Island Group and Byam Martin Island, Arctic Canada, (Operation Bathurst Island).* Geological Survey of Canada, Memoir 378.

Mihalasky, M.J. and Bonham-Carter, G.F. 2001. *Lithodiversity and its spatial association with metallic mineral sites, Great Basin of Nevada.* Natural Resources Research, 10(3), pp. 209-226.

Mihalasky, M. J., 2001, Mineral Potential Modelling of Gold and Silver Mineralization in the Nevada Great Basin - A GIS-Based Analysis Using Weights of Evidence: U.S. Geological Survey Open-File Report 01-291, 448 p.

Picklyk, D.D., Rose, D.G., and Laramée, R.M., 1978. Canadian mineral occurrence index (CANMINDEX) of the Geological Survey of Canada. Geological Survey of Canada, Paper 78-8, 27p.

Sangster, D.F. 1995. *Mississippi Valley-type Lead-Zinc;* in *Geology of Canadian Mineral Deposit Types,* (ed.) O.R. Eckstrand, W.D. Sinclair, and R.I. Thorpe; Geological Survey of Canada, Geology of Canada, no. 8, p. 253-261.

Scoates, R.F.J., Jefferson, C.W., and Findlay, D.C., 1986. *Northern Canada Mineral Resource Assessment.* In: *Prospects for Mineral Resource Assessment on Public Lands: Proceedings of the Leesburg Workshop.* Editors: S.M. Cargill and S.B. Green; U.S. Geological Survey, Circular 980, p. 111-139.

Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V., Roest, W.R., 1997. *Geological Map of Canada, Map 1860A.* Geological Survey of Canada, CD-ROM Publications.

Wright, D.F., 1996. *Evaluating Volcanic -Hosted Massive Sulphide Favourability using GIS-based spatial data integration models, Snow Lake area, Manitoba.* Ph.D. dissertation, University of Ottawa, Canada, 338p.

Zedah, L.A. 1965. *Fuzzy sets.* Information and Control, 8 (3). p. 338-353.

References for PAPER B

Adams, F. 2001. Information Theory (definition of). *In* The Cambridge Dictionary of Philosophy. *Edited by* R.Audi. Cambridge University Press, Cambridge. pp. 435-437.

Burrough, P.A.and MacDonnell,R.A. 1998. Principles of Geographical Information Systems. Oxford University Press, New York. 333 p.

Chrisman, N. 2002. Exploring Geographic Information Systems. Wiley, New York. 305 p.

Clarke, K.C. 2001. Getting Started with Geographic Information Systems. Prentice Hall, Upper Saddle River, N.J. 352 p.

Copi, I.M. 1982. An Introduction to Logic. MacMillan, New York. 604 p.

De Blij, J.and.Muller, P.O. 1997. Geography: realms, regions and concepts. Wiley, New York.

Eddy, B. G. 2002. Cybercartographic Integrated Research Framework. Presentation to Research Workshop on Cooperation between Carleton University and The National Atlas of Canada, Carleton University, Ottawa, April 15.

Eddy, B.G., Bonham-Carter, G.F. and Jefferson, C.W. (2006). Mineral Potential Analyzed and Mapped at Multiple Scales: A Modified Fuzzy Logic Method Using Digital Geology. Geological Association of Canada (GAC): Special Volume on GIS Applications in the Earth Sciences (in press): 39 p.

Eddy, B.G. (in press, b). Integral Geography: Space, Place and Perspective. World Futures: Journal of General Evolution. Special Volume on Integral Ecology: 28 p.

ESRI Inc. 1997. Understanding GIS: the Arc/Info Method. Wiley and Sons, New York.

Fisher, H.T. 1982. Mapping Information: The Graphic Display of Quantitative Information. Abt Books., Cambridge, MA. 384 p.

Freeman,O.W. 1949. Essentials of Geography. McGraw-Hill Book Co., New York. 487 p.

Haggett, P. 1983. Geography: A Modern Synthesis. Harper & Row, New York. 644 p.

Koestler, A. 1967. The Ghost In The Machine. MacMillan, New York. 384 p.

Lauriault, T. and Taylor, D.R.F (2005). Cybercartography, research integration and collaboration in action. Chapter VIII (this volume).

Latour, B. 1999. Pandora's hope : essays on the reality of science studies. Harvard University Press, Cambridge Mass. 324 p.

Leung, Y. 1997. Intelligent Spatial Decision Support Systems. Spriner Verlag, New York. 470 p.

Lexicon. 1987. The New Lexicon Webster's Dictionary of the English Language. Lexicon Publications, Inc.

Lindholm, M.and Sarjakoski, T. 1994. Designing a Visualization User Interface. *In* Visualization in Modern Cartography. *Edited by* A.M. MacEachren and D.R.F Taylor. Elsevier Science, Oxford pp. 167-184.

Lock, C.B. 1976. Geography and Cartography: A Reference Handbook. Bingley, London. 762 p.

Longley, P.A.,Goodchild, M.F.; MaGuire, D.J.,and Rhind, D.W. 2001. Geographic information systems and science. Wiley, Chichester ; New York . 454 p.

Medyckyj-Scott, D.,and Hearnshaw,H.M. 1993. Human Factors in Geographical Information Systems. Belhaven Press., London.

Peterson, M.P. 1995. Maps and the Changing Medium. *In* Interactive and Animated Cartography. *Edited by* M.P.Peterson. Prentice Hall, pp. 3-9.

Pulsifer, P. and Taylor, D.R.F. 2005. The cartographer as mediator: cartographic representation from shared geographic information. Chapter VII (this volume).

Raper, J. 2000. Multidimensional geographic information science. London ; New York. 300 p.

Rasmussen, J. 1999. Ecological Interface Design for Reliable Human-Machine Systems. International Journal of Aviation Psychology 9: 203-223.

Reeve, D.E and Petch,J.R. 1999. GIS, organisations and people : a socio-technical approach . Taylor & Francis, London ; Philadelphia .

Robinson, A.H. 1995. Elements of Cartography. Wiley, New York. 674 p.

Shaw, E.B. 1965. Fundamentals of Geography. Wiley, New York. 414 p.

Small, R.J.and Witherick,M. 1995. A Modern Dictionary of Geography. Edward Arnold, London.

Stonier, T. 1997. Information and Meaning: An Evolutionary Perspective. Springer-Verlag, New York. 255 p.

Szegö, J. 1987. Human Cartography. Swedish Council for Building Research, Stockholm, Sweden. 237 p.

Taylor, D.R.F. 2003. The Concept of Cybercartography. *In* Maps and the Internet. *Edited by* M.P.Peterson. Elsevier, Cambridge. pp. 403-418.

Teilhard de Chardin, P. 1969. The Phenomenon of Man. Harper Torchbooks., New York. 318 p.

Tomlin, C.D. 1990. Geographic Information Systems and Cartographic Modelling. Prentice Hall, Englewood Cliffs, N.J. 249 p.

Ullman, E.L. 1980. Geography as Spatial Interaction. U. of Washington Press., Seattle. 231 p.

Wicken, J.S. 1987. Evolution, Thermodynamics, and Information: Extending the Darwinian Program. Oxford University Press, Oxford. 235 p.

Wilber, K. 1995. Sex, Ecology, Spirituality: The Spirit of Evolution. The Collected Works of Ken Wilber. Shambhala, Boston. 853 p.

Wilber, K. 1996. A Brief History of Everything. Shambhala, Boston. 339 p.

Wilber, K. 2000. Waves, Streams, States, and Self: Further Considerations for an Integral Theory of Consciousness. Journal of Consciousness Studies, 7, No.11-12. pp. 146-176.

Wilber, K. 2002. Excerpts A-G - Volume 2 of the Kosmos Trilogy. Shambhala, Boston. (in prep). www.shambhala.com.

Winder,R., Probert,S.K., and Beeson,I.A. 1997. Philosophical Aspects of Information Systems. Taylor and Francis, London. 247 p.

Wood, D.and Fels, J. 1992. The Power of Maps. Guilford Press, New York. 248 p.

References for PAPER C

Beck, D. and Cowan, C. 1996. *Spiral Dynamics: Mastering Values, Leadership, and Change.* Blackwell Publishers Inc., Malden, Mass. 335 p.

Couclelis, H., 1992. *Location, Place, Region, and Space.* In: Ronald F. Abler, Melvin G. Marcus, and Judy M. Olsen (eds.) Geography's Inner Worlds: Pervasive Themes in Contemporary American Geography, New Brunswick, N.J.: Rutgers University Press. p. 215-233.

Gober, P., 2000. p. 1-11. *Presidential Address: In Search of Synthesis.* Annals of the American Association of Geographers. p. 1-11.

Gregory, K.J., 2000. *The Changing Nature of Physical Geography.* London: Arnold. p. 229-290.

Haraway, D., 1991. *Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective.* In: Simians, Cyborgs, and Women: The Reinvention of Nature. New York: Routledge. pp. 183-201.

Harding, S.1986. *The Science Question in Feminism.* Cornell University Press. Ithaca and London. 261 p.

Hargens, S., 2002. *Morphic Fields as Interobjective Structures: A Counter-weight to Phenomenologically Based Approaches to "Collectivity".* California Institute of Integral Studies. (Phd work in progress). 85 p.

Harrison, R.T. and Livingstone, D.N., 1980. *Philosophy and Problems in Human Geography: A Presuppositional Approach.* Area, Vol. 12, no. 1. pp. 25-31.

Hartshorne, R., 1939. *The Character of Regional Geography.* In: The Nature of Geography: A Critical Survey of Current Thought in Light of the Past. Association of American Geographers, Washington, D.C. Extract from 1961 edition. pp. 388-397.

Kropotkin, P., 1885. *What Geography Ought To Be.* The Nineteenth Century, 18. pp. 940-56.

Leopold, A., 1949. *A Land Ethic.* In: A Sand County Almanac and Sketches Here and There. Oxford: Oxford University Press.

Mackinder, H.J., 1887. *On the Scope and Methods in Geography.* Proceedings of the Royal Geographical Society 9. pp. 141-160.

Sauer, C.O., 1925. *The Morphology of Landscape.* University of California Publications in Geography 2. pp. 19-54.

Sayer, A., 1992. *Problems of Explanation and the Aims of Social Science.* In: Methods in Social Science. Routledge, New York. pp. 232-266.

Semple, E., 1911. *Influences of Geographic Environment on the Basis of Ratzel's System of Anthropogeographie.* New York: Holt. pp. 1-32.

Vidal de La Blache, P. 1927-48. *Géographie universelle*, publié sous la direction de P. Vidal de La Blache et L. Gallois. Vols. 1-7. Publisher Paris, A. Colin, 1927-48.

Wilber, K. 1995. *Sex, Ecology, Spirituality: The Spirit of Evolution.* The Collected Works of Ken Wilber, Volume 6, 2nd Ed. Shambhala Publications Inc., Boston, Mass. 853 p.

Wilber, K. 2002. *Excerpt A: Volume 2 of the Kosmos Trilogy.* wilber.shambhala.com. 137 p.

Wynn, G., 1999. *A Fine Balance? Geography at the Millenium.* The Canadian Geographer, 43 , no 3. pp. 220-243.

References for PAPER D

Agre, P. 2003. *Networking on the Network: A Guide to Professional Skills for PhD Students.* Dept.of Information Studies, University of California, Los Angeles, California, USA. http://polaris.gseis.ucla.edu/pagre/network.html {last accessed, June 25th, 2006}

Alexander, V. N. 2002. *Narrative telos: The ordering tendencies of chance.* Ph.D. dissertation. Graduate Center, City University of New York. http://www.dactyl.org/directors/vna/Narrative_Telos.htm {last accessed, June. 25th, 2006)

Beck, D. and Cowan, C. 1996. *Spiral Dynamics: Mastering Values, Leadership, and Change.* Blackwell Publishers Inc., Malden, Mass. 335 p.

Bossel, H. 1999. *Indicators for Sustainable Development: Theory, Method, Applications.* International Institute for Sustainable Development (IISD). 139 P.

Brown, B. C. 2004. *The Use of the Integral Framework by the United Nations Development Program in Their Global Response to HIV/AIDS.* Integral International Development Center, Integral University. 18 p.

Burrough, P.A. and MacDonnell, R.A. 1998. *Principles of Geographical Information Systems.* Oxford University Press: New York. 333 p.

Copi, I. M. 1982 *An Introduction to Logic*, 6th Ed., MacMillan:New York. 604 p.

Crompvoets, J., Bregt, A., Rajabifard, A., and Williamson, I. 2004. *Assessing the worldwide developments of national spatial data clearinghouses.* International Journal of Geographical Information Science, vol. 18, no. 7, pp. 665-689.

Csillag, F. and Boots, B. 2005. *Statistical inferential decisions in spatial pattern analysis.* The Canadian Geographer, vol. 49, no. 2, pp. 172-179.

Dale, A. 2001. *At The Edge: Sustainable Development in the 21st Century.* UBC Press: Vancouver. 212 p.

Demeritt, D. 2001. *The Construction of Global Warming and the Politics of Science.* Annals of the Association of American Geographers, 91(2). pp. 307-337

DiBiase, D., Reeves, C., MacEachern, A., von Wyss, M., Krygier, J., Sloan, J. and Detweiler, M. 1994. *Multivariate Display of Geographic Data: Applications in Earth System Science.* In: Visualization in Modern Cartography, MacEachren, A.M. and Taylor, D.R.F. (Editors). Elsevier Science:Oxford, pp. 287-312.

Dobson, A. 2000. *Sustainable Development and the Defense of the Natural World.* In: Sustainable Development in the 21st Century. Lee, K., Holland, A. and McNeill, D. (Editors). Edinburgh University Press. pp. 49-61.

Doubleday, N.C. 1993. *Finding Common Ground: Natural Law and Collective Wisdom.* In: Traditional Ecological Knowledge, Inglis J., (Ed). International Development Research Centre (IDRC): Ottawa. pp. 41-53.

Dyck, E. 2005. *Feminist geography, the 'everyday', and local-global relations.* The Canadian Geographer, vol. 49, no. 3, pp. 233-243.

Eagleson, S., Escobar, F. and Williamson, I. 2003. *Automating the administration boundary design process using hierarchical spatial reasoning theory and geographical information systems.* International Journal of Geographical Information Science, vol. 17, no. 2, pp. 99-118.

Eddy, B. Taylor, D.R.F, Lauriault, T., and Pulsifer, P. 2003. *Cybercartography and the New Economy: Research Questions and Issues.* Presentation and Abstract: CAG-CCA Conference, Victoria, B.C.

Eddy, B., and Taylor, D.R.F. 2005a. *Cybermapping the Enterprise: Cybercartography, Visualization, and Information Management.* Presentation made to the Information Highways Conference and Showcase, Toronto, Ontario. April 7th, 2005.

Eddy, B. and Taylor D.R.F. 2005b. *Exploring the Concept of Cybercartography Using The Holonic Tenets of Integral Theory.* In: D. R. F. Taylor (2005). (ed.), Cybercartography: Theory and Practice, Amsterdam: Elsevier. pp. 35-61.

Eddy, B.G., Bonham-Carter, G.F., and Jefferson, C.W. 2006. *Mineral Potential Mapped and Analyzed at Multiple Scales: A Modified Fuzzy Logic Method Using Digital Geology.* In: Harris, J.R., Editor, GIS Applications in the Earth Sciences: Geological Association of Canada, Special Paper 44, pp. 143-163.

Eddy, B.G. 2005. *Integral Geography: Space, Place and Perspective.* World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp. 151-163.

Esbjörn-Hargens, S. 2005. *Integral Ecology: The What, Who and How of Environmental Phenomenon.* World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp. 1-49.

Favis-Mortlock, D. and de Boer, D. 2005. *Simple at Heart? Landscape as a self-organizing complex system.* In: Contemporary Meanings in Physical Geography, Trudgill, S. and Roy, A. (Editors). Arnold: London, pp. 127-172.

Fotheringham, A. and Brunsdon, C. 2004. *Some thoughts on inference in the analysis of spatial data.* International Journal of Geographical Information Science., vol. 18, no. 5, pp. 447-457.

Frodeman, R. 2003. *Geo-Logic: Breaking Ground Between Philosophy and the Earth Sciences.* State University of New York (SUNY) Press: New York. 184 p.

Galton, A. 2003. *Desiderata for a Spatio-temporal Geo-ontology.* In: Spatial information theory : foundations of geographic information science. Kuhn, W., Worboys, M., and Timpf, S. (Editors). International conference, COSIT Kartause Ittingen, Switzerland, September 24-28, 2003

Gardner, M. 1972. *The quest for mind: Piaget, Levi-Strauss, and the structuralist movement.* New York:Knopf, 276 p.

Gebser, J. 1985. *The ever-present origin.* New York: Basic Books. 576 p.

GEO (Group on Earth Observations) 2005. *Global Earth Observation System of Systems (GEOSS): 10-Year Implementation Plan.* ESA Publications, Netherlands. 209 p.

Gober, P. 2000. *Presidential Address: In Search of Synthesis.* Annals of the American Association of Geographers. Vol. 90(1). pp. 1-11.

Gregory, K. J. 2000. *The Changing Nature of Physical Geography.* London: Arnold. 368 p.

GSDI. 2004. *Developing Spatial Data Infrastructures: The SDI Cookbook, Version 2.0.* Douglas D.Nerbert, Technical Workding Group Chair. www.gsdi.org/ {last accessed, June 25th, 2006}

Hargens, S. 2002. *Integral Development: Taking the Middle Path Towards Gross National Happiness.* Journal of Bhutan Studies, Vol. 6, Summer 2002. pp. 24-87.

Harley, J.B. 1989. *Deconstructing the Map.* Cartographica, 26/2, pp 1-20.

Hartshorne, R. 1939. *The Character of Regional Geography.* In: The Nature of Geography: A Critical Survey of Current Thought in Light of the Past. Association of American Geographers, Washington, D.C. pp. 388-397.

Harvey, D. 1969. *Explanation in Geography.* Edward Arnold:London. 521 p.

Hochackha, G. 2005. *Integrating Interiority in Community Development.* World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp. 110-126.

Hochachka, G. 2006. *Developing Sustainability, Developing the Self: An Integral Approach to International and Community Development.* POLIS Project on Ecological Governance, University of Victoria. 137 p.

IISD. 1997. *Assessing Sustainable Development: Principles in Practice.* Hardi, P., and Zdan, T. (Editors). International Institute for Sustainable Development (IISD). 175 p.

Juster, N. and Feiffer, J. 1961. *The Phantom Tollbooth.* Dell Yearling: New York. 256 p.

Kay, J. 2000. *Ecosystems as Self-organizing Holarchic Open Systems: Narratives and the Second Law of Thermodynamics.* In: Handbook of Ecosystems Theories and Management. Jørgensen,S.E., and Müller, F., (Editors). Lewis Publishers. pp. 135-159.

Knox, P.L., Martston, S.A., and Nash, A.E. 2004. *Human Geography: Places and Regions in Global Context.* Pearson-Prentice Hall: Toronto. 577 p.

Koestler, A. 1967. *The Ghost In The Machine.* MacMillan, New York. 384 p.

Laszlo, E., Ignazio, M., Artigiani, R., Csányi , V. 1993. *The Evolution of cognitive maps: new paradigms for the twenty-first century.* Yverdon: Switzerland, Langhorne, Pa. 292 p.

Lomborg, B. 1998. *The Skeptical Environmentalist: Measuring the Real State of the World.* Cambridge University Press: New York. 515 p.

Longley, P.A., Goodchild, M.F., MaGuire, D.J., and Rhind, D.W. 2001. *Geographic Information Systems and Science.* Wiley, Chichester ; New York . 454 p.

MacEachren, A. 1994. *Visualization in Modern Cartography: Setting the Agenda.* In: Visualization in Modern Cartography. MacEachren, A.M. and Taylor, D.R.F. (Editors). Elsevier Science:Oxford, pp. 1-12.

MacEachren, A. 1995. *How maps work: representation, visualization, and design.* Guilford Press:New York. 526 p.

MacEachren, A., Robinson, A., Hopper, S., Gardner, S., Murray, R., Gahegan, M., and Hetzler, E. 2005. *Visualizing Geospatial Information Uncertainty: What We Know and What We Need to Know.* Cartography and Geographic Information Science , vol. 32, no. 3, pp. 139-160.

Maldonado-Torres, N. 2004. *The Topology of Being and the Geopolitics of Knowledge: Modernity, Empire, Coloniality.* City, Vol. 8(1), pp. 29-56.

May, T. 2005. *Gilles Deleuze: An Introduction.* Cambridge University Press, New York. 184 p.

Muehrcke, P. C. and Muehrcke , J. O. 1989. *Map use: reading, analysis, and interpretation.* JP Publications:Madison, Wis. 647 p.

Nørretranders, T. 1998. *The User Illusion: Cutting Consciousness Down to Size.* Penguin: New York. 467 p.

NRTEE. 2003. *Environment and Sustainable Development Indicators for Canada.* A State of the Debate Report: National Roundtable on the Environment and Economy. Renouf Publishing: Ottawa. 93 p.

OGC. 2003. *OpenGIS Reference Model (ORM): Version 0.1.3.* Editor: George Percivall. Open Geospatial Consortium Inc. www.opengeospatial.org/ {last accessed, June 25th, 2006}

Onsrud, H. 1998. *Tragedy of the Information Commons.* In: Policy Issues in Modern Cartography. D.R.F.Taylor, (Ed.), Elsevier Science: Oxford, pp. 141-157.

Owens, C. 2005. *An Integral Approach to Sustainable Consumption and Waste Reduction.* World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp. 96-109.

Peirce, C. 1958. *The Collected Papers of Charles Sanders Peirce.* Vols. 1-8, Hartshorne, C and Weiss, P. (Editors). Harvard University Press: Cambridge (1931-1958).

Peterson, M. P. 1995. *Maps and the Changing Medium.* In: Interactive and Animated Cartography, M. P. Peterson, (Editor)., Prentice Hall, pp. 3-9.

Prescott-Allen, R. 2001. *The Wellbeing of Nations: A Country-by-Country Index of Quality of Life and the Environment.* Island Press / International Development Research Centre: Ottawa/Washington, D.C. 342 p.

Sack, R. 2003. *A Geographical Guide to the Real and the Good.* Routledge:New York/ London. 302 p.

Sharpe, C. 2006. *President's Column: On the Question of a Core in Geography – Part IV.* Canadian Association of Geographers, Newsletter, Vol. 12, No. 5.

Slocum, T., McMaster, R., Kessler, F, and Howard, H. 2005. *Thematic Cartography and Geographic Visualization.* Pearson Prentice Hall: New Jersey. 518 p.

Smith, B., and Mark, D. 2001. *Geographical Categrories: An Ontological Investigation.* International Journal of Geographical Information Science, Vol. 15(7), pp. 591-612.

Taylor, D. R. F. 1994. *Perspectives on Visualization and Modern Cartography.* In: Visualization in Modern Cartography. MacEachren, A.M. and Taylor, D.R.F. (Editors). Elsevier Science:Oxford, pp. 333-342.

Taylor, D. R. F. 1998. *Modern Cartography, Policy Issues and the Developing Nations: Rhetoric and Reality*. In: Policy Issues in Modern Cartography, D.R.F.Taylor, (Editor). Elsevier Science:Oxford, pp. 185-274.

Taylor, D. R. F. 2003. *The Concept of Cybercartography*. In: Maps and the Internet, M. P. Peterson (Editor), Elsevier:Cambridge, pp. 403-418.

Taylor, D. R. F. 2005. *Cybercartography: Theory and Practice*. Amsterdam: Elsevier. 454 p.

Urban, M., and Rhoads, B. 2005. *Conceptions of Nature: Implications for an Integrated Geography*. In: Contemporary Meanings in Physical Geography. Trudgill, S. and Roy, A. (Editors). pp. 211-231.

Wilber, K. 1995. *Sex, Ecology, Spirituality: The Spirit of Evolution*. The Collected Works of Ken Wilber., 2nd Edition, Shambhala:Boston. 853 p.

Wilber, K. 1996. *A Brief History of Everything*. Shambhala: Boston. 339 p.

Wilber, K. 1999. *Integral Psychology*. In: The Collected Works of Ken Wilber, Vol. 4., Shambhala:Boston. pp. 423-718

Wilber, K. 2000a. *A Theory of Everything: An Integral Vision for Business, Politics, Science and Spirituality*. Shambhala:Boston. 189 p.

Wilber, K. 2000b. *Waves, Streams, States, and Self: Further Considerations for an Integral Theory of Consciousness*. Journal of Consciousness Studies, 7, No.11-12, pp. 146-176.

Wilber, K. 2002a. *Excerpts A-G - Volume 2 of the Kosmos Trilogy*. http://wilber.shambhala.com/html/books/kosmos/index.cfm/{Last accessed June 25th, 2006}

Wilber, K. 2002b. *The Four Drives of All Holons*. Interview Transcript. http://wilber.shambhala.com/html/interviews/interview1220_2.cfm/ {Last accessed June 25th, 2006}

Wynn, G. 1999. *A Fine Balance? Geography at the Millennium*. The Canadian Geographer, vol. 43, no. 3, pp. 220-243.

Zimmerman, M. 2005. *Integral Ecology: A Perspectival, Developmental, and Coordinating Approach to Environmental Problems*. World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp.50-62.

Taylor, D. R. F. 1998. *Modern Cartography, Policy Issues and the Developing Nations: Rhetoric and Reality*. In: Policy Issues in Modern Cartography, D.R.F.Taylor, (Editor). Elsevier Science:Oxford, pp. 185-274.

Taylor, D. R. F. 2003. *The Concept of Cybercartography*. In: Maps and the Internet, M. P. Peterson (Editor), Elsevier:Cambridge, pp. 403-418.

Taylor, D. R. F. 2005. *Cybercartography: Theory and Practice*. Amsterdam: Elsevier. 454 p.

Urban, M., and Rhoads, B. 2005. *Conceptions of Nature: Implications for an Integrated Geography*. In: Contemporary Meanings in Physical Geography. Trudgill, S. and Roy, A. (Editors). pp. 211-231.

Wilber, K. 1995. *Sex, Ecology, Spirituality: The Spirit of Evolution*. The Collected Works of Ken Wilber., 2nd Edition, Shambhala:Boston. 853 p.

Wilber, K. 1996. *A Brief History of Everything*. Shambhala: Boston. 339 p.

Wilber, K. 1999. *Integral Psychology*. In: The Collected Works of Ken Wilber, Vol. 4., Shambhala:Boston. pp. 423-718

Wilber, K. 2000a. *A Theory of Everything: An Integral Vision for Business, Politics, Science and Spirituality*. Shambhala:Boston. 189 p.

Wilber, K. 2000b. *Waves, Streams, States, and Self: Further Considerations for an Integral Theory of Consciousness*. Journal of Consciousness Studies, 7, No.11-12, pp. 146-176.

Wilber, K. 2002a. *Excerpts A-G - Volume 2 of the Kosmos Trilogy*. http://wilber.shambhala.com/html/books/kosmos/index.cfm/{Last accessed June 25th, 2006}

Wilber, K. 2002b. *The Four Drives of All Holons*. Interview Transcript. http://wilber.shambhala.com/html/interviews/interview1220_2.cfm/ {Last accessed June 25th, 2006}

Wynn, G. 1999. *A Fine Balance? Geography at the Millennium*. The Canadian Geographer, vol. 43, no. 3, pp. 220-243.

Zimmerman, M. 2005. *Integral Ecology: A Perspectival, Developmental, and Coordinating Approach to Environmental Problems*. World Futures: The Journal of General Evolution, Edited by Ervin Laszlo. Special Issue: Integral Ecology. Guest Editor: Sean Esbjörn-Hargens. Vol. 61, No. 1,2. pp.50-62.