**An Ontological Exploration of Antarctic Environmental Governance: Towards a
Model for Geographic Information Mediation**

by

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ABSTRACT

This thesis examines integration of digital geographic information in the context of Antarctic Environmental Governance (AEG). AEG is a complex domain that ideally draws on a wide variety of perspectives and information resources. Such complexity can present challenges with respect to semantic interoperability – the ability to effectively exchange meaning among information systems and the end users of those systems. Emerging approaches such as the development and application of formal ontologies provide new possibilities for facilitating semantic interoperability.

This thesis provides an overview of general trends in the domain of geographic information technology followed by a focused review of the application of formal ontology in information systems. The review reveals the potential power of semantic mediation for the purpose of information integration. Additionally, the examination reveals presuppositions and requirements associated with, and the potential implications of, using a formal ontology for semantic modelling and mediation.

Members of the Antarctic geographic information community have established a simple semantic model – the SCAR Feature Catalogue (SCAR FC) – to support the sharing of geographic information. To ground this thesis, the content of documents reporting the results of the Antarctic Treaty Consultative Meeting are analyzed to establish geographic feature definitions. These definitions are compared to those in SCAR FC for consistency

and completeness. The evolution of features is also examined. The analysis reveals inconsistencies and gaps when comparing AEG features to SCAR FC. Through this analysis, the nuanced and dynamic nature of AEG feature semantics is established.

In considering the results of the review and the content analysis, a conceptual model for geographic information integration is proposed. *Geographic mediation* is proposed as a model to facilitate the conceptualization of multilevel, distributed, information systems for the purpose of providing information representation that is meaningful to the end user. This means considering technical components (including semantic mediators) as part of an overall information *system* that includes human and machine-based mediators. It is argued that *geographic mediation* can be the basis for developing effective environmental information systems for the AEG domain. The thesis concludes with a summary discussion and the establishment of future research directions.

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LIST OF ACRONYMS

ADD	Antarctic Digital Database
AEG	Antarctic Environmental Governance
ASPA	Antarctic Specially Protected Area
ATCM	Antarctic Treaty Consultative Meeting
ATS	Antarctic Treaty System
CCAMLR	The Convention on the Conservation of Antarctic Marine Living Resources
CEP	Committee for Environmental Protection
CFC	Chlorofluorocarbon
CRAMRA	The Convention on the Regulation of Antarctic Mineral Resource Activities
GIS	Geographic Information System
HTML	HyperText Markup Language
IAATO	International Association of Antarctic Tour Operators
ISO	International Organization for Standardization
JCADM	The Joint Committee on Antarctic Data Management
OCF	Open Cartographic Framework
OGC	Open Geospatial Consortium

OWL	Web Ontology Language
RDF	Resource Description Framework
SCAR	The Scientific Committee on Antarctic Research
SC-AGI	The [SCAR] Standing Committee on Antarctic Geographic Information
SCAR FC	The SCAR Feature Catalogue
SDI	Spatial Data Infrastructure
SLD	Styled Layer Descriptor
SOS	Sensor Observation Service
SVG	Scalable Vector Graphics
UCD	User Centred Design
XML	eXtensible Markup Language
W3C	World Wide Web Consortium
WMC	Web Map Context
WMS	Web Map Service
WFS	Web Feature Service
WCS	Web Coverage Service

CHAPTER 1. INTRODUCTION

1.1 *Introduction*

At the highest level, this thesis deals with integration in geography. More specifically, the thesis examines the integration of digital geographic information in a machine environment in the context of Antarctic Environmental Governance (AEG).

Environmental Governance is a complex domain that ideally draws on a wide variety of perspectives and information resources to develop an improved understanding of environmental issues and ways to address these issues. The developments in information technologies seen over the last three decades present new possibilities for informing environmental governance while at the same time, create new challenges that emerge in relation to sharing information constructed from many different sources. The lack of interoperability is defined here as: the inability of information systems to exchange information or to effectively use the exchanged information. Researchers from Geography and other disciplines have been studying and developing theory, methods and technology to facilitate interoperability at many levels. Central to addressing interoperability at the level of information content (as opposed to the technology level) is the creation of a semantic model called a formal ontology. This approach holds promise for facilitation of improved machine-to-machine mediation of information semantics and

the subsequent integration of information resources. While the promise of improved interoperability exists, the semantic mediation approach may not be conceptually or practically accessible to those who can benefit from the results (i.e. policy makers, community stakeholders in environmental decision making contexts).

The applied research reported in this thesis aims to contribute to the AEG community by synthesizing, analyzing and theorizing in the area of geographic information interoperability. Specifically, the analytical component of the research constructs and critically evaluates a basis for a formal ontology representing the semantics of the AEG domain. To ground the results, the thesis provides a conceptual framework and technical design pattern that situates the various interoperability approaches within a larger application development environment.

1.2 *Environmental Governance and Information*

Although the discipline of geography has many specialized sub-disciplines (e.g. human, environmental, geomatics, physical etc.), a common thread linking geographic discourse is the examination of the interrelationship of human beings and the environment. The interface between humans and their environment is increasingly important as we grapple with global environmental change including but not limited to phenomena such as global warming, ozone depletion, desertification, loss of biodiversity and resource depletion. The discipline of geography has recognized the relationships between human societies and global environmental change as a central theme of disciplinary discourse and much scholarly work has been focused on examining issues and formulating and assessing

responses (e.g. Marsh, 2002; Taylor *et al.*, 2002; McGordon, 2004; Easterling & Apps, 2005). Geographers are improving our understanding of the human-environment interface from a number of perspectives including economic, political, historical, physical, cartographic and geographic information science. While the understanding and knowledge gained through geographic research has intrinsic value, much of the work is applied and is thus aimed at addressing specific issues relevant to particular, current geographic contexts (e.g. Hazen & Anthamatten, 2007; Kettle, 2007; Napieralski, 2007) at a variety of levels of analysis (e.g. technological, methodological, theoretical) and geographic scales.

In our academic endeavours, geographers look not only at ‘what is?’ and ‘how does it work?’ but what ‘ought to be’ and ‘how might it work’. Thus, the work of geographers as a whole is relevant in discussions of governance in general and environmental governance in particular. Governance can be defined as:

“...the sum of the many ways individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting or diverse interests may be accommodated and cooperative action may be taken. It includes formal institutions and regimes empowered to enforce compliance, as well as informal arrangements that people and institutions either have agreed to or perceive to be in their interest.” (Dalby, 2002:420)

Environmental governance can be defined simply as understanding the “nature of environmental problems and the measures needed to deal with these problems” (Dalby, 2002:429). Understanding the complexity of issues at many conceptual and spatial scales requires myriad perspectives from many disciplines that range from physical and life

science to economics, to aesthetics, law and philosophy to name a few. Managing our common affairs in a pluralistic, multi-scale world presents complex challenges. While the challenges of environmental governance are not new, the growing interconnections between individuals, communities and institutions in an increasingly globalized and localized world adds complexity to the process. In the previous sentence, I use the seemingly contradictory phrase “increasingly globalized and localized” to point out the difficulties in categorizing environmental issues into definitive geographic scales. In discussing the relationship between global and local scale environmental issues, Elliot (1998:3) quotes Wood *et al.* (1989) regarding the relationship between local and global scale environmental issues:

“at the local level, a problem such as deforestation primarily affects slash and burn cultivators and peasants attempting to establish stationary farms. But the same problem, multiplied by thousands of small farms and combined with extensive commercial logging, can exacerbate the global-level issue of accelerated atmospheric warming” (Wood *et al.*, 1989:32)

Thus, environmental governance deals with complex phenomena that are situated in individual and collective conceptual space (e.g. scientific models, values, normative systems) and perceptual, multi-scale geographic space (e.g. objects, space, time) (Berkman, 2002:20-21; Peuquet, 2002:89-90). Information is an important part of conceptualizing and understanding environmental phenomena. People are often

dependent upon mediated forms of information to experience their environment, as it is not always possible to experience the environment directly. In some cases this is due to the difference in the location of the individual relative to the environment, however the inability to experience an environment may also be related to spatial and temporal scale (variations on the same theme). Using the senses of touch, vision and hearing, the extent to which humans can directly experience an environment is limited to from fractions of a millimetre to a landscape scale of a few to perhaps tens of kilometres. This primary level of experience (Kitchin & Blades, 2002:35) does not let us directly experience our world at, for example, quantum or global scales. Although a person can conceptualize Canada as an entity, they cannot directly perceive Canada with their senses at an instant in time. The temporal scale of primary individual perception is also limited from fractions of a second to at most just over 120 years. Experience of the environment in microseconds or beyond ones lifetime must be gained through secondary learning either through reference to sensory devices, inference, historical materials or predictive models. Beyond the limits of direct primary experience, if individuals are to conceptualize their environment, then the process of conceptualization and the result of understanding must be built on some form of *secondary information* be it stories told by others, data collected by a measuring device, photographs, videos, written texts, maps or a variety of other sources. Thus, the use of secondary information (henceforth referred to simply as information) is an important aspect of contemporary environmental governance. Here I use a broad definition of information, such as that proposed in the recently released Canadian Digital Information Strategy (Library and Archives Canada, 2007) that uses the term

‘information’ to describe a continuum that includes perceptual elements at one end and more processed conceptual elements at the other.

“Information can be conceptualized as existing along a value chain with raw data at one end and packaged content, such as videos or scholarly articles in peer-reviewed journals, at the other end.” (Library and Archives Canada, 2007:7)

It is important to note that a material and operational use of ‘perception’ and ‘experience’ is presented here in keeping with the dominant definition of these terms within the domain of geographic information and cartography. Recent discourse in human geography (see Davidson & Milligan, 2004) suggests that other aspects of sense and perception such as emotion are an important aspect of geographic conceptualization. While this thesis focuses on a more operational treatment of perception, integration of other theoretical perspectives provide a potentially productive area for future research.

In the context of environmental governance, information is required to support a number of activities including developing understanding, monitoring the state of the environment (Ditor *et al.*, 2001; Belbin *et al.*, 2003), negotiating agreement (Nichols *et al.*, 2000), decision support (Abel *et al.*, 1992) and enforcing compliance (Nichols *et al.*, 2000). The importance of information in environmental governance is becoming increasingly evident as society in general moves into the ‘information age’.

Theorists suggest that we now live in the ‘information age’ (see Davis & McCormack, 1979). It is suggested in this thesis that the term is used not because of the recent introduction of ‘information’ to the world, but rather because of the introduction of machines that can capture, convert, store, manage, analyse, retrieve, present and re-present information. In the past two decades, information technologies have in some way transformed how many of the Earth’s inhabitants live and experience the world. The ubiquity of personal computers combined with increasing access to the Internet provides those with access the ability to manipulate and transmit information with a level of speed and connectedness that is many orders of magnitude greater than even twenty years ago. Understanding and developing the practical and theoretical aspects of machine-based computing has spawned many new academic disciplines and sub-disciplines including Computer Science, Artificial Intelligence and Information Science while social scientists have focused on critical assessment of the social consequences of established and emerging technologies (e.g. Pickles, 1995a; e.g. Dodge & Kitchin, 2005; Klinkenberg, 2007).

In addition to influences on the general public and academia, the pervasive nature of computing technology has implications for environmental governance. The process of environmental governance comprises many activities that have been or are in the process of being revolutionized through changes in information technology. State of the environment reporting and environmental monitoring and modeling have been affected by developments in remote and in-situ sensor technologies (Marsh, 2002:393-404).

Sensor Webs (Open Geospatial Consortium Inc., 2006), also known as virtual observatories, are being developed to survey a variety of phenomena ranging from land cover to traffic patterns (Chong & Kumar, 2003), to physical oceanographic parameters (<http://www.openioos.org>). Computational approaches have been used for environmental modelling (Clarke *et al.*, 2002) and the development of decision support systems (Guariso & Werthner, 1989). These new technologies typically produce geographic information - information that is referenced to a location on the earth.

Geographic information is seen as particularly useful in supporting the environmental governance process. Agenda 21 is the comprehensive implementation plan for a global sustainable development program established as part of the 1992 United Nations Conference on Environment and Development (Earth Summit) held in Rio de Janeiro. It was seen as a blueprint to be used by actors within the environmental governance domain. Chapter 40 of Agenda 21 stresses the need for environmental information at a variety of scales. A follow up report developed by the American National Research Council (American National Research Council, 2002) stresses the importance of computer based Geographic Information Systems for developing environmental early warning and decision support systems.

The cited works provide examples of how information in general and geographic information in particular is being developed and applied by governments, universities and the NGO sector in support of environmental governance activities. In addition to

environmental information systems used by experts, developments in information technology, theory and methodology are supporting a new era of participatory environmental governance whereby members of the public affected by an environmental governance issue can participate in the decision making processes. Leroy and Arts (2006:2) suggest that the domain of environmental governance experienced a 'discursive turn' in the 1980s and 1990s that included a move towards more integrative, participatory approaches to environmental policy development and implementation. Geographers have published widely on participatory mapping and GIS methods and results in the domain of environmental governance (Harris *et al.*, 1995; Sawicki & Craig, 1996; Jankowski & Nyerges, 2001; Schroeder *et al.*, 2001; Balram, 2002b, 2002a; Haklay, 2002). At present, we are seeing increasing possibilities in this area with the advent of publicly available, Internet-based mapping tools (e.g. Google maps/Earth, Microsoft Virtual Earth).

The preceding discussion asserts that information is an important aspect of the environmental governance process. With the increasing availability of information and computing power, a number of new possibilities are presented for informing environmental governance. However, the possibilities related to information access and computation also present a variety of new challenges related to the vast amount of information available from a multitude of information sources. These challenges include finding the information needed when it is needed and integrating information originating from a variety of disparate sources. These challenges can affect actors at all levels of environmental governance from those aiming to manage local development to those

implementing global environmental policy regimes. This thesis examines aspects of these challenges facing a regional environmental governance domain – Antarctic Environmental Governance.

1.3 *Antarctic Environmental Governance*

Antarctica is the coldest continent on earth, is primarily covered by ice and has no permanent human inhabitants. The closest continent to Antarctica, South America is more than 1000 km away. Despite its harsh environment and remoteness, there are a number of reasons for growing interest in Antarctica and the Polar Regions in general. The Polar Regions are increasingly being seen as unique laboratories for studying global processes like climate change. The ecological sensitivity of the poles makes them useful as early warning indicators to detect global environmental change trends and effects. Antarctica also provides an interesting and unique environmental governance model that has emerged as a culmination of exploration, territorial claims and international negotiation.

For centuries the Antarctic region was either unknown or untouched due to its remote location and harsh environment. An initial period of exploration starting in the late 18th century and ending in the early 20th century expanded knowledge of the continent and opened Antarctica to human activity. This period of exploration resulted in a series of territorial claims that have ultimately been suspended as a result of the Antarctic Treaty of 1959. Thus, at present no country has established sovereign rights in Antarctica. The continent is not quite a global commons due to suspended territorial claims. Rather,

Antarctica and to some extent the Southern Ocean are governed by an international treaty system known as the Antarctic Treaty System (ATS). The region falls under a unique geopolitical system. Parties to the treaty currently meet annually (bi-annually in the past) at the Antarctic Treaty Consultative Meeting (ATCM). The ATCM allows voting or 'consultative' members to establish policy with respect to the common affairs of the region. Signatory nations not having voting privileges can participate at the ATCM as observers, and other groups, such as the Scientific Committee on Antarctic Research (SCAR) (<http://www.scar.org>) play a formal advisory role to the ATCM. Within the ATS, a comprehensive environmental protection regime has emerged. This Antarctic Environmental Governance (AEG) regime is still evolving and members of the community are working to respond to a number of important and dynamic environmental pressures (Sánchez & McIvor, 2007).

Full and open information exchange is a central principle and set of processes within the AEG domain. As the domain evolves and strives to develop a coordinated information system to support regime objectives, community members are faced with challenges related to information exchange in a distributed and heterogeneous domain. To establish a coordinated system will require the ability to find information and to ensure that, once found, information from disparate sources can be effectively integrated in a way that allows for evaluation of information resources in terms of fitness for use and comparability among similar information resources. Ultimately, the objective is to establish an information system that supports environmental monitoring across

environmental regions, which will in turn support environmental governance activities (Personal communication, Ewan McIvor – Australian representative to Committee on Environmental Protection, Dec 7, 2007, Bush, 2000).

The AEG domain is distributed, multi-level and heterogeneous. The domain draws on information from a variety of communities including international law, science, logistics and operations and environmental management to name a few. The diverse nature of the domain presents challenges in terms of information exchange. Moreover, the fact that there is no central government for the Antarctic means that efforts to develop environmental information systems are collaborative, negotiated and are typically funded and implemented by individual members of the domain. Because the various individuals and institutions involved do not necessarily share methodological, theoretical or technical foundations or infrastructure, many different forms of information resources can and do exist resulting in both rich and diverse information stores from one perspective, and potential barriers to interoperability from another perspective.

Interoperability can be described as a situation where data and operations can easily shared and individuals do not require product specific expertise to use a given software system (Goodchild et al., 1999a). Interoperability challenges are not unique to the AEG domain or the South Polar Region as a workshop addressing the establishment of information systems for the current International Polar Year has identified (Parsons, 2006). It is in the area of addressing problems of interoperability that the interests of the

AEG domain and the discipline of Geography intersect. Addressing problems of interoperability of geographic information systems has been a research focus within the discipline for more than a decade (Goodchild et al., 1997a). The following section elaborates on issues related to interoperability and some implications for the AEG domain.

1.4 Antarctic Environmental Governance and Geographic Information – The Challenge of Interoperability

Impediments to interoperability can occur at several levels within an information system and are related to some form of information heterogeneity. Syntactic interoperability relates to the basic way in which information is represented in a system. Syntactic heterogeneity can cause problems exchanging information between different computer operating systems or multi-lingual character sets for example. Schematic heterogeneity is related to how information, typically in database form, is structured (hierarchies, attribute structures etc.). Semantic interoperability relates to the ability to effectively exchange meaning between information systems and is typically the result of differences in the assignment of symbols to referents (see Section 4.2.6). Many effective strategies have been developed to address syntactic interoperability as evidenced by the ability to exchange information across operating systems and translate between multilingual file encodings. Similarly, if data models are well understood, computer algorithms can effectively restructure data. Semantic interoperability has been identified as a particularly difficult objective to achieve in the broader realm of information systems (Berners-Lee et al., 2001) and specifically in relation to geographic information systems

(Goodchild et al., 1999a). Semantic interoperability is a very active area of research in the field of Geographic Information Science (Agarwal, 2005; Bishr, 2006; Schuurman & Leszczynski, 2006; Tomai et al., 2007; Lemmens, 2008). Central to efforts promoting semantic interoperability is the concept of *semantic mediation* in which machine-based mediators dynamically resolve semantic conflicts to integrate information among different, typically distributed, information systems. Mediator components use various information processing and logical inference techniques that typically operate on a descriptive model that makes assertions about the various information resources. This declarative model is known as a formal ontology.

The general study of ontology and the more specific study and application of formal ontology are proposed as an approach to addressing the problem of semantic interoperability. A more detailed discussion of ontology and formal ontology is provided in Chapter 4 of this thesis. In summary, analysis of the particular world-views of information communities can be formalized and modelled within an information system. This model, called a formal ontology, can then be used for inferential reasoning to support a number of information system tasks including information discovery, semantic translation and complex modelling. Thus, semantic interoperability developments in the geographic information domain (including technology, methods and theory) have the potential to facilitate more effective information exchange in the AEG domain. However, developing a semantic interoperability strategy based on formal ontology requires an understanding of the theoretical, methodological and technological details and

nuances of the field. Developing a consistent, complete and expressive formal ontology is a complex undertaking potentially requiring a collective effort by stakeholders (Noy & McGuinness, 2001; Schuurman, 2006).

In addition to theoretical, methodological and technical considerations related to implementing a formal ontology, there are philosophical, social and political implications to adopting a highly formalised approach. Due to the computer-based information technology environment underpinning GIS and distributed systems, a formalist approach is often used to model information and frame problems. This can present difficulties when trying to consider environmental problems that are heterogeneous, diffuse and/or involve multiple perspectives meeting at the intersection of human and physical domains, if such a distinction can still be made (Castree, 2001; Schuurman, 2004:31-32; Ahlqvist *et al.*, 2005; Castree, 2005). Additionally, the recognized difficulty in dealing with space-time in geographic information modelling systems (Peuquet, 1994; Wachowicz, 1999; Peuquet, 2001; Raper, 2005) contributes to the challenge. Although not the focus of this thesis, these issues are discussed in more detail in chapters 3 and 4.

The previous sections provided context with the purpose of situating ‘information’ within environmental governance, described the AEG domain and provide an overview of the possibilities and challenges related to improved interoperability in the AEG domain. The next section establishes the specific objectives of the thesis and a discussion of the methods used.

1.5 Thesis Objectives and Methods

This thesis has three key objectives that are addressed in subsequent phases of the thesis. Phase I (chapters 2,3,4) synthesizes literature through review, Phase II (Chapter 5) critically analyzes AEG documents to identify opportunities and constraints related to developing an AEG formal domain ontology. Phase III (Chapter 6) makes a theoretical contribution through the presentation and development of the concept of *geographic mediation*.

1.5.1 Phase I

The first objective is to provide the AEG domain community with an improved and critically informed understanding of the emerging theories and practices related to geographic information interoperability in general and semantic mediation using formal ontology in particular. The literature has identified that even within academia, the concepts surrounding formal ontology can be unclear and difficult for non-experts to comprehend (Winter, 2001; Hunter, 2002). Although formal ontology and semantic mediation (an important theme explored in this paper) are becoming well known to geomatics practitioners and scholars as ways to promote semantic interoperability, many potential end-users (i.e. scientists, policy makers) do not know how these methods and technologies can or should be applied in their domains. In several years of interacting with members of the polar science and policy community I have often been asked questions such as: How can our community use new technologies to support more effective information sharing? What is a formal ontology? What will a formal ontology do for me? If I see the development of a formal ontology as beneficial to me, how would

I go about constructing one while maintaining focus on my chosen field (e.g. biology, geology)? Thus, the first objective of this research is to, through review, synthesize a broad range of literature related to semantic interoperability and present the material in a way that is useful to members of the environmental governance community. This review can provide the basis for further dialogue with respect to developing interoperability strategies. To support the achievement of Objective 1, the following thesis question is posed:

- 1) What are the possibilities and implications for applying emerging approaches to geographic information interoperability (i.e. semantic mediation) to facilitate improved information sharing in the context of the Antarctic Environmental Governance domain?

1.5.2 Phase II

As is established in Chapter 4, developing a formal ontology requires the establishment of a shared set of terms and associated meaning. Efforts to establish a formal semantic model of Antarctic geography have already begun in the form of a general geographic domain vocabulary for the Antarctic called the SCAR Feature Catalogue (SCAR FC) (SC-AGI, 2008). The SCAR FC was originally conceived as the foundation for a formal ontology to be used by those developing information systems for the Antarctic region (Brolsma & Ryan, 2002). In theory, this shared geographic vocabulary can be used to develop a formal ontology for the AEG domain. What has not yet been established is

whether the SCAR FC is consistent (provides semantic agreement) and complete (all concepts are captured) with respect to AEG regime semantics.

Thus, the second objective of this thesis is to analyze the SCAR FC for consistency and completeness with respect to established domain semantics of the AEG domain. Due to the geographically distributed location of stakeholders, performing focus groups or other such face-to-face approaches to analysing AEG domain semantics was beyond the scope of this research. As a starting point, the body of documents that report the results of the ATCM (henceforth the ATCM corpus) was selected as a representative sample and were analysed using a content analysis approach. The methodology was built on Krippendorff (2004) and Kuhn (2001) and is explained in more detail in Chapter 5. To support the achievement of Objective 2, the following general thesis question is posed:

(2) Is a general domain vocabulary for Antarctic geography (i.e. SCAR FC) consistent and complete with respect to a vocabulary of the AEG domain as established through content analysis of the ATCM corpus?

This question is addressed by testing several hypotheses as described in detail in Chapter 5.

1.5.3 Phase III

While formal ontology and semantic mediation provide possibilities for improved semantic interoperability, these constructs and processes do not exist in isolation but are

coupled with information resources (e.g. databases, sensor feeds), transformative analytical processes (e.g. scientific models) and user interfaces (e.g. Web sites, cartographic applications). Objective 3 of this thesis aims to place approaches to interoperability, including semantic mediation processes, in an application context so as to provide the reader with a holistic system design pattern. To guide this discussion, the third and final thesis question is posed:

- (3) How might emerging approaches to interoperability be applied to an end user application, including geographic information mediation, within the AEG domain?

While Objective 1 aims to synthesize literature through review and Objective 2 uses an analytical approach to establish domain vocabulary, Objective 3 integrates the results of Objectives 1 and 2 to develop an abstract model of information system designed using a conceptual framework termed *geographic mediation*. *Geographic mediation* is an integrative concept that considers the human actors and machine-based elements involved in the design, operation and use of an information system. Moreover, the *process* of mediation is seen as central to the concept as the agents of mediation (mediators) are. It is argued that an integrative, dynamic and theoretically informed practice is necessary if we are to develop information systems that provide meaningful information to a wide variety of users. In considering contemporary interoperating geographic information systems, understanding formal ontology and semantic mediation is increasingly necessary if integrative, dynamic and theoretically informed practice is to be achieved.

CHAPTER 2. ANTARCTIC ENVIRONMENTAL GOVERNANCE

2.1 Introduction

Before presenting the reader with the details of various approaches to interoperability and the results of analyses and integration, the AEG domain is reviewed to provide historical context and a sense of the information needs of actors and applications within the domain. Some ideas presented here are expanded in subsequent chapters, however, they are presented here to explain the necessity of understanding the physical, environmental, social and historical context in which information is created and used.

After providing some historical and operational context, this chapter provides an overview of how geographic information is implicated in AEG activities. The chapter concludes by introducing how emerging approaches to mediating geographic information may facilitate more effective information exchange.

2.2 A Brief History of Antarctica

2.2.1 Terra Incognita Australis

Before the 18th century, Antarctica was simply a concept. It was deduced that a Southern continent would need to exist to counter balance the known ice cap of the Arctic. It was

not until advancement in marine navigation supporting long-distance ocean voyages that the actual existence of the continent was confirmed. The subsequent period of exploration become known as the Heroic Era of exploration.

2.2.2 Heroic Age of Exploration (1770 – 1915)

From the period 1770 – 1915 a number of exploration and commercial expeditions to Antarctica gradually revealed the geographic detail of the continent. Early expeditions simply involved sightings of the continent while latter journeys involved landings on the continent. As marine expeditions advanced, a number of terrestrial explorations were carried out. Some ended in conquests such as the arrival at the South Pole by Roald Amundsen. Others, such as Scott's contemporary last expedition ended in tragedy. Towards the end of the heroic era, curiosity and exploration turned to territorial interest and thus the imperialist era began.

2.2.3 The Imperialist Era (1908 – 1950s)

As the Heroic Era of exploration drew to a close in the early 20th century, nation states attempted to establish sovereignty over sections of the continent through the establishment of territorial claims. Claims were related to the establishment of national priority (colonial powers) and desire to exploit resources. The United Kingdom started territorial claims (1908) followed by New Zealand (1923), France (1923), Australia (1933), Norway (1939), Chile (1940) and Argentina (1943). The U.S.A. has not made a formal claim - nor do they recognize claims by other nations - however, in 1939,

president Roosevelt voiced the perceived right and possible intention to do so (Moore, 2004).

The years following the Second World War saw a flurry of scientific station building activity by Britain, Chile and Argentina as well as some tensions between these nations. In 1948, armed warships were sent to the region by Britain and Argentina. In 1952, while the Argentinean troops rebuilt Hope Bay station - which was destroyed by a 1948 fire shots were fired by Argentinean troops over the heads of U.K. personnel. The sub-Antarctic islands region has also seen conflict related to these claims. The Falklands-Malvinas war of 1982 is a recent example of disputes related to sovereignty claims in the South Polar Region of the globe. As illustrated in Figure 2.1, claims are based on a sector theory - scribed territorial boundaries extended to the South Pole similar to the 'slicing of a pie'. These claims were based on discovery and a sufficient display of authority in the sector claimed.

The development of the Antarctic Treaty in 1959 provided a method to manage but not resolve territorial claims. The Antarctic Treaty deals with claims through deferral as follows:

"Article IV: No acts or activities taking place while the present treaty is in force shall constitute a basis for asserting, supporting or denying a claim to territorial

sovereignty in Antarctica or create any rights in Antarctica". (Antarctic Treaty, 1959)

This approach, originally championed by Prof. Julio Escuerdo of Chile to prevent territorial issues from interfering with scientific research, has become central to the Antarctic Treaty System (ATS). The geopolitical stability afforded by the Antarctic Treaty has facilitated the cooperation necessary to develop the comprehensive environmental protection regime established in subsequent years.

Figure 2.1 Antarctic territorial claims

The International Geophysical Year (IGY) (1957-58) was a program of intensive global scientific observations expanding the model established in the first International Polar Years of 1882-1883 and 1932-1933. Leading up to and during this period, a number of new Antarctic research stations were built including the American South Pole station and Britain's Halley Research Station. The unprecedented success of the IGY in terms of fostering international scientific collaboration was the impetus for the development of the Antarctic Treaty.

2.2.4 1959 – Present – The Antarctic Treaty Regime - Towards International Stewardship

Territorial disputes, cold war tensions and the success of the International Geophysical Year (IGY) (1957-58) led to the organization of a conference in Washington D.C. that resulted in the signing of the Antarctic Treaty on December 1, 1959. In this treaty, the original 12 signatory nations (Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, USSR, South Africa, United Kingdom, United States of America) formalized a set of values into a document, which, although legally binding, is vague enough to allow individual parties room for negotiation. Thus, the treaty is a framework that revolves around negotiation and consensus-based decision-making. Decisions are made at a now annual (formerly bi-annual) meeting called the Antarctic Treaty Consultative Meeting (ATCM).

The treaty document is focused on a number of themes, including:

- Ensuring activities dedicated to peaceful purposes
- Facilitation of scientific research
- Suspension of territorial claims
- Exchange of information
- Preservation and conservation of living resources

Through the work of the ATCM, the themes, values and procedures related to the treaty have been developed throughout the ensuing decades. In keeping with the focus on scientific research and cooperation, the science community in the form of the Scientific Committee on Antarctic Research (SCAR), which was established during the IGY, was formally recognized for its role in advising the ATCM (ATCM I, 1961). This is an important development, in that it formally links the science community to the policy community.

It is important to note that, from its inception, the Antarctic Treaty System has used a combination of formal International law and 'soft law' approaches (e.g. resolutions) outlining instruments without binding force to establish normative practices rather than promulgating international law in all cases.

The primary focus of the AT was on establishing Antarctica as a reserve for peaceful uses, particularly scientific study. This makes sense when one considers the historical context described (following the IGY, during the cold war). Although some environmental concerns are implied, with the exception of Article IX(f), very little detail

is established in terms of environmental themes. However, Article IX(f) provided flexibility for interpretation and elaboration that was used to build on environmental themes throughout the 1960s, 70s and 80s and beyond. The treaty procedures support expansion through the development of additional instruments and several instruments have been established since the ratification of the treaty in 1961. These instruments create a cluster of sub-regimes with all sub-regimes linked with common goals, norms and procedures to the Antarctic Treaty and each sub-regime (Joyner, 1998:97). The instruments have primarily dealt with the issues of environmental governance including pressures on the environment related to resource extraction and other human activity.

Sub-regimes – The Development of the Antarctic Treaty System

Soon after the ratification of the Antarctic Treaty in 1961, the attention of the ATCM turned to matters of environmental governance – specifically, the preservation and conservation of living resources. The 1964 ATCM resulted in the first extension of the Antarctic Treaty with the development of the Agreed Measures For The Conservation Of Antarctic Fauna And Flora (ATCM III, 1964). The Agreed Measures, as they are known, were an early attempt at establishing norms around the preservation and conservation of living resources in the Antarctic Treaty area. The document presents concepts such as *rational use* of resources while establishing Antarctica as a special conservation area. The Agreed Measures also establish methods for enforcement and reiterate the role of SCAR as the primary scientific advisor to the ATCM.

An increase in international sealing activity in the 1960s led the ATCM to become concerned about the potential for sealing in the Antarctic region. The Agreed Measures had jurisdiction on the continent and ice shelves but not in the oceans of the Treaty Area. Responding to this concern, the ATCM held in London drafted the Convention On The Conservation Of Antarctic Seals (1972). The convention recognizes concerns around the over-exploitation of seals and establishes a regulatory framework for the rational and humane harvesting of seals in the area. As with the Agreed Measures, SCAR is formally established as an advisor with regard to monitoring and evaluating the status of seal populations.

The most comprehensive conservation instrument developed to that point in the history of the ATS was the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) (CCAMLR, 1980). This convention gives priority to the concept of conservation through management of the Antarctic marine ecosystem. Unlike other instruments, this convention is defined by the Antarctic Convergence (an oceanographic feature) rather than the political boundaries of the Treaty area. In terms of procedures and implementation, the convention established a commission, scientific committee and a secretariat. In contrast to the previously discussed instruments, CCAMLR explicitly addresses the relationship between the convention and territorial claims by establishing Article IV, Territorial Sovereignty and Coastal State Jurisdiction. CCAMLR's Article IV establishes that Articles IV and VI of the Antarctic Treaty bind all contracting parties, regardless if they are parties to the Antarctic Treaty. This effectively suspends territorial

claims within the region. Thus, the adoption of CCAMLR represented a significant development in terms of the evolving complexity and breadth of the AEG domain. Comprehensive legal instruments along with regulatory bodies and information gathering strategies emerged from CCAMLR.

In response to technological advances in polar mineral exploration, as early as 1972 the ATCM formally addressed the need to study the potential effects of mineral resource exploration in the Antarctic region. This initiative ultimately resulted in the signing of the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) (CRAMRA, 1988). This convention was developed over the course of many years and, in 67 articles and related annexes, provided a comprehensive legal and administrative framework for prospecting, exploration and development of mineral resources in the Antarctic region. The instrument laid out a series of processes related to evaluation of the feasibility of activities and the potential environmental impacts. The ATCM adopted CRAMRA and it was opened for signature in November of 1988. In the spring of 1989, France and Australia announced that they would not sign CRAMRA. In addition, New Zealand, who had already signed CRAMRA, indicated that it would not ratify the convention. This became known as the “CRAMRA crisis” (Vidas, 2002). The crisis happened amidst a series of international voices that proposed that Antarctica be given World Park status under the UN (May, 1989). In addition, this was a time of increasing environmental awareness that developed between the UN Conference on the Human Environment (Stockholm, 1972) and the UN Conference on Environment and

Development (Rio de Janeiro, 1992). During the mid-1980s, concerns were also being raised by developing nations about the seemingly 'closed' nature of the ATCM and the potential equity of the developing CRAMRA regime (Berkman, 2002:73). Although CRAMRA is still officially an active convention in the process of being ratified, it is currently politically and legally inert (Joyner, 1996:78).

In the wake of the CRAMRA crisis, a number of nations suggested the development of a comprehensive environmental protection system for the Antarctic. The Protocol on Environmental Protection to the Antarctic Treaty, typically referred to as the Madrid Protocol was adopted at the ATCM in October of 1991 after three specially convened meetings held in November of 1990 and April and June of 1991. The Madrid protocol is a comprehensive, multilateral environmental instrument that, in some regards is a complete reversal from the direction taken in CRAMRA. The Annexes to the protocol address a number of issues including: Environmental Impact Assessment, Waste Disposal and the Antarctic Protected Areas system. While some point out that the adoption of the Madrid protocol was rushed (Vidas, 2002) due to various political pressures (e.g. Greenpeace, 2008), nevertheless, having been legally appended to the AT, it provides a foundation for environmental governance within an environmental protection paradigm.

The Madrid Protocol came into force on January 14, 1998 and in doing so, established a comprehensive environmental protection regime for the Antarctic region. The primary

advisor to the ATCM on matters related to the protocol is the Committee on Environmental Protection (CEP) (<http://cep.ats.aq/cep/>) (Sánchez & McIvor, 2007). The CEP advises the ATCM on the protocol and the five annexes of the protocol while working with a number of observers including the Scientific Committee on Antarctic Research, the Council of Managers of National Antarctic Programs, the International Association of Antarctic Tour Operators, United Nations Environment Program and a number of others. Since its establishment in 1998, in addition to providing advice to the ATCM, the CEP has achieved a number of goals including a series of advice papers for Antarctic operators, improved committee operating procedures, and adoption of new information technologies (Sanchez and McIvor, 2007). While the CEP has been a productive entity, it faces a heavy workload in the near term related to increasing environmental pressures (see next section). An important aspect of addressing these challenges is the development of effective and efficient information exchange practices (personal communication, Ewan McIvor, 13 Dec 2007).

2.3 Environmental Pressures

The Antarctic region is complex and the continent and the surrounding ocean are critical components of the global environmental system. The area is remote and in some respects a pristine wilderness. On the other hand Antarctica is particularly vulnerable to the effects of global environmental change and is increasingly a tourist destination. Changes in technology are enabling increased access to the continent and the surrounding ocean. This is presenting opportunities in terms of better understanding the local and regional environmental systems and the linkage of processes operating at these scales to the larger

global system. At the same time, this increased access is threatening to damage or destroy several valuable aspects of the region, including: the value of the continent as a relatively undisturbed region which can act as a baseline for evaluating global environmental change; the habitat of local, sometimes endemic species; the ecosystem which supports various species; historically significant entities; the less tangible aesthetic value of the area. A number of human activities are seen to have an impact on the environment including activities related to science, tourism, resource extraction and global environmental change.

Antarctic Science

Antarctica is often referred to as the continent of science. Since the mid-twentieth century, much of the activity there has been related to scientific research. As questions about global environmental change become central to the discourse of many disciplines and we become interested in phenomena such as global warming, ozone depletion, habitat degradation, decreasing biodiversity etc., scientific activity in the Antarctic region continues to expand. As a case in point, the ongoing International Polar Year (2007-2009) has an aggressive Antarctic-focused research program. The IPY initiative builds upon the past activities carried out under the International Geophysical Year. Science is the primary human activity in the Antarctic, and the data, information and knowledge produced by this activity can currently be seen as the primary resource or output coming from the region. As with any resource extraction activity, the act of science results in human impact on the environment. Scientific bases produce waste and have a footprint as do fieldwork and other scientifically related activities.

Antarctic Tourism

Tourism in the Antarctic region is increasing. Decades ago, very little existed in the way of tourism due to the high costs and the challenges of accessing the area. Due to a decrease in the cost of air travel and increased availability of adequate vessels, Antarctica has become more accessible to tourists. The International Association of Antarctic Tour Operators (IAATO) estimates that the number of ship and land based tourists increased from approximately 6,500 in 1992 to approximately 29,000 in 2006 (International Association of Antarctic Tour Operators, 2008). This significant increase in the number of tourist must be considered in terms of the current environmental protection regime.

Resource Extraction

Although remote and harsh, the Antarctic region presents much in the way of resources. Key resources extracted to now have been living resources such as seals, whales and fish. Over the course of the 19th and 20th century some stocks were destroyed. While there is currently a moratorium on mineral extraction through Article 7 of the Madrid Protocol, Article 27(5a) (ATCM XVI, 1991) suggests that the protection afforded is not indefinite or absolute:

a. With respect to Article 7, the prohibition on Antarctic mineral resource activities contained therein shall continue unless there is in force a binding legal regime on Antarctic mineral resource activities that includes an agreed means for determining whether, and, if so, under which conditions, any such activities would be acceptable. This regime shall fully safeguard the interests of all States referred to in Article IV of the Antarctic Treaty and apply the principles thereof. Therefore, if a modification or amendment to Article 7 is proposed at a Review Conference referred to in paragraph 2 above, it shall include such a binding legal regime.

Bioprospecting is the most recent resource issue in the region that needs to be addressed by the AEG regime (Weber , 2006). Bioprospecting is “the search for and sourcing of organisms from the natural environment with the purpose of extraction of compounds for further investigation of their potential for development in therapeutic or industrial applications” (Jones, 1998:89). Currently, bioprospecting is not addressed in the Madrid Protocol or other ATS instruments.

Global Pressures

In addition to the local and regional pressures related to science, tourism and resource extraction activities, the Antarctic region faces pressure from a number of global phenomena. Specifically, global warming could potentially have a significant impact through the melting of ice shelves, glaciers and possibly continental ice sheets, which in turn could have the global effects of raising sea levels. Another global phenomenon is the well-documented ozone hole above the Antarctic caused by the use of Chlorofluorocarbons (CFCs). As the Southern Ocean is part of the global ocean, global marine pollution is also a consideration for the AEG regime. Although the pressures related to these phenomena are global, they can also have local effects negatively impacting, for example, microorganisms that in turn can affect the entire Antarctic trophic system.

2.4 Environmental Protection, Conservation and Management

In an attempt to support the principles of conservation and the management of the impacts related to global and local human activity, a comprehensive legal and policy regime has evolved around Antarctic environmental protection. Protection implies a defence against harm or danger or activities that reduces losses or risks while maintaining basic conditions and values. Environmental Protection does not necessarily imply environmental *preservation* that can be defined as the isolation of natural resources to prevent the use of or contact by humans.

On the whole the AEG regime adopts a conservation approach to environmental protection. Conservation is characterized by management, rational or sustainable use and restoration of natural resources and the environment to ensure long-term survival (Park, 2007:95). Conservation aims to prevent activities or development that would destroy habitat while respecting natural environmental variations.

The Madrid Protocol defines conservation by reference to CCAMLR that established principles of conservation CCAMLR (1980) (Article II) as follows:

- 1. The objective of this Convention is the conservation of Antarctic marine living resources.*
- 2. For the purpose of this Convention, the term 'conservation' includes rational use.*

3. *Any harvesting and associated activities in the area to which this Convention applies shall be conducted in accordance with the provisions of this Convention and with the following principles of conservation:*

- a. prevention of decrease in the size of any harvested population to levels below those which ensure its stable recruitment. For this purpose its size should not be allowed to fall below a level close to that which ensures the greatest net annual increment;*
- b. maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in subparagraph (a) above; and*
- c. prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effect of the introduction of alien species, the effects of associated activities on the marine ecosystem and of the effects of environmental changes, with the aim of making possible the sustained conservation of Antarctic marine living resources.*

To respect and promote the principles as set out in the regime, the Madrid Protocol establishes a series of environmental management practices that include inspections, Environmental Impact Assessment, waste management, pollution prevention measures, a protected area system (later added as Annex V) and a strong exchange of information component. These management approaches bring with them a particular set of norms, rules and procedures.

2.5 The Role of Information in Antarctic Environmental Governance

Information is central to the operations of the AEG sub-regime. Effective environmental governance in an area requires knowledge of the environmental region and associated regions. The environmental governance and management model adopted within the

Antarctic regime is based on knowledge of initial and projected states of the environment, and modeling of future environmental states including possible impacts of activities at a variety of levels and time scales. This also includes gap analysis and establishment of levels of uncertainty. To support these requirements, a variety of information resources are necessary.

For example, information is the foundation of environmental impact assessment. If the assessment supports moving forward with a particular activity or development, then environmental monitoring information is required to evaluate the activity against the impact assessment and subsequent management plan. Similarly, emergency response situations require a wide variety of information that may include operational information such as ship, vehicle and equipment locations and characteristics.

Although the AEG sub-regime establishes principles, norms and procedures, the resources allocated for permanent institutions are limited. There exists a small secretariat for the Antarctic Treaty System (<http://www.ats.aq>), however, national institutions of parties to the Antarctic Treaty fund members of the CEP. For example, in Canada, Environment Canada participates in CEP activities. Enforcement operations are also carried out and funded by national bodies. Information is constructed by national bodies in association with organizations such as SCAR, CCAMLR, the Council of Managers of National Antarctic Programs (COMNAP), IAATO and others. As a result of this model of distributed effort, the principle of the free and open exchange of resources (including

personnel, infrastructure and information) is central to the ATS regime and, as such, is formalized in the Antarctic Treaty (1959) (Article IV).

Article IV

[International Cooperation]

1. In order to promote international cooperation in scientific investigation in Antarctica, as provided for in Article II of the present Treaty, the Contracting Parties agree that, to the greatest extent feasible and practicable:

- a. information regarding plans for scientific programs in Antarctica shall be ex-changed to permit maximum economy of and efficiency of operations;*
- b. scientific personnel shall be exchanged in Antarctica between expeditions and stations;*
- c. scientific observations and results from Antarctica shall be exchanged and made freely available.*

While exchange of resources holds the promise of maximizing efficiency and regime effectiveness, the goal brings with it a number of challenges, particularly in the area of information exchange.

2.5.1 Information Exchange in the Context of the AEG Domain

The principal of free and open “information exchange” pervades the AEG regime. The Antarctic Treaty System (ATS) community has an interest in information exchange with the principle of free exchange of scientific information being codified within the aforementioned Antarctic Treaty in Article IV 3(c). Soon after the AT’s entry into force in 1961, the concept of information exchange is elaborated to explicitly include scientific data. Recommendation II-I of the 1962 ATCM (ATCM II, 1962) states:

[Exchange of scientific data]

The Representatives recommend to their Governments that, in accordance with Article III of the Antarctic Treaty and in the light of recommendations made by SCAR, they take measures contributing to:

- 1. The completion by 1st July 1963, or as soon thereafter as practicable, of the transmission by scientific organizations to the recognized international data gathering centres of scientific observations carried out in Antarctica from 1957 until 1959 inclusive, and 1960 if possible.*
- 2.*
 - a. The free availability and exchange, by all appropriate means, of scientific observations and results, in every scientific discipline, obtained by expeditions in any part of Antarctica;*
 - b. the prompt transmission, preferably within a year of the receipt in each country of the data from Antarctica, of such observations and results to the recognized international data gathering centres, where such centres exist.*
- 3.*
 - a. The free availability of published results of Antarctic research carried out since the beginning of the International Geophysical Year;*
 - b. the transmission to the recognized, international data gathering centres, before 1st July 1963, of such publications already issued;*
 - c. the transmission to these centres of future publications within two months of their issue or as soon thereafter as practicable.*

This principle of full and open information exchange not only has practical aspects in terms of supporting efficient and effective operations in the region, it also aligns with the overall ‘open’ approach to governing the region through the AT regime. Information exchange is seen as a key promoter of cohesion within the regime as stated by Joyner (1998:51):

“Scientific research and the exchange of that information are the foundation stones for the ‘commonness’ of Antarctica, and they provide the cardinal motive for governments to cooperate in the region”

Further, Berkman (2002:221) proposes that science and scientific information and knowledge are an important and central component for developing Antarctic environmental and resource policies. While some point out the difficulties of establishing an effective science-policy link (see Owens, 2005), Berkman convincingly argues that the effectiveness of the science and policy link in the Antarctic domain can act as a model for other contexts.

Thus, information exchange has many perceived and realized benefits in the ATS context. However, since the ratification of the Treaty in 1961, there have been many significant changes in the larger domain of information and information exchange. Digital computers and the Internet have revolutionized how we collect, store, analyse, display and exchange information. As information systems change, there is an increasing need to modernize the process of information exchange and sharing in the Antarctic context (ATCM XXVIII, 2005b). The recently established Antarctic Treaty Secretariat which has made important advances in making materials related to the treaty available is now leading this effort. Other initiatives such as the Antarctic Treaty Searchable Database project (Berkman et al., 2006) (<http://aspire.tierit.com>) are using advanced technology and information processing techniques to provide powerful tools supporting the analysis of documents related to the ATS. These activities are concurrent with the development of Antarctic information infrastructure including the Antarctic Master Directory (JCADM, 2007) and the Antarctic Spatial Data Infrastructure (SC-AGI, 2007).

While various elements of an Antarctic information infrastructure are being developed to facilitate the exchange of scientific information, integration with the Antarctic environmental protection regime are in the early stages of development making this research a timely effort.

An examination of the ATS corpus reveals many other instances demonstrating the value placed on information exchange and the policy established to facilitate it. Considering the overarching reasons for information exchange, we can infer that this exchange must involve shared understanding between participants. This is different than exchange for the purpose of archiving, for example, where the goal is simply to preserve the information. The requirement for shared understanding stems from the need for the information to be understood and utilized for the advancement of science, policy and environmental protection. Henceforth, the concept of information exchange will assume the need for information sharing through shared understanding.

The requirement for shared understanding can present a significant challenge when working in a heterogeneous and distributed domain as is the case in the AEG domain. Berkman and others propose that “information has three indivisible elements – content, context and structure – that together provide meaning” (Berkman *et al.*, 2006:85). Assuming multiple instances of the same type of information content in need of exchange (e.g. environmental monitoring information), Berkman *et al.*’s model suggests that different information contexts and/or information structures can affect meaning or

interpretation. Conversely, information with identical context and structure but qualitatively different content will obviously affect meaning and thus shared understanding.

The ability to exchange information is also related to the 'level' of information involved. As introduced in Chapter 1 and elaborated in Chapters 3 and 4, information can be theorized as a continuum that can be interpreted as having multiple tiers. While the number of tiers varies, the general model that emerges is typically referred to as the "knowledge" or "information pyramid", where various processes can funnel large amounts of data to smaller amounts of information, knowledge and wisdom as follows:

Data:	observation, symbols
Information:	data that are processed to be useful; provides answers to "who", "what", "where", and "when" questions
Knowledge:	application of data and information; answers "how" Questions
Understanding:	appreciation of "why"
Wisdom:	evaluated understanding.

after (Ackoff, 1989, Bellinger *et al*, 2004)

Eddy and Taylor (2005) provide a model that reflects this segmentation and applies it to a contemporary geographic information-processing context. Eddy proposes primary, secondary and tertiary levels. Each level is characterized by a number of categories, however, to frame our discussions here, typical outputs are presented

<i>Level</i>	<i>Output</i>
Primary	Primary geospatial data collection e.g. filed to computer, GPS, remote sensing observations, in-situ sensor
Secondary	Specialized models and applications framed within the context of a given theoretical framework
Tertiary	Educational, mass communication, policy support information framed according to its higher level meaning in a given context

Table 2.1 Building on Eddy's information levels. After (Eddy 2005:55-56) with additions from author

This model might be applied to the AEG domain as follows:

<i>Level</i>	<i>Example Information</i>
Primary	Air temperature measurement
Secondary	Glacier mass balance model
Tertiary	Report on the status of glaciers to policy body

Table 2.2 Applying Eddy's information levels to the AEG domain

The AEG process uses information at all levels. By definition, many environmental indicators are based on primary level resources (e.g. temperature, marine species catch counts). Other useful primary level resources include satellite remote sensing coverages, basic topographic data, marine survey data (e.g. multibeam sonar, physical oceanographic) etc.. Various activities related to AEG require processed, secondary information in the form of maps, models etc.. Tertiary level information in the form of advisory reports and similar information is also important in the AEG domain.

The importance of the cited concepts and theories to our discussion of AEG information exchange is that the models suggest that information from different levels cannot be directly exchanged and that the ability to exchange between levels is unidirectional. Primary data can be processed to create secondary information, however a tertiary resource cannot be de-synthesized to create secondary or primary information. While this seems obvious, the implications are profound when discussing information exchange. This infers that designing and developing information systems in the AEG domain requires consideration of both ‘bottom’ (primary level), ‘top’ (tertiary level) and intermediate (secondary level) information requirements. Thus, an interoperable system designed to provide meaningful information to a wide variety of end users cannot provide dominant privilege to a ‘top down’ or ‘bottom up’ design perspective.

A more detailed discussion of information theory is presented in subsequent chapters. At this stage, it is important to note that information that is part of the AEG domain has different forms and characteristics that will have implications for how it is managed, exchanged and used by various members of the community. The subsequent section briefly elaborates on the type of information of primary interest in this thesis – geographic information.

2.5.2 Geographic Information in the Antarctic Environmental Governance Domain

In the context of Geographic Information Science, geographic information can be defined as any information that can be geographically referenced, i.e. describing a location or any

information that can be linked to a location on the earth (Goodchild, 1997b). In more general terms, geographic information can be defined as knowledge about where something is, or knowledge about what exists at a given location.

Using these definitions, much of the information produced by science in general and Antarctic science in particular can be considered geographic information. Antarctic operations (movement of people and goods, management of stations etc.) also use and produce geographic information. Geographic information is also used and produced in a variety of forms and at a variety of levels by the AEG domain.

Cordonnery (1999), provides a comprehensive discussion of the potential for using Geographic Information Systems to support the AEG regime. Three key areas of application are identified: environmental impact assessment, environmental monitoring and environmental management. Cordonnery also discusses the benefit of developing a coordinated, federated geographic information database to support environmental protection. Examples of federated databases such as Australia's ARIS and the European Union's CORINE system are outlined. Cordonnery's argument is that the use of GIS and coordinated data systems can support an approach to environmental decision-making by providing new tools to synthesize and analyze large amounts of spatial information.

Others are in the process of developing a *systematic environmental geographical framework* as called for in Annex V, Article 3(2) of the Madrid Protocol. This project is

using Environmental Domains Analysis to develop a regional environmental classification system for use in implementing the Madrid Protocol. This classification system will be released as data compatible for use in most GIS systems (New Zealand, 2007).

Due to the governance model for Antarctica, there is no central institutional organisation tasked with managing geographic information or knowledge for the area. There are however two SCAR groups tasked with facilitating the organisation, management and development of information produced by the science community. These groups are: The Joint Committee on Antarctica Data Management (JCADM) and The Standing Committee on Antarctic Geographic Information (SC-AGI). These groups act as an important link to various Antarctic communities of practice and support discovery of and access to a range of geographic information. Services include a catalogue of scientific data (<http://gcmd.gsfc.nasa.gov/Data/portals/amd/>), topographic information (<http://www.add.scar.org>), a composite gazetteer (http://www3.pnra.it/LUOGHI_ANT/SCAR_GAZE) and other local information resources (e.g. <http://www.kgis.scar.org>)

While both groups have been very successful in providing advice and services to the Antarctic community as a whole, both must address the difficult challenge of providing information resource to a wide variety of end users ranging from scientists to operations

personnel to policy makers. This can be seen as a challenge with regards to geographic information exchange.

2.5.3 Mediating Geographic Information

The current approach to mediating differences between information communities has been to establish standards related to information resources (e.g. categories describing scientific data, geographic feature names). The difficulty here is in establishing agreement between the communities. Even within the cartography and GIS community, there can be challenges in establishing consensus around meaning of terms and the structure of information. The following quote outlines some of the difficulties in aligning a geographical database (the Antarctic Digital Database - ADD) with a standardized list of geographic features (SCAR FC) established by SC-AGI:

A long-standing aim of the ADD has been to align the pre-existing data structure with the SCAR Feature Catalogue (FC)... Difficulties that have had to be addressed include semantic differences between the ADD and the Feature Catalogue, and a completely different set of assumptions concerning data organization.... In some cases, the correspondence between ADD features and Feature Catalogue Features is tentative; for example, the ADD uses "land" in the sense "not sea, ice shelf, ice rumple or ice tongue", whereas the Feature Catalogue relates the term to its use in place names (e.g. Wilkes Land). This type of issue has been raised with the maintainers of the Feature Catalogue.

Another issue is that in some cases the ADD carries more detail than is required by the Feature Catalogue, and in some cases attributes have been used that, although defined in the Feature Catalogue, are not required by the feature type in question.

(<http://www.add.scar.org:8080/add/whatsnew.jsp> - accessed Feb 2, 2008):

In this case, the difficulties are not necessarily insurmountable, however considerable effort can be expended in attempting to exchange information if many instances of the data are not considered or understood in designing the standards system. In the realm of

geographic information processing, these types of problems relate to interoperability.

Currently, the geographic information research community has established that the most challenging impediment to interoperability is the semantic component rather than the technical components of interoperability.

In this context, semantics are related to the meaning we assign to information and includes how we define data and information in systems. These ideas are elaborated upon in subsequent chapters. It is sufficient to state here that the problem of semantics has implications for the development of a comprehensive information systems for AEG. In the first instance – differing semantics can affect the ability to discover or find data. If one can manage to find information, problems related to structure and semantics arise in relation to how we effectively integrate data – how to make it compatible with other related resources.

The AEG domain stands to have significant challenges in attempting to completely standardize information exchange processes. Completely standardizing implies that all community members use the same syntax, structures, semantics, technology etc. The challenges to full standardization in the AEG domain include:

- Due to the non-mandatory nature of soft law approaches, imposition of standardization in terms of data systems, structure and semantics can be difficult if not impossible

- The lack of central institutions and the resulting distributed community results in a wide variety of technical platforms and system designs that, even in the event of standards adoption, can make the move to standardization costly
- Much of the information used in the AEG domain comes from practices such as science, the results of which may have very specific and inflexible information content and constructs
- High-level debates and conflicts around values and procedures exist within the AEG domain – e.g. what is the appropriate balance between conservation, resource extraction and human activities have existed for decades and are ongoing (e.g. Hemmings & Rogan-Finnemore, 2005). The dynamic nature of the domain can challenge attempts to standardize (see chapter 6)
- The use of different natural languages within the domain can make exchange difficult

Thus, in situations where full standardization is difficult or impossible to implement, the field of Geographic Information Science and the geomatics industry are developing and promoting a range of technical, methodological and theoretical solutions to interoperability that do not require complete standardization. A prominent and promising approach to addressing semantic interoperability is the process of semantic mediation using formal ontologies (explained in detail in Chapter 4). This thesis argues that, with adequate understanding of semantic mediation this approach can contribute to more effective information exchange within the AEG domain.

2.6 Conclusion

This chapter described a complex domain that is the result of decades of negotiations that have had to deal with historical tensions around territoriality, resource management and appropriate uses of the Antarctic region to name a few. A key result of these negotiations has been a comprehensive environmental protection regime as articulated in the Madrid Protocol and extensions (e.g. Annex V) since its adoption in 1991. The regime under the Madrid Protocol aims to manage a multitude of important and dynamic environmental pressures using a conservationist approach. Full and open information exchange is explicitly established as a principle and procedure that will support these regime goals. In an effort to understand and share information related to such a complex and nuanced region, one must ask what are the theoretical, methodological and practical tools available to assist in the task? This chapter provided an overview of some of the potential application uses for and sources of geographic information and identified some of the challenges related to exchanging geographic information. Moreover, the review has revealed the potential need for deeper levels of negotiation that go beyond the syntactical and schematic properties of information and moves into the semantic aspects of AEG information that are central to a semantic mediation approach. Subsequent chapters of this thesis contribute to addressing these questions by providing critical insight into the possibilities related to emerging machine-mediated approaches to geographic information exchange.

CHAPTER 3. DEVELOPMENTS IN THE GEOGRAPHIC INFORMATION DOMAIN

3.1 *Introduction*

This chapter provides a brief review of developments in the geographic information domain that are seen as particularly relevant to information exchange in the context of the AEG domain. Contemporary systems are built on technology, however the resulting technological constructs involve a multitude of actors, non-technological methods, usage contexts, activities etc.. This reality is increasingly being recognized in research and practice including, for example, undergraduate level GIS textbooks (e.g. Lo & Yeung, 2008) that outline not only the technology but also the need to evaluate the entire application domain. This review provides a high level discussion of interrelated concepts (technology, methodology, theory), some of which are further elaborated in subsequent chapters.

3.2 *Standardization*

In the early stages of development of the computer and the Internet, closed, proprietary data and software could result in the inability for different systems to exchange information or processes. There was a time in the not-so-distant past when a file created on a Macintosh computer could not be readily used by a computer using the Microsoft Windows operating system. Similarly, many Geographic Information Systems could not

read data produced by a system running another vendor's software. Standardization is quickly reducing these technical problems of interoperability. The Internet itself is a good example of standards in action. Information is transported over the Internet using a standard base protocol (TCP/IP) and additional specialized standard protocols for Web pages (http), encrypted Web pages (https), file transfer (FTP) and e-mail (SMTP) to name a few examples. As increasingly complex systems are developed, new standard protocols and syntaxes are being developed. The standards bodies most relevant to the geographic information domain are the World Wide Web Consortium (W3C) (<http://www.w3c.org>), the Open Geospatial Consortium (OGC) (<http://www.ogc.org>) and the International Organization for Standardization's Technical Committee 211 (ISO TC211) (<http://www.isotc211.org>).

The W3C is the standards body that deals with standards for the latest generation of Internet as a whole (World Wide Web, Web Services, RDF, OWL etc.). "The World Wide Web Consortium (W3C) is an international consortium where Member organizations, full-time staff, and the public work together to develop Web standards."(<http://www.w3.org/Consortium/>). Although the W3C does not develop standards specific to geographic information, the specifications and standards developed by the OGC and ISO TC211 are predominantly built on W3C standards.

The OGC is a member-driven, non-profit international trade association that is leading the development of geoprocessing interoperability and computing standards. The OGC is

working closely with the International Organization for Standardization's (ISO) Technical Committee 211 (TC211) towards establishing standards for geographic information and the geomatics industry. In general, ISO TC211 "aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth" (<http://www.isotc211.org>). OGC and ISO TC211 have a liaison relationship and, in some cases, OGC specifications evolve into ISO standards.

3.3 Distributed Systems

The advent and ubiquity of the Internet has provided a technical environment that supports distributing information and processing resources across networks. Data and processing resources no longer need to be federated and maintained at a central location by a central maintainer. This provides a number of benefits including the potential elimination of unnecessary copies of data (and the resulting consistency and maintenance issues) that are common in federated approaches. The ability for distributed systems to synchronize between nodes using networks means the inverse is also true. If desired, multiple copies can be effectively maintained at multiple locations to introduce system redundancy, minimizing the chance of service disruption and data loss. Distributed systems also support the sharing of computational resources providing processing power far exceeding the power of any single computer (see Section 3.9). Increasingly, a *Service Oriented Architecture* approach is being taken to developing these systems. This architecture uses messages exchanged by Web Services to achieve operational goals.

3.4 Web Services

A Web Service can be defined as a software system designed to support interoperable machine-to-machine interaction over a network. To facilitate communication between geographic information software agents, a Web Services development approach is increasingly being adopted within the geographic information domain. Generally, the term Web Service describes a standardized way of integrating Web-based applications over an Internet protocol backbone. Web services allow organizations to communicate data without users (human or software) needing detailed knowledge of how a given service is implemented. Standard interface protocols are established and responses to requests are delivered in a standard format. The interoperability specifications put forward by the OGC and ISO are based on a Web Services model. Some key examples of geographic information Web Services are (Open Geospatial Consortium, 2003b):

- *Web Map Service (WMS)*: Standardizes the way in which clients request and receive maps
- *Web Feature Service (WFS)*: Standardizes the retrieval and manipulation of geographic feature databases including the ability to INSERT, UPDATE, DELETE, QUERY and DISCOVER geographic features.

- *Web Coverage Service (WCS)*: The Web Coverage Service supports the networked interchange of geospatial data as "coverages" (imagery, rasters, DEMs etc.) containing values or properties of geographic locations.
- *Gazetteer Service*: The Gazetteer Service retrieves the known geometries for one or more features, given their associated identifiers (i.e. place name)

The OGC specifications for geo-processing interfaces largely eliminate the need for costly data conversion. A query returns not a whole data file, but only the "result," or the answer to the query, and thus the network model eliminates the need for users to keep (usually outdated) copies of whole datasets. In some contexts, these Web services can be seen as system agents.

3.5 Metadata

To facilitate the effective exchange of geographic information, the geographic information technology community has been promoting the use of metadata, or data about data, to describe geographic information resources. This approach attempts to allow users to understand the syntax, structure, semantics and production context of a given information resource by documenting the resource with well defined descriptive attributes. Currently, the ISO international standard 19115:2003 (ISO, 2003) is emerging as the dominant approach to developing geographic information metadata although there are a number of other prominent specifications including the *American Content Standard for Digital Geospatial Metadata* (Federal Geospatial Data Committee, 1998) and the

Directory Interchange Format (Global Change Master Directory, 1991). The Directory Interchange Format has been adopted for the Antarctic Master Directory, the central directory system containing all Antarctic data set descriptions gathered by National Antarctic Data Centres.

Metadata allows a producer to describe a dataset so users can understand the assumptions and limitations and evaluate the dataset's applicability for their intended use (Kim, 1999). Metadata aims to make explicit how data were collected, conceptualized, compiled, processed etc., and thus provides the opportunity to better identify perspectives related to a given dataset. However, it is important to note that metadata in an interoperable geographic information system context is usually codified using one or more national and/or domain specific standards. To some extent, these standards are well formed and control what is described and how, although some elements of a given metadata record – such things as data quality, completeness and lineage - are free form. Thus, an information community identifying needs with respect to metadata requirements must critically evaluate a metadata standard in terms of the *standard's* fitness for use. That is, does the “meta-language” established by the standard support the needs of the community? Can the significant concepts and descriptive elements related to an information resource be communicated through the standard? If not, then efforts can be made to extend the standard or create a domain specific profile that builds on the standard.

Although this thesis focuses on analysing the AEG with respect to development of formal ontology, formal ontology is in essence a form of metadata. Thus, the analysis required to establish a sufficient metadata profile or profiles for an information community can inform the process of developing a formal ontology and vice-versa. Indeed, development of metadata models and formal ontologies can be seen as highly interrelated in that both activities attempt to describe information resource in a 'standard' way while attempting to avoid the loss of the richness of the original information resources.

3.6 Sensor Webs

A Sensor Web refers to a Web-accessible sensor network and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces (Open Geospatial Consortium Inc., 2006:4). Sensor Webs build on distributed sensor networks and provide end-users with access to information about physical phenomena that can be observed and measured. The environmental parameters measured by sensors are typically delivered along with metadata that reports properties including location, orientation and qualities of the measurement.

The OGC has been developing a series of specifications as part of its Sensor Web Enablement (SWE) project (Open Geospatial Consortium, 2006). The SWE project effectively establishes a variety of interlinked specifications that define domain semantics at a variety of levels. At the highest level, specifications related to observation and measurement define fundamental concepts related to how data are collected and

represented. At lower levels, specifications related to Web-based information services establish how nodes in a computer network can exchange sensor related data.

Although the scope of this work does not allow for a comprehensive discussion of sensor networks, this is an area of development that will almost certainly have important implications for how the AEG community monitors and manages the Antarctic environment. Sensor Webs are already being used in environmental monitoring applications in temperate areas (Delin et al., 2005) and in the Antarctic region (Delin et al., 2003) and are proposed as part of Arctic environmental monitoring programs as well (Uttal, 2008).

3.7 *Agent Based Computing*

Distributed computing and Service Oriented Architectures can facilitate agent-based computing. A software agent is a software entity that functions continuously and autonomously in a particular environment. Each software agent has specific functions and responds to specific events, based on predefined knowledge rules, the collaboration of other agents, or users' instructions (Ming-Hsiang, 2003). While a detailed discussion of agent based computing is beyond the scope of this work, of primary interest is the idea that, using this method, tasks are performed by distributed entities in a collective process with a requirement that each agent presents both data and semantic (contextual) information.

Agent based computing is central to visions of the next generation World Wide Web currently termed the ‘Semantic Web’ (Berners-Lee *et al.*, 2001). Berners-Lee states that “to date, the Web has developed most rapidly as a medium of documents for people rather than for data and information that can be processed automatically. The Semantic Web aims to make up for this.” The concepts and technologies of the Semantic Web are elaborated in subsequent chapters.

3.8 eXtensible Markup Language

An integral part of the Web Service and Semantic Web models is the use of the eXtensible Markup Language (XML). XML is a simple, very flexible text tag based markup format (World Wide Web Consortium, 2004a). In contrast to the tags used by the well-known HyperText Markup Language (HTML) to define how a Web page is formatted and displayed, XML tags reflect semantic content. The intention is to separate the content from its presentation. XML can still be used in displaying information as is the case when XML is translated into HTML. As an example, in the case of HTML, a person’s name might be marked up as follows:

`<H2>John Doe</H2>` (displayed in a Web browser as a second level heading)

Using XML, the same information might be marked up as follows:

`<FullName>John Doe </FullName>`

In the first example, a browser can display the information to be read by a human, however an information processing system cannot readily process the information between the tags – it lacks semantic description. The XML example states that the information between the tags is included in the category ‘FullName’. To format this information for display, a simple transformation rule can be established such that all <FullName> items are marked up with an <H2> tag.

The usefulness of XML is in its extensibility. The browser software does not define the tags that can be used, but rather this is done by users or communities and stored in *schemas* that contain *namespaces*. Namespaces define tag vocabularies that give precisely defined meanings to each element and attribute used in an XML document. A namespace is made available on the Internet using a Uniform Resource Identifier (URI) that resembles a common Web site address. The ability to include several namespaces in a single XML document while avoiding potential homonyms across domains is important in the context of geographic information integration where integration of information from multiple domains is necessary (Zaslavsky, 2003).

Additionally, the use of XML as a means to encode information presents the possibility of transforming information into a variety of representation forms including Web pages, paper maps, digital documents etc. (Lehto, 2003). This capability is important in the context of information integration where the goal is to produce a representation that is

meaningful to a particular end user that may or may not be part of the community that produced the information. Many organizations have created domain specific XML profiles. Two that are relevant to cartography and geography are the Scalable Vector Graphics profile (World Wide Web Consortium, 2004b) and the Geography Markup Language (Open Geospatial Consortium, 2003a)

3.9 Grid Computing

The term grid computing attempts to integrate work being done in the areas of high performance cluster, peer-to-peer and Internet computing (e.g. Seti@Home). A broad definition of grid computing is:

“Grid computing enables virtual organizations to share geographically distributed resources as they pursue common goals, assuming the absence of central location, central control, omniscience, and an existing trust relationship” (Abbas, 2004)

In contrast to general Web Services, the grid model elements attempt to address: identity and authentication, authorization and policy, resource discovery, resource characterization, resource allocation, resource management, accounting/billing etc. and security. Thus a grid system must know who a user is so that it can then allocate seamless access to various information or services and monitor usage etc.. This is particularly important when using grids in scientific research as the user specific and fine-grained resource control can allocate resources (e.g. running a complex model)

based on priority established by the community. This is quite different than a system using the Internet.

There are a variety of grid types including desktop, cluster, High Performance Computing (HPC), and data grids. In terms of current practical implementation, the Open Grid Services Architecture (OGSA)(<http://www.globus.org/ogsa/>) attempts to integrate Web Services architecture with grid computing architecture.

The implication for the AEG domain is that if grid computing is widely adopted there may be significant effects on data modelling and management methods. It is likely that the extensive computing power provided by grids will enable the development of more comprehensive and accurate scientific and environmental models, which will in turn inform AEG. Ensuring that grids are interoperable with other elements of an environmental information system is an important consideration in terms of supporting information exchange in the future.

3.10 Theoretical Focus on Geographic Information Representation

Although mapmakers have been considering theories of geographic representation for many centuries, there is a re-emergence of focus on matters related to geographic information representation at many levels. New paradigms emerging to describe and explain emerging information constructs and related social patterns (e.g. Taylor – cybercartography (Taylor, 2003); Goodchild – GIScience (Goodchild, 1992); Geo-ontology (Peuquet, 2002; Schuurman, 2006)) suggest that aspects of the renewed focus

on representation are related to the emergence of ontological modeling and the increased awareness of representation when attempting to develop modern geographic information systems. Representation is a central theme of interest in this thesis and our discussion is expanded in subsequent chapters.

3.11 New Data Structures

Historically, GIS has been dominated by the raster and vector data models (see Appendix A). In recent years, the object-oriented data model has emerged as an important information structure. In this model, the world is made of objects and objects have properties expressed as attributes. Attributes describe the state of an object. Objects also have inherent behaviours enabled by methods (programs). Objects communicate using messages that invoke methods (events). Objects sharing attribute definitions and methods belong to a class with class structure being hierarchical and subclasses inheriting attributes and methods of superclasses (specialization / generalization). Objects can contain other objects (aggregate) and association objects can be used to create sets with multiple object-object relationships possible. As we will see in a subsequent review (Chapter 4), the object-oriented approach aligns well with theories in spatial cognition and ontology.

The object-oriented model is seen to have a number of modeling benefits for geographic information (Yapa, 1998). The model separates the entity concept from the entity geometry. Treatment of location (including location in time) as an attribute allows for easy and frequent update of dynamic objects. Encapsulation (combination of data and

methods) allows for “self-aware”, “intelligent” objects where the application logic is, at least in part, stored in the data model rather than external procedural instructions. Many of the specifications and standards being released by OGC and ISO use an object-oriented modeling approach.

3.12 New Design Philosophies

It is suggested that the predominant model of information systems design was, for many years, the waterfall approach (Pulsifer et al., 2005). Figure 3.1 illustrates the traditional waterfall approach. In this approach, the user is not consistently involved in the design process.

Recently, alternative design philosophies such as User Centred Design (UCD) have emerged and have increased in level of adoption (Williams & O'Brien, 2003; Tsou & Curran, 2008). UCD is an iterative approach in which the needs, wants, and limitations of the end user of an interface or system are given extensive attention at each stage of the design process. Figure 3.2 presents a schematic of a UCD design approach. The expectation is that a UCD approach will provide a higher quality results that will ultimately be more effective and cost less to develop.

Figure 3.1 A waterfall design approach. (after (Pulsifer et al., 2005:466) – image by Parush)

Other interesting design approach philosophies include the use of pattern languages (Graham, 2003; Harrap et al., 2005), and the overarching concept of information architecture (Rosenfeld & Morville, 2002). Information architecture is an important philosophy with respect to designing for information exchange and interoperability. Central to the information architecture philosophy is the development of a conceptual and semantic model of the domain of interest. Due to the importance of the concept, it is discussed in more detail here with a reference to its application in an Antarctic context.

Effective information architecture is defined in this thesis as the organization of information content in a way consumers of that content understand it effectively. More typical formal definitions are found in Rosenfeld and Morville (2002:3):

1. The structural design of shared information environments.
2. The combination of organization, labelling, search, and navigation systems within web sites and intranets.
3. The art and science of shaping information products and experiences to support usability and findability.
4. An emerging discipline and community of practice focused on bringing principles of design and architecture to the digital landscape.

This philosophy suggests that effective design of information systems in general and, by extension, geographic information systems, must consider a variety of interdependent

elements such as content and user requirements within an environmental context that may include culture, management objectives, politics and economy. Thus, when designing cybercartographic (Taylor, 2003) atlases, for example, the design of the information *landscape* is ideally a holistic consideration of context using a variety of methods including UCD. This design process begins with the development of a semantic model.

The semantic model reflects the meaning of the content and its categorical divisions and sub-divisions. Probably the most common semantic model is topic-oriented where the domain is divided into categories that express logical domain units, such as Climate, Geology, and Geopolitics etc. Each of these major categories is further sub-divided into finer units such as Global Climate, Local Seasons, etc. Another common semantic model is task-oriented where the organizing and categorizing principles revolve around the tasks the user is expected to perform and complete.

For example, a digital environmental atlas would examine particular themes or regions through maps and supporting material. Thus, a starting point for information system development is the establishment of an appropriate semantic model that identifies concepts, categories and relationships. Establishment of a semantic model can use formal or informal methods or a combination of both. Informal methods use individual or collective knowledge and wisdom to establish the model elements. More formal methods may, for example, use tools such as formal logic, pattern matching algorithms or

grounded theory methods to establish concepts, categories and relationships. Formal methods may be used independently or combined with informal methods.

A variety of approaches are used to implement and manage semantic models in a digital geographic information development process. These include: metadata (as previously described); controlled vocabularies, glossaries or geographic feature classification schemes; thesaurus - a semantic network of concepts, connecting words to their synonyms, homonyms, antonyms, broader, narrower and related terms. As we will see in Chapter 4, the components of a semantic model developed under the information architecture philosophy are strongly interrelated with the concepts of formal ontology. The major difference is the level of formalization. Information architecture uses a broader definition of semantic model whereas formal ontology uses a particular information modelling methodology and associated set of tools. It is important to note as we move forward that formal ontology can be seen as a part of the semantic model concept proposed under the information architecture philosophy.

As an example of the practice of an the information architecture philosophy, establishing the preliminary semantic model for The Cybercartographic Atlas of Antarctica, a prototypical general audience atlas of the Antarctic region (Pulsifer et al. 2005), involved the use of formal and informal methods drawing upon the knowledge of students, teachers, psychologists, cartographers, domain experts and a variety of texts (McGonigal & Woodworth, 2001). Model development was supported using a number of resources

including general subject taxonomies, a geographic feature catalogue being developed by the Antarctic science community (SCAR FC), school curriculum materials (see Baulch et al., 2005), and a variety domain related glossaries. Figure 3.3 presents a graphic illustration of a semantic model developed during the atlas prototyping process.

Figure 3.3 High level abstraction depicting nested categories.

The outermost (black) ring represents the entire earth system with the inner (medium gray) ring representing the Antarctic system. The 'scribe' of the circle represents the concept of the interface between systems the topic of Volume 1 of the atlas. Other volumes address the Antarctic from a regional, physical environment and human activity perspective respectively with modules on related sub-categories such as the Committee for Environmental Protection or 'CEP'.

Adopting an information architecture philosophy conceptually connects the more specific implementation approaches associated with Service Oriented Architectures, formal ontology and the Semantic Web and, as a result, may provide a high level theoretical and methodological basis for establishing interoperable information systems within the AEG domain. Selected elements of the information architecture design philosophy and general methodology are used as a basis for developing a preliminary semantic model (e.g. establishing terms etc.) and applications for the AEG domain as reported in Chapters 5 and 6.

3.13 Spatial Data Infrastructures

Increased connectivity resulting from the development of the Internet and Service Oriented Architectures has resulted in the emergence of new political/social/technical structures designed to manage the distribution of digital geographic information. The Spatial Data Infrastructure (SDI) concept was popularized in the early 1990s and early adopters started to establish implementation strategies (Clinton, 1994; Coleman & McLaughlin, 1994; Morain, 1997). SDI programs are typically led by public agencies interested in facilitating the cooperative production, use and sharing of geospatial information (Boxall, 1998; Masser, 1998; Lachman, 2002). These infrastructure programs encompass policies, standards, technologies and procedures and often depend on collaboration between public, private and academic agencies. SDIs are being developed at a number of geographic scales including local (Harvey et al., 1999), national (McLaughlin & Nichols, 1994; Rhind, 1998), continental (Coleman & Nebert, 1998) and

more recently, global (Coleman & McLaughlin, 1994; Lachman, 2002; Nebert, 2004).

Global SDIs are typically used for such applications as evaluating global environmental change or disaster response.

Funds, primarily public, being spent on the development of spatial data infrastructures are significant, with countries like Canada directly spending 60 million dollars (\$CAD, 1998) on establishing the Canadian Geospatial Data Infrastructure (Canadian Geospatial Data Infrastructure, 2004). Korea in contrast, is spending on the order of hundreds of millions of dollars (Masser, 1998). These investments are likely a fraction of those made to support major programs in countries like the United States and United Kingdom (Rhind, 1998; Federal Geospatial Data Committee, 2002). While investments in spatial data infrastructures are large, so too are the expectations for these programs. In launching the Canadian program, The Honourable Ralph Goodale, then the federal Minister of Natural Resources had these comments:

“We want to exploit the vast potential of integrating information from maps, satellite images, statistics and other sources into geospatial data infrastructures. These data infrastructures are opening up a whole new way of understanding our world.” (Goodale, 1999)

As governments and institutions develop SDIs, it will be increasingly possible to obtain public and private geographic information using Internet based delivery services based on

SDIs. Some national mapping agencies have already moved to this approach for delivering geographic information (Rhind & Nanson, 1998). The developing Canadian program aims to provide citizens “common-window” access to geospatial services and information through the Internet by “harmonizing” the public and privately collected geospatial information into easily accessible and searchable databases (Canadian Geospatial Data Infrastructure, 2004). In the early stages of SDI development, the Internet was used for data discovery through on-line directory searches. Data were then provided on digital media such as CD-ROM disks and shipped rather than being visualized or accessed directly on the Internet – thus data were not harmonized to any extent and the ‘common window’ was not a reality. New technologies and approaches are supporting the transmission of geographic information over the Internet in a way that the information can be visualized or accessed directly. Key elements in these developments are the concepts of information communities and interoperability.

The development of a SDI and all that that entails is based on the assumption that geographic information is produced within an *information community*. In general terms, an information community can be defined as “a group of spatial data producers and users who share an ontology of real-world phenomena.” (Bishr et al., 1999a:58) The use of the concept of an “information community” appears to be increasingly accepted within the geographic information domain as a framework to establish a consensus on the semantic value of geographic information and the development of interoperability strategies (Bishr et al., 1999a).

3.14 Web 2.0

Web 2.0 is the term used to describe current movements in Web application development that is characterized by web-based communities who use a variety of tools (wikis, blogs, social networking sites, folksonomies etc.) to facilitate relationship building and/or generate content. The geographic information domain is highly implicated in the Web 2.0 movement. In the first half of 2005, the Google Corporation released *Google Maps* and soon after, *Google Earth*. These releases followed by others such as Microsoft Corporation's *Digital Earth* took the already existing Internet map scene dominated by sites like MapQuest to the next level. These applications provide better performance and integration with general search functions and the ability to upload and display your own data. Application Programming Interfaces (APIs) can be used to create 'hacks' or 'mash-ups' that adapt for use in a developer's own on-line applications (Erle et al., 2005). This opens new horizons in the way we map the world.

The changes associated with the Web 2.0 movement have resulted in the development of knowledge construction communities. Wikipedia (<http://www.wikipedia.org>) is probably the best-known example of knowledge construction through collaborative effort enabled by these new technologies. Examples such as *Placeopedia*, *Openstreet*, or *Geowiki* are emerging from the similar communities. Anybody with Internet access can now access and provide geospatial information. In the context of this thesis, this has implications for how an environmental information system might be developed. In addition to observations from scientists and sensors, other actors may be able to contribute valuable

information (e.g. tourists). Implementation using a Web 2.0 approach could also draw from the Public Participation GIS literature previously cited in Chapter 1.

3.15 Critical GIS

Starting in the late 1980s and continuing through the 1990s, a body of 'critical GIS' literature emerged from within the discipline of geography. This work aimed to identify the broader social impacts and implications of geographic information technologies (See for example, Pickles, 1995). While the critical GIS debates have not immediately resulted in more reflexive GIS research and practice a result has been the development of at least one major research program from within GIS that aims to examine the social implications of research, technology and practice of GIS (Goodchild et al., 1999b) and other increasingly prominent theorist-practitioners (Kwan, 2002; Schuurman, 2004). While much research and development is being carried out to address the scientific and technological challenges related to the geographic information domain, there has been little critical discourse on the broader political and social implications unique to distributed systems, SDI etc.. These new forms of information system involved development by communities using distributed resources. This introduces a whole set of issues related to governance (what are our goals and principles), politics (what are our procedures, how are actors represented), power and access (who can use it). Critical academic discourse in the realm of ontology and semantic interoperability is emerging (e.g. Schuurman, 2006, Fisher and Unwin, 2005) and is reviewed in more detail in Chapter 4.

3.16 Conclusion

This chapter provided a broad review of interrelated technologies, methods and theories that have emerged in recent years in the information technology domain in general and the geographic information domain in particular. All of these technologies or movements will in some way effect and have implications for the possibilities for designing information systems that support effective information exchange. While many of the developments discussed are technical, the challenge of providing the ‘common window’ proclaimed by proponents of SDI is not strictly technical. Developing a common window requires a common understanding of domain semantics (e.g. semantic models) amongst developers, users and other stakeholders. Developing such a model requires a broad and deep understanding of the domain of discourse. Building such an understanding requires knowledge not only of technology and information structures but also of the perceptions, concepts, goals and political context of the information community. While establishing this understanding in the AEG domain may seem as straightforward as creating an inventory of mapped features, the review in Chapter 4 and the study results presented in Chapter 5 reveal the potential complexities and nuances of developing a semantic model.

CHAPTER 4. ONTOLOGY

4.1 Introduction

The developments discussed in Chapter 3 provide a foundation for improved interoperability and information sharing. These developments alone will not address the problem of semantic interoperability though. To elaborate on the term previously introduced, semantic interoperability is fundamentally related to the overall concept of interoperability in that pure data transfer makes no sense if the members of the user community interpret the data differently (Bishr et al., 1999b:204). If semantic interoperability is not considered, then a situation can arise where data transfer is successful but information is not in fact *shared* – that is, the meaning is not communicated. This situation is conceivable in the case where Web Services with heterogeneous semantics are used together. The problem of semantic interoperability has been recognized by researchers and practitioners focused on developing geo-information systems

Within interoperability research and development, three primary areas of interest are being addressed, namely syntax, schema and semantics. The bulk of the interoperable geographic information systems literature states the assumption that issues of syntactic

and schematic interoperability have been or are being resolved by industry (Goodchild et al., 1997; Egenhofer, 1999; Goodchild, 1999a; Kottman, 1999). The concepts of syntactical and schematic interoperability were discussed in Chapter 3. This chapter places the focus on topics related to semantic interoperability.

In simple terms, geospatial data semantics encompasses how – typically through the use of language – computer-based representations stored in information systems are related to entities and concepts in the real world. Central to data semantics is the process of categorization of geographic phenomena. There are a number of reasons for semantic difference in geographic information including differences in classification schemata, difference in the rules that define if an instance of a geographic phenomenon is included in a particular class definition and lastly, differences in geometric representation. A number of examples of semantic difference in an application context are provided in the section on critical geo-ontology in this chapter.

To address the issue of semantic interoperability, academia has been primarily focused on developing a semantic translation approach to address the problem. That is, translating meaning from one information resource to another. This approach first uses the strategy of formally modelling the semantics of an information community and then using the developed model to translate semantics within and among knowledge domains. Subsequent sections of this chapter provide some elaboration on how this is accomplished.

In addition to the use of such resources as metadata, the understanding of community semantics is established using a variety of processes including, for example, textual interpretation (Kuhn, 2001), and other methods such as those applying Bruno Latour's ethnographic methods of collaborative action (Harvey, 1999). The semantic information collected as part of these processes is modelled and stored in a *formal ontology*.

The term ontology has at least two meanings, which can cause some confusion. In the context of philosophy, the term ontology is related to presuppositions about what constitutes reality. The interoperability literature often terms this *reality-based* ontology or *r-ontology*. In the context of the field of knowledge engineering, an ontology can be defined as a formal conceptualization of a specific domain that attempts to capture and constrain a set of conceptualizations (Guarino & Poli, 1995). This formal ontology approach is used in, for example, the computer science, artificial intelligence and geographic information science domains to refer to computer-based implementations that model and process representations of objects, properties and relationships. Peuquet (2002 :311) clarifies this distinction by establishing an *r-based* ontology as a *descriptive ontology* and ontology as it is referred to in knowledge engineering simply as a *formal ontology*. For the remainder of this thesis, *descriptive ontology* will be used in reference to *r-based ontology*. If the term ontology is used, one can assume reference to *formal ontology*.

The challenge of addressing semantic interoperability through translation is an ongoing area of research within academia and increasingly the private sector. This chapter provides a necessarily brief overview of the research focused on ontology and semantic translation. Outside of academia, formal ontology and semantic translation are typically referred to under the umbrella term ‘Semantic Web’. The Semantic Web has been presented as the next generation World Wide Web whereby self-described data services interoperate to exchange, process and understand data (Berners-Lee *et al.*, 2001). Essentially, this is achieved through machine reasoning on detailed metadata about the data being served (i.e. a formal ontology).

As stated, there are many different, yet interconnected research frameworks working under the general label of ‘ontology’. Some of this work falls within the category of descriptive ontology while others address the use of formal ontology in applications. A review of a representative sample of research is presented to provide the reader with some understanding of the research topics being addressed.

4.2 Descriptive Ontology

In relation to geographic information, descriptive ontology is a multifaceted area of research involving cognitive models, philosophy, category theory, establishment of *geographic kinds* and relations, models of space and time, social theory and other areas of inquiry. These are active areas of research and, at present, there is no clear consensus amongst researchers on models that can be applied across a wide range of applications.

The notion of [descriptive] “ontology” has been implicated in constructing models and developing theories that describe our world at least since the time of the Greek philosopher Aristotle. Within the context of philosophy, the term ontology is related to presuppositions about what constitutes reality, the real and imaginary elements of our world. At the highest level, philosophers such as Aristotle (Aristotle, 1963), Kant (Kant, 1998), Hegel (Hegel, 1991) and others, attempt to theorize the world in terms of fundamental modes of description that can be used to categorize things. For example, Aristotle’s descriptors include substance, quantity, quality, relation, place, time, position, state, and action (Aristotle, 1963). At another level, ontology examines the necessary and sufficient conditions for a thing to be of a particular kind of entity within a given domain. This is the level of ontology familiar to many in the domain of geographic information and can be seen as a cognitive-level construct (Peuquet, 2002: 311). In this thesis, this level of ontology is most representative of what is meant by descriptive ontology. The remainder of this chapter focuses on various aspects of descriptive ontology and then formal ontology and suggests that while the concepts are seen as distinct, there exists a strong and interdependent relationship between the two.

4.2.1 Cognitive Models

Cognition is fundamentally related to our establishment of our conceptualizations of space and place and thus our construction of individual and collective descriptive ontology. Research has been extensive in the area of cognitive mapping – an umbrella term referring to research into people’s spatial, geographical and environmental knowledge through development of cognitive configurations of space and place (also referred to in terms of mental maps, place schemata, spatial representations etc.) – and its relation to construction of geographic information (Montello, 2002). This field has

produced a number of theories and models that aim to establish how we conceptualize and interact with space.

Within the field, there is a distinction made between primary acquisition of spatial knowledge - learning through direct interaction with the environment (Kitchin & Blades, 2002:35) - and the secondary learning established through use of maps, texts and other media (Kitchin & Blades, 2002:44). Each type of learning is seen to interact with and affect the other in terms of establishing a personal internal model of space and cognitive maps of a place. Additionally, it is theorized that there are a number of factors that effect how we perceive, learn about and conceptualize space and environment. These factors include age, disabilities, personality traits, social and cultural factors, education and familiarity and experience with a place. Familiarity and experience of a place can be conceived as a five level continuum as follows: identification and recognition by name, recognition when presented with a picture, knowing a location (either egocentrically, topologically, or in absolute coordinate space), knowledge through frequent interaction, and knowledge of historical, political aspects of the place etc. (Gale et al., 1990 in Kitchin & Blades, 2002:49). In these models cognitive mapping involves a number of cognitive, environmental and social factors.

Tversky (2000) discusses theories about the level and structure of spatial knowledge, particularly in relation to wayfinding. Tversky adds though that this same spatial knowledge is used to understand history, politics and make sense of the natural world

around us. This knowledge is *schematized* using generalization, abstraction and idealization to establish objects or features that have relations in space. This discusses the concept of *frames of reference* that serve to orient objects within them and serve to integrate different spaces into a common framework. These frameworks include hierarchical organization and canonical axes (e.g. N, S, E, W) (Tversky, 2000:24-27).

Language and cognitive mapping is also an area of research interest. Levinson (2003) argues that language influences how people think, memorize and reason about spatial relations, highlighting the transformative power of language in spatial cognition and thought. Examining other facets of language and space, Taylor (2000) establishes that the literature linking the fields of spatial cognition and psycholinguistics indicates the usefulness of languages in establishing properties of spatial representations. Similarly, Tversky (2000) states that:

“Spatial descriptions... locate landmarks, typically relative to each other and to a reference frame. When complete and coherent, spatial descriptions by themselves have the power to provide an adequate representation of an environment”
(Tversky, 2000:31)

There are different perspectives on whether spatial and geographic concepts are formed from innate, universal, mental spatial models that result from evolutionary psychology (Egenhofer & Mark, 1995; Smith & Mark, 2001) or social construction (Bowker, 2000;

Levinson, 2003; Poore, 2003). For example, Rundstrom (1995) notes conclusions drawn by scholars grounded in formalist traditions that declare that the four cardinal directions (North, South, East, West) are axiomatic of spatial relations. Rundstrom identifies the failure of this work to recognize the seven dimensional spatial schematization of the Zuni nation of the Southwestern United States (Frank & Mark, 1991; Rundstrom, 1995). Similarly, Hutchins (1995: cited in Poore, 2003) maintains that cognition and establishment of meaning are active processes of interaction among people and their environments.

Although theory in cognitive mapping continues to develop and debates exist, within the discipline of geography there is recognition that cognition and psycholinguistics are components of how we establish higher order concepts and categories in geographical information (MacEachren, 1995:150; Kitchin & Blades, 2002:57-83; Peuquet, 2002:115 etc.) and is thus an important element of studying descriptive ontology.

4.2.2 Categories

Categories can be seen as a fundamental aspect of all levels of ontology. Many of the cognitive models previously discussed are based on categories, a category here being a grouping of similar things that are assumed to share common properties that are inherent to the thing or abstract concept (Peuquet, 2002:70). Categories provide an organizing structure for knowledge and act as a repository for our knowledge and beliefs about the world. In addition to things, places, events, actions, spatial relationships, social relationships, and many other types of entities can be categorized (Lakoff, 1987).

Categories also entail relationships and abstraction at a variety of levels and thus categories can represent complex phenomena as well as simple objects. Rosch (Rosch, 1973; Rosch & Mervis, 1975; Rosch & Stausfeld, 1978 as cited in; Mennis et al., 2000) proposes that categories as they are known in an individual's mind are a function of properties of the elements within the environment, but as interpreted by the perceiver. Thus, individuals understand the world in terms of their knowledge organized by interpreted categories and properties.

Categories are central to the study of descriptive and formal geographic information ontology (Mennis et al., 2000) as categories establish what some refer to as geographic kinds – or categories that we can consider geographic.

4.2.3 Geographic Kinds

Geographic kinds can be considered to include categories that include entities having geographic properties. Smith and Mark (1998) present a system of geographic kinds that are considered “conceptually sound” and are based on properties of spatial location, topology and whole-part relationships (mereology). This descriptive ontology establishes a mesoscopic (naïve, normal, everyday, lay) stratum that has three different types:

- 1) Objects of a straightforwardly physical sort--such as *rivers, cliffs, bridges* etc.
- 2) Geographic objects like *bay* and *sea* (e.g. Ross Sea) which are in a sense parts

of the physical world but which exist only in virtue of demarcations induced by human cognition and action.

- 3) Geopolitical objects like *nations* and *neighbourhoods*, which exist only as the hybrid spatial products of human cognition and action.

While these categories appear straightforward, the authors point out the need to distinguish boundary types when defining spatial objects. *Bona fide* boundaries (expanded in Smith and Varzi, 2000) are those that correspond to genuine discontinuities in the world, whereas fiat boundaries are projected onto geographic space in ways that are to a degree independent of such discontinuities. A cliff would be an example of the former while a political boundary is an example of the latter. A bay, which has physical form but no physical demarcation along its boundary, would be considered to have a 'non-social' fiat boundary (Smith & Varzi, 2000:402). Smith et al.'s (1998, 2000) descriptive ontology elucidates a number of important concepts with respect to establishing geographic kinds. First, in many cases, vagueness is inherent to the definition of geographic fiats. Second, there are different types of geographic fiats, including but not limited to consensus fiats (agreed upon), legal fiats (defined by law) and representational fiats (e.g. established in a computer model). These ontological considerations are strongly linked to how we define categories using properties, and at a pragmatic level, how we model these categories in information systems (e.g. object or field from Chapter 3, Appendix A).

Frank (Frank, 2001, 2003) presents a five-tier descriptive ontology that has similarities to Smith et al.'s (1998, 2000) model. Frank's ontological tiers are as follows:

0. Human independent reality
1. Observations of physical world
2. Objects with properties
3. Social reality
4. Subjective reality

These tiers are discussed in terms of the constraints that must be applied when establishing an information system. For example, at Level 1, observations must be constrained by descriptions of measurement scales and uncertainty. Level 4, which includes administrative and legal domain, is constrained by legal definitions. The higher-level tiers discuss issues related to bona fide and fiat objects and boundaries and thus there is some similarity to Smith and Mark's model.

Although much research is focused on establishing broad descriptive ontologies, some researchers are examining the ontological aspects of a particular domain. Smith (2001) establishes an ontological framework for the domain of ecology through physical-behavioural units (e.g. animal, person) and their relation to foreground (internal) and (external) background patterns (e.g. environments, niches). These relations are the result

of behaviours and may result in the casting of ‘spatial shadows’ that endure over time. Despite the seemingly obscure language, ultimately this ontology can be applied to domains such as AEG in that it deals with features of the environment (background patterns), people/fauna/flora etc. (physical-behavioural units) and impacts over time (spatial shadows).

The body of literature addressing descriptive geographic ontology is large and broad, discussing issues that include: the difficulty of formally establishing the existence of fiat features like mountains and other landforms (Smith and Mark, 2003); establishing a descriptive ontology of field phenomena (Peuquet, Smith and Brogard, 1998); integrating object and field conceptualizations (Kjenstad, 2006); definition of ontologies of space-time (Bittner 2003a, Galton, 2003, Peuquet 2001, Worboys, 2005); understanding whole-part relationships (Varzi, 1998) and establishing ontologies for multi-scale applications (Bittner, 2003b). These works use a combination of logic, reasoning and rhetoric to establish ideas on the nature of existence and geographic kinds. Another body of literature examines descriptive and sometimes formal ontology using a critical theory approach. Critical theory approaches examine the current and historical social and political systems surrounding conceptualizations, practices and technologies, while attempting to understand the implications of practices and technology rather than strictly methodological aspects of practices or the analytical results. While some have suggested that this type of analysis and the often-ensuing debate can be divisive and possibly counterproductive (Openshaw, 1991) others see the integration of critical theory

approaches with geographical information discourse as a way towards an expanded and improved practice with respect to geographic information technologies (e.g. Kwan, 2002). While fully engaging critical theory in relation to the geographic information domain is not possible within the scope of this thesis and will be developed by the author in future work, a limited discussion is presented here to expose the reader to an important facet of the discourse surrounding geographic ontology.

4.2.4 Critical Geo-Ontology

Critical theory approaches are not new to geography and work in this area predates examination of GIS and emerging geographic information technologies. The late J. Brian Harley's seminal works in critical cartography (Harley, 1988, 1989) examined the agency of maps and the power relations around maps. Harley sees the map not as an objective representation of the world but rather a device to service specific functions related to the exercise of power. Thus maps must be examined with consideration of their social and historical context with attention paid to the implicit and explicit objectives of the mapmaker and an understanding of the power relations between mapmaker and map consumer. From a critical perspective, the late geographer Peter Gould (Gould, 1999a, 1999b) examined the larger issue and problem of scientific and geographic classification. He argued that assuming that phenomena can be classified in a particular way, based on general scientific or geographic methodological directives, without consideration for the specific and contingent aspects of the phenomena can result in cogent but ultimately meaningless results. In a related essay, Gould challenged the validity and usefulness of applying computational approach to certain problems in human geography. The problem

lies in the necessity of breaking down complex phenomena with complex relationships into discrete elements. As Gould puts it:

“ Our traditional ideas of classification force us to take a set of things and break it up in order to stuff the pieces into separate little boxes that are not allowed to overlap in any way”...”The problem is that these principles of partitional thinking are not only carried over into other, quite different realms, but also increasingly incorporated into the algorithms – the step by step instructions and procedures – that are written for computers to mechanize the whole process of classification”
(Gould, 1999c:305)

The problem identified by Gould is in the use of categorical computation with phenomena or contexts that do not lend themselves to simple classification. He concedes that, to some extent, as humans we must partake in categorization due to the constitutive nature of language. However, he cautions against using the ‘verbal concrete’, taking imprecise language that reflects uncertain and changing knowledge and attempts to ‘harden’ it to support computation (Gould, 1999:306). While Gould does not specifically address the use of GIS or other emerging geographic information technologies, his critical commentary is at the core of subsequent critical treatment of GIS – the challenges and problems of formalizing and representing a complex and dynamic world in a machine environment.

Starting in the late 1980s and continuing through the 1990s, a body of 'critical GIS' literature emerged from within the discipline of geography. This work aimed to identify the broader social impacts and implications of GIS (see for example, Pickles, 1995). Many who are using geographic information technologies may not be aware of these historical and ongoing debates among geographers and related disciplines around the implications of the use of GIS research and practice. This series of - sometimes intense and abusive - debates occurred primarily during the 1990s. A comprehensive review of critical GIS is not provided here, as this has been done elsewhere (see Schuurman, 2000). However, to provide background useful to this discussion a summary of the criticisms - often referred to as 'critical GIS' - is useful. In general critical GIS has been focused on four key themes:

- The perceived ontological and epistemological underpinnings of GIS, particularly a criticism of positivist perspectives
- Access to GIS technology and geographic information
- Privacy issues
- The profit motive in GIS innovation

The first theme is most relevant to our discussion here and relates to the ideas put forward by Harley and Gould. The critical GIS school saw problems with the spatial analytic tradition perceived as central to GIS theory and practice. The spatial analytic tradition is defined here as a perspective that sees: location/distance/direction as predictive

variables; space as a container populated with discrete entities; possibility of analyzing spatial patterns to uncover process; value in objectivity, empirical evidence, rationality, formalization, laws and repeatability. While the details of the debates are discussed elsewhere (Taylor, 1990; Lake, 1993; Pickles, 1995, 1997; Schuurman, 2000; Sieber, 2000; Fisher & Unwin, 2005), in general, critics suggested that while GIS is useful in the realm of information management it lacked the ability to make meaningful contributions to geographic knowledge construction (Taylor, 1990:211). In response, researchers from within GIS research suggest that consideration of the limits of GIS has been an integral part of the research program in the form of studies of uncertainty, fuzziness and generalization (Goodchild, 1991). A review of GIS literature supports this assertion (Zhang & Goodchild, 2002; Couclelis, 2003) while at the same time; efforts continue to establish universally representative geographic data models for use in GIS (Goodchild et al., 2007).

In addition to concerns about the limitations of GIS as a means to represent complex geographic phenomena and contribute to geographic knowledge construction, a fundamental criticism of GIS related to the potential for these limited but increasingly pervasive methodologies and representations to become constitutive of world views and intellectual practices within and beyond academic geography and that these methods would produce a 'doomed discourse on method' (Pickles, 1993:451). In this regard, Clark (1992) suggests that the major driver of methodological trends will be industry

rather than academia and that this should be of greater concern to academics than differences in theoretical perspective.

Of interest to our discussion here, are the critical research studies related to GIS and other geographic information technologies and ontology. Early critical GIS work focused on the epistemological and ontological underpinnings of GIS. Lake (1993) argued that GIS was inherently positivist in its history and design and, in its current form, was inconsistent with the theoretical sensibilities of the discipline of human geography.

Applied geographic studies in the ethnographic tradition provide grounded accounts of the difficulties and problematic aspects of adhering to positivist ideals in complex application domains. In the context of mapping biodiversity, Bowker (2000) sees that attempts to formalize and stabilize meaning through consensus and establishment of shared categories can result in the construction of new meaning with a loss of the semantic richness characteristic of the original, heterogeneous definitions.

Landuse classification schemes are a classic example of potential problems in categorizing and stabilizing meaning. Difference exists either in the label used to describe a class (i.e. fallow land vs. set aside land) or the label may be the same with the class inclusion rules being different. An example case that is prominent in North America is the class of 'wetland' – the inclusion rules are very different depending on the context and the individual stakeholder (Smith & Mark, 1998). While class definition and inclusion rules may be similar, the geometric representation may be different as with the example of a 'road' feature. A transportation engineer may "see" roads as line features

(vectors that carry traffic) whereas a utilities engineer will see the same road as an area feature containing other feature i.e. lines such as gas mains and points such as water valves. In the domain of landuse studies, Bibby and Shepherd (2000:583) argue that the unquestioning epistemology of the prior, unproblematic existence of objects within GIS (as representative of the real world) provides a 'cripplingly restrictive' (Bibby & Shepherd 2000:583) conceptualization of objects that limits its applicability to landuse studies. A specific problem identified in this work is the propensity for traditional GIS data models to focus on the formal aspects of ontological representation (attributes that distinguish one geographic kind from another) at the exclusion of the ontological aspects of an object related to purpose, whole-part relationships and transformative abilities.

In some cases, establishment of semantics is relatively uncomplicated. Drawing on my own experience, I have found little difficulty in establishing agreement on the definition of a 'hydrant' within a multi-stakeholder municipal domain. However, to further illustrate the challenges of categorization, I will use an example from my experience in the Antarctic geographic information domain. While participating in a working group tasked with establishing definitions of topographic classes for the Antarctic region, agreeing on the definition of apparently straightforward features such as "lake" proved to be quite challenging. This is not surprising though when one takes the time to consider the concept of "lake". A lake can be a well-defined, two-dimensional polygonal feature with a limited areal extent. This works well from a topographic mapping perspective. However, a lake can be seen as habitat by an ecologist. In this case, the fuzzy boundaries

of the land/shoreline/riparian/lake zones become important. A limnologist may require a three dimensional definition of the lake as temperature and chemical profiles related to depth are critical to the analytical context. Lakes can also be seen from a resource perspective. The Australian members of the working group suggested that a lake be part of the more general class “reservoir”. This is not surprising given the generally dry conditions and scarcity of fresh water in Australia. As discussed in Section 4.2.3, the differences in the difficulty of classifying some features can be related to whether an object is considered bona-fide or fiat.

While these debates and discussions around semantics may seem esoteric, they have real world implications for decisions related to information construction and management. The following quote is from a personal communication with the manager and a co-developer of the Antarctic Digital Database (ADD), an authoritative topographic database for the Antarctic region. In discussing the construction of the Antarctic Digital Database, Paul Cooper (personal communication, June 14, 2007) states:

“The ADD uses a very low level of abstraction; its policy from its very beginning is that the ADD only represents things that can in principle be seen or measured directly on the ground. So, we provide rock outcrop, not nunataks; we provide contours (which in principle could be validated by measuring elevations), not mountain ranges. The ADD has, quite deliberately, always disassociated itself from higher level abstractions, partly because higher level abstractions often come with political implications that would be inappropriate for the ADD, but also because higher-level abstraction often means that we would be applying an unjustifiably high level of interpretation in many cases. I recall long and arduous discussions with [a late colleague] over this issue; we did not even feel able to provide “glaciers” as entities,

because this would mean deciding where a glacier started and ended - a difficult matter for an entity which merges seamlessly with other entities at its upper and lower extremities! The example (one of many) we always quoted was Byrd Glacier, which can be seen to have absolutely continuous flow from somewhere near Dome C down to the front of the Ross Ice Shelf. To map glaciers - seemingly a reasonable request - would have meant making interpretation of observations that are the province of glaciologists and which are ongoing matters of debate.”

This quote establishes that questions of geographic ontology addressed in descriptive ontology research (e.g. Smith & Mark, 2003) are questions that are pertinent to real world application design and are somewhat independent of the form of representation within an information system.

Although much of the research cited in this section is typically categorized under the label of ‘critical GIS’, we see relationships between and overlap with scholarly work in other areas of geography including information ontology and philosophy (e.g. establishment of geographic kinds), geographic cognition (e.g. innate versus constitutive categories) and definition of the discipline (Wolman, 2004). Although important, the critical GIS debates of the 1990s are inadequate to address the current issues in the geographic information domain as technologies, theories and methods grow to include massively parallel geo-computation (e.g. grid computing), social computing (Web 2.0), User Centred Design and Spatial Data Infrastructures (including virtual planet technologies). However, the earlier debates provide important critical commentary about the importance of foundational assumptions and the potential implications of making such assumptions. As we move towards an increased use of computational solutions to

solve the problems that face us, we can ask questions related to our assumptions. With respect to formal ontology (discussed in the next section), we must consider the potential problems with using operational thought models or seeing aspects of ontology as innate. Additionally, the limits of formal logic based on foundational laws (either true or false) must be considered. The foundation of formal ontology, formal logic, is based on particular axioms (truths), however if one casts aside these axioms to include other possibilities, new forms of logic are required. New forms of logic that can, for example, account for an evaluation of the 'possible'. For example, the statement "In 2050, global average temperatures will have increased by 2.0 degrees Celsius" cannot currently be objectively evaluated as true or false. This leads to the question of the validity of using formal logic methods and potentially investigating other logic possibilities such as fuzzy logic.

These are important issues to consider as we examine the use of ontology in the AEG domain – one that has elements of probabilistic science and human dimensions (aesthetics, politics, law etc.). Additionally, the critical theory approach discussed has the potential to unpack the implications of reification of concepts and the problems related to single authoritative ontologies and the potential for imbalances in power relations and access.

A comprehensive review of research in the area of descriptive geographic ontology is beyond the scope of this work, however the brief review provided establishes a number

of important insights. Various research programs address aspects of descriptive ontology that are highly relevant to the complex AEG domain. Developing ontological models in the domain of ‘geographical information’ is a complex undertaking that involves an understanding of cognition, language, concepts, modeling and social relations. The uncertain, vague and socially contingent nature of many geographical phenomena suggests that building a single unifying ontology is impractical (Frank, 1997 as cited in Peuquet, 2002:317) and, possibly more importantly, may result in a reduction in the richness of knowledge and the privileging of particular perspectives. Current approaches to modelling ontology for interoperability focus on the concept of “information communities” that share conceptualizations of phenomenon, conceivably making the challenge of establishing shared semantics more tenable. The challenge here is in ensuring that the ‘community’ is both inclusive and representative of all of those with a stake in the domain.

The research reviewed in the first section of this chapter examined high-level topics relating to descriptive ontology, however these topic directly relate to formal ontology in that formal ontology attempts to model elements of descriptive ontology (categories, properties, relations) in a machine environment. The following section provides a more detailed discussion of formal ontology.

4.3 Formal Ontology

Reference has already been made to formal ontology and its potential use in supporting semantic interoperability. The following sections define formal ontology, expand on

theoretical foundations, explain operational aspects and discuss the tools used in formal ontology. The section then goes on to explain the general method used to formalize geographic information using a formal ontology approach.

4.3.1 Definition

Formal ontology can be defined in a number of ways. Definitions include:

- A specification of a conceptualization (Gruber, 1993)
- Formal explicit description of concepts in a domain of discourse (Noy & McGuinness, 2001)
- A data model that represents a domain and is used to reason about the objects in that domain and the relations between them (Wikipedia, 2006)

In explaining the use of formal ontologies, Ciocoiu et al. (2001) agree with Gruber's definition and go on to say that 'ontology' is borrowed from philosophy (what exists) – in the case of formal ontology, what exists is what can be represented in a computer environment. Ciocoiu et al. also point out that a fundamental rationale for using formal ontology is to avoid the ambiguity and vagueness of natural language. Thus, to some extent, formal ontology is a response to the inability of machines to effectively and consistently interpret natural language. In describing the OGC's language-based approach to interoperability, Kottman (1999) builds on ideas from 18th century philosopher John Locke to establish the importance of consistency in meaning:

“There is nothing special about one word or another relative to its symbolic use to represent a given idea. What is important is the consistent and uniform use of it for that idea. If more than one person is involved, there must be consensus on that usage.” (Kottman, 1999:47)

Bishr (2006) states that defining fundamental meaning is outside the realm of formal ontology. When referring to a formal ontology containing the concept of ‘person’, Bishr (2006:146) writes:

“One might argue that we still need to define the meaning of ‘person’. Doing this would actually mean that we are going beyond ontology and defining what we call epistemology. Epistemology is the study of theories of knowledge or ways of knowing. What makes something to be truly a person, for example, has been investigated and answered by philosophers and is referred to by ontology. Therefore, ontology assumes some level of epistemological agreement, which is beyond the scope of this chapter.” (Bishr, 2006:146)

Thus, at some level, formal ontology assumes a pre-established semantic model that defines concepts independent of attributes and structural context.

Formal ontology approaches are being developed for a number of reasons including the sharing of common understanding of information structure, enabling reuse of domain knowledge, making domain assumptions explicit and mediating between information resources (semantic translation).

There are many interpretations of the term ontology or formal ontology. It is increasingly a widely used term and, depending on the application or discipline the term can (ironically) mean very different things to different people. Figure 4.1 synthesizes a number of sources to establish a depiction of the semantic continuum. These concepts will likely be familiar to those in library science and archiving. Referring to Figure 4.1. from left to right, a list simply enumerates terms and assumes that definitions are implicit or unnecessary. A glossary is a list of terms with the definitions for those terms and defines terms but not relationships between terms. A weak taxonomy establishes hierarchical relationships, however these relationships are not necessarily based on strong logic or a rule set (e.g. A Web menu system, a person's folder tree on a PC) with relationships being somewhat arbitrary. In this case, the perceived hierarchical relationships would not necessarily hold-up outside of an application or domain.

Figure 4.1 The semantic continuum. Synthesized using ideas from (Guarino, 1998; Bittner, 2004; Orbst, 2006)

Thesauri are controlled vocabulary structures designed to reveal associations and relationships (i.e. synonym, antonym, homonym, hierarchical, association). A thesaurus models terms rather than concepts with rules being linguistic rules rather than conceptual.

Metadata or "data about data", is information that describes another set of data.

Complex metadata models typically incorporate lists, glossaries and possibly thesauri and taxonomies. The ISO 19115 standard discussed in Chapter 3 is an example of a metadata approach to ontology.

Schemas can also incorporate the previously discussed constructs and adds the elements of strong data typing and validation of data. Conceptual models are the base of schemas and move us very close to what are typically accepted as a formal ontology. These constructs model concepts, properties and values, with constraints, relations and rules related to concepts (e.g. cardinality). Unified Modelling Language or UML, popular with software designers, has the potential to model very complex domains in this way. The Geography Mark-up Language and the Sensor Model Language mentioned in Chapter 3 are examples of the conceptual model and schema approach to ontology. However, a conceptual model of this type typically does not include logical constructs that can be used directly for machine-based reasoning. In some cases, lower level approaches (to the left on the line) are more expressive in some respects. For example the Resource Description Framework (RDF) actually has very weak data typing whereas XML schema is very strong in this respect. In an application environment though, XML schema can be

incorporated within an RDF model (these concepts are discussed in more detail in Section 4.4.2).

Description logics provide a set of constructs which can provide strong semantics and increased expressivity (e.g. first order predicate logic). Those working in knowledge engineering see the far right of Figure 4.1 as a “formal ontology”. The bottom row of Figure 4.1 provides sample statements that would relate to a given approach. The idea of a semantic continuum relates back to our discussion of semantic models in Section 3.12. From an information architecture perspective, any of the constructs illustrated in figure 4.1 would be considered a form of semantic model. However, the knowledge engineering community reserves the use of the term formal ontology for those constructs that contain description logic or formal logic. In popular usage, this distinction is problematic in that some communities equate the term of controlled vocabulary (glossary in Figure 4.1) with the term ontology (Marine Metadata Initiative, 2008). This presents the potential for misunderstandings with respect to what can be achieved using formal ontology. To avoid such misunderstandings, when examining the potential for developing a formal ontology for the AEG domain, it is important to consider the potential variations in the meaning of the term ontology (or formal ontology).

4.3.2 Theoretical Foundation of Formal Ontologies

Guarino’s seminal article (1998) provides a very useful introduction to the theoretical foundations of formal ontology. Guarino explains that formal ontology is based on

linguistic and semiotic theory that deals with symbols (terms) and referents (objects) (Figure 4.2).

Concepts are seen to be independent of the symbols used to reference them and are language independent. Formal ontology is concerned with approximating a set of intended models that can reflect the ontological commitment of a language to a conceptualization. Thus, the best formal ontology provides the best approximation of intended meaning of a particular term within an overall model.

Figure 4.2 Symbols and referents

Guarino discusses the notion of the resolution of a formal ontology. This idea is related to our previous discussion that states that categories can be more or less abstract and usually exist in a hierarchical frame of reference. A top-level ontology (low resolution) models very general but foundational concepts such as space, time, matter, event, action etc. that are related to studies in descriptive ontology. Top-level ontologies are intended to be domain independent and can conceivably serve a large number of communities. Domain-level (or simply domain) ontologies model either objects or tasks (activities) and describe vocabulary related to a generic domain (e.g. earth science), or process (e.g. flow). Domain ontologies specialize terms from top-level formal ontologies. An application-level formal ontology describes vocabulary related to a union of domain/task ontology in the context of a particular set of roles or entities performing a certain activity within a very specific application environment. Considering the resolution of a formal ontology becomes quite important as we attempt to apply a formal ontology in an application domain.

Formal ontology granularity relates to the level of detail included in a model. A coarse grained formal ontology provides a minimal set of axioms coded in a low expressivity language. It is easy to create and use, is computationally efficient, and can be shared among users/agents that already agree on underlying conceptualization. A fined-grained formal ontology provides a large set of axioms using highly expressive language. Although potentially a powerful tool, due to its complexity, a fine-grained ontology may be difficult to use for reasoning or developing applications.

An important statement by Guarino is that the ability to effectively share a formal ontology between agents (communities, computer systems) is inversely proportional to the resolution – low-resolution ontologies are highly portable – and granularity – fine granularity ontologies are less portable. This is intuitive in that low-resolution formal ontologies (top-level) model language that represents concepts that many can agree upon. Similarly, a highly axiomatized representation of language can be very expressive but makes many assertions. If a community rejects one or more assertions for a given term, then effective exchange is less likely. Similarly, to make use of a highly axiomatized system presents the necessity for understanding and implementing a highly complex model.

4.3.3 Information Communities

Previous sections of this paper have established that formal ontology requires agreement on the conceptualizations used in the formal model. To assist in the identification and modelling of the set of conceptualizations that are to be specified within the formal ontology, the concept of an *information community* is used to establish a category of people who conceptualize the world within a particular ‘universe of discourse’ (also referred to as a domain of discourse). A particular information community will have a shared interest in a set of geographic features in the real world with the implied or explicitly delineated geographic extent provided by the spatial boundaries of the features of interest (Bishr et al., 1999:58). In defining information communities, there is a distinction made between the information community that comprises people,

organizations, concepts and information, and the *project world* that is a computer representation of a particular application domain. This distinction is analogous to the distinction made between *domain* and *application* ontologies. To mediate between the fixed vocabulary, information schemas and other elements of a project world and an information community, a higher level, expressive language (i.e. formal ontology) is used.

4.3.4 Logic and Formalization

Formal logic is at the foundation of strong formal ontology (description logics, general logic). In general, logic is the study of how to decide the circumstances in which a set of true premises leads to a conclusion that is also true. Logic has been at the foundation of math and philosophy for at least a century and has been developed by a number of notable theorists including Aristotle, Euclid, Gottfried Leibniz, George Boole, Georg Cantor, Gottlob Frege, Bertrand Russell and Kurt Gödel. Formal logic moves from application of logical principals on a case-by-case basis (rhetoric) to a system that can allow arguments to be evaluated based on their truth-value and structure but independent of their content. Formal logic uses a symbolic approach (premises represented by variables) to apply axioms and develop logical theorems and proofs. Using this method, practitioners can evaluate the truth of conclusions based on a set of operators (e.g. and, or, not), implication rules (e.g. hypothetical syllogism) and equivalence rules (e.g. implication). Logic can be applied to establish tautologies (a situation where a statement is true under all interpretations) or to judge semantic equivalence (a situation where two statements have the same truth value under all interpretations).

Formal logic is based on three fundamental laws of thought:

- 1) The law of identity states that every individual thing is identical to itself
- 2) The law of excluded middle states that every statement is either true or false
- 3) The law of non-contradiction states that given a statement and its opposite, one is true and the other is false.

Formal logic and all of its rules and assumptions are fundamental to formal ontology. In essence, logical constructs are used to model domain semantics and then the laws and rules of logic are applied in a machine environment to process information (e.g. establish semantic equivalence or lack thereof, integrate similar information etc.). For a detailed treatment of formal logic, the reader is directed to general texts on logic (e.g. Tomassi, 1999)

To ground the discussion of how logic is used to facilitate information exchange and interoperability, a summary of a study by Kavouras and Kokla (2002) is presented as an example of how formal logic is applied to a formal ontology in an application environment. For other informative works, the reader is directed to Arpinar et al. (2006), Frank (2003) and Fonseca et al. (2002).

In their paper, Kavouras and Kokla (2002) present a method to integrate different geographic categories by applying Formal Concept Analysis (FCA) and concept lattices.

FCA is a model for the formal representation of conceptual knowledge that defines concepts as a subset of objects and attributes in the form GIM where G and M are objects and attributes respectively and I is a binary relation between G and M (Kavouras & Kokla, 2002:442). So, for a particular concept, gIm would be stated as g has the attribute m . In this particular study, the researchers integrate data categorized by landuse from a national database (Hellenic cadastre from Greece) with landuse data for a regional database (Europe's CORINE database). While the landuse concepts had some similarity, there were different labels in use and different hierarchical strategies and concept inclusion rules. For example, the Hellenic Cadastre contained a class of *Tertiary Sector* that overlapped two classes in the CORINE system (Commercial units; Artificial, non-agriculture vegetated areas).

The salient idea presented by Kavouras and Kokla is that new information can be constructed as a result of semantic mediation. Through logical evaluation among all objects and associated attributes concepts, inference is made to establish if classes were identical (same attributes even if the name was different), more generalized (smaller subset of shared properties), more specific (larger set of defining properties) or completely different (a separate concept). The result of the logical analysis in this case was a new, integrated classification scheme that could incorporate data from both source data sets. The new scheme retained some of the original classes from both original systems and derived a new subclass (Artificial Surfaces) and a new superclass (Commerce). In this case, the method used allowed for the integration of hierarchical,

overlapping geographical categorizations resulting in new concepts (i.e. landuse classes) being established and supporting interoperability between national and regional databases. It is however important to note that the initial stage of the analysis in which semantic relationships were formalized (e.g. synonyms, homonyms and naming heterogeneities in relation to attributes) was based on human expert knowledge of the domain of discourse. Thus, while the algorithm can process logical statements to infer semantic information, it cannot establish the initial relationship between objects, attributes and their relationship to real world entities (e.g. the semantics of attributes). To clarify, in the case of object A described by a set [] of attributes and object B defined by a set of attributes as follows:

$$A[t,u,v]$$

$$B[t,u,v]$$

An algorithm can infer that A and B belong to the same concept (are defined by the same attributes). However, the algorithm cannot establish what attributes t, u and v refer to in the real world and if, in fact, they are describing the same phenomena. It is for this reason that the development of sound top-level and domain ontologies are seen as important for the development of ontology applications.

4.4 Applied Perspective - Formalisation of Geographic Information

Formalisation of information is not a new concept within geography. For centuries, geographers have been attempting to establish systems of knowing in relation to the earth and the organisms that inhabit the planet. Cartographers have historically focussed on the

formalization of the graphic symbolic representation of geographic phenomena and have attempted to establish high-level theories to account for geographic observations (Robinson, 1984; Forrest, 1999). At a practical level, mapping agencies establish standard feature and symbology models such as that used for the National Topographic System in Canada (http://maps.nrcan.gc.ca/topo101/symbols_e.php). Although formalization is not new to geographers or cartographers, what has emerged in recent years is a new awareness of the impact and the implications of formalisation and ontology on the development of information systems. In many regards, this awareness is being driven by the movement towards formal ontology (Schuurman, 2006). As practitioners attempt to capture categories, attributes and relationships in a formal environment, there is a necessity to make explicit assumptions and definitions that may have previously been tacit, implied or assumed to be self-evident. As suggested by the discussion of cognitive models and other aspects of descriptive ontology, understanding and formalising geographic information is complex due to its multidimensional, multifaceted and sometimes vague nature. Geographic information combines linguistic, geometric and temporal concepts. Moreover, formalisation of geographic information involves various forms of representation (e.g. object vs. field / vector vs. raster vs. object-oriented); coordinate systems and datums ; units of measurement ; temporal concepts (instants, periods, tracks, feature succession) ; topological relationships, direction and more. Furthermore, geographic information formalisation arguably involves the incorporation of 'graphic language' and symbolization – i.e. cartography. A primary construct of descriptive geographic ontology and formalisation that has been

used for centuries by cartographers, and has been maintained in current geographic information systems that may or may not produce maps, is the geographic feature.

4.4.1 The Geographic Feature

At the highest level, a geographic feature is a concept. However, in real terms, the definition of concept comes from philosophy where a concept entails some form of categorization. From an information systems perspective, it is an element of information *about* phenomena with a relationship to the earth. A feature can be defined as:

“descriptions of real-world objects, which are categorized into particular types. Features can be concrete and tangible or abstract and conceptual. Features are described by properties that can be geometry properties or non-geometry properties (Lake et al., 2004). The International Organization for Standardization (ISO 19107) defines a feature as follows. “A feature is an abstraction of a real world phenomenon; it is a geographic feature if it is associated with a location relative to the Earth.” (ISO, 2005). Features are not strictly defined in that the construct can be used to represent atomic, aggregate, generalized and specialized concepts. While academic geography discusses geographic concepts, categories and kinds, in the applied world of geographic information, a geographic feature is an instantiation of concepts and consequently is reflective of descriptive geographic ontology. Geographic features are a primary input to formal ontologies dealing with geographic phenomena.

Although widely applied, formal ontologies in the strictest sense (description logics, general logic) are only just emerging and are still primarily in the realm of academia.

Less strict forms of ontology (metadata schema, conceptual models, UML etc.) have been developing for more than a decade due to the activities of organizations such as the Open Geospatial Consortium, ISO and the World Wide Web consortium (W3C). These schemata and models are being implemented in a wide variety of applications and many tools designed on these models have emerged. The next section of this chapter provides some discussion of the tools and standards related to developing various levels of ontology for geographic features.

4.4.2 Standards, Specifications and Serialization

The OGC and ISO have been developing a series of specifications and standards that formalize how we structure and exchange geospatial data. Using these specifications and standards, data is transformed to a format that can be directly transferred or readily translated. These data models are actualized through the use of Web Services such as Web Map Services (deliver graphic representations of geographic information), Web Feature Service (delivers raw data for object-based geographic information), Web Coverage Service (delivers raw data for field-based geographic information) and Sensor Observation Service (similar to Web Feature Service but delivers sensor information). All of these services deliver varying levels of metadata along with data and, in the most complete implementations, this metadata includes a full description using standardized metadata (e.g. ISO 19115). These information services were discussed in Chapter 3 and are mentioned here to establish where these services are situated on the semantic continuum. While the models used to design and implement the services provides fairly strong semantics, the service would not be as strong as a strict formal ontology (i.e. less

expressive) and therefore would not typically be appropriate for use in machine reasoning applications.

The data and metadata are obtained from geographic information services are typically delivered in an eXtensible Markup Language (XML) format and data can optionally be validated against an XML schema to ensure consistency and completeness. XML schema focuses on data typing and validation of data and combined with XML, facilitates ‘accurate’ transmission of data. Often, community schemas exist to support shared semantics for improved information exchange. For example, the OGC schemata provide models that validate information against agreed upon information elements such as geometry types, cartographic projections, measurement scales etc.. These general schemata can be extended to develop an *application schema* that considers the semantics specific to a particular domain. Geographic features are at the core of the specifications, standards and services discussed. Metadata ultimately describes features and schemas validate features and attributes against various models or other features. Thus, through the development of these metadata, conceptual and schema models, a semantic model of the foundational construct of the geographic feature is being established. Recalling Guarino (1998), geographic features are being defined either at the domain level (OGC) or the application level (application schema). Of course the domain level models derive from top-level ontologies that make certain assumptions about the nature of time and space etc..

Moving beyond XML schema to towards more expressive models, we move into the realm of the Semantic Web (Berners-Lee *et al.*, 2001). The Semantic Web is a broadly available instantiation of semantic mediation theory and research in the form of open standards that ultimately aim to achieve interoperability between information systems. The body leading the Semantic Web initiative describes it as such:

“The Semantic Web is a vision: the idea of having data on the web defined and linked in ways so that it can be used by machines – not just for display purposes – but for automation, integration and reuse of data across various applications, and thus fully harness the power of information semantics.” (Berners-Lee, 2000)

Figure 4.3 illustrates the Semantic Web ‘technology stack’. At the lowest level is a persistent and unambiguous syntactic level in the form of Unicode¹. At the same level, Universal Resource Identifiers (URIs) are a method for specifying a unique address for an information item. URIs

Figure 4.3 Semantic Web Technology Stack.

The bottom of the stack deals with syntactic information elements and fundamental semantics that would fall to the left of the semantic continuum presented in figure 4.1, while the top of the stack would be associated with the right-most portion of the semantic continuum (after Berners-Lee, 2000)

1 an industry standard allowing computers to consistently represent and manipulate text expressed

are often used to reference the unambiguous, stable vocabularies used in formal information approaches. Although XML and XML Schema are included in the technology stack, the more semantically expressive but lesser-known approach to describing semantics at the model level is through the use of the Resource Description Framework (RDF) developed through the W3C (Powers, 2002). Where XML is concerned primarily with data transmission and validation, RDF is concerned with data description. Effectively, RDF supports exchange and integration of metadata. It is a toolkit for making statements and connecting statements to derive meaning and so has its roots in formal logic. RDF supports the establishment of assertions made about resources accessible on the Web. The specification facilitates the exchange of metadata between systems and domains through reducing concepts to ‘triplets’ (subject, predicate, object) thus formalizing elements of a conceptual model. Triplets are expressed in the form:

<subject> HAS <predicate> <object>

RDF is not inherently hierarchical – multiple associations can be made resulting in very flexible ‘directed graphs’. A graph is another term for the subject, predicate and object relationship and are often expressed graphically (see Figure 4.4).

RDF provides a method and syntax for describing the objects and properties of a domain-specific schema by making assertions about objects and their attributes and relationships

within a specific domain of discourse. Hierarchical and quantifier properties such as *subClassOf*, *range*, and *domain* etc. can help to more precisely describe resources.

Figure 4.4 Visualization of a directed graph of a feature model

The graphic depicts the $\langle \text{subject} \rangle$ has $\langle \text{predicate} \rangle \langle \text{object} \rangle$ triplet. An example from this diagram is $\langle \text{scarfc:fa_asset_No} \rangle$ HAS $\langle \text{scarfc:dataType} \rangle \langle \text{character(20)} \rangle$. The scarfc: prefix is associated with a URI. This prefix eliminates ambiguity from the reference – when we talk about dataType we know we are referring to scarfc:dataType.

In summary, RDF supports relatively basic description of web-based resources and allows for basic reasoning from established associations (i.e. the directed graph). RDF does not support complex semantic modelling. The specification is appropriate where there exists a need to share information between disparate domains – the added complexity and overhead of implementation does not warrant use between relatively homogeneous domains. RDF is typically a starting point for developing a more expressive ontology using stronger types of formal ontology such as description logics and general logic.

If stronger semantic representation is required in the form of a more expressive modelling language, the primary tool in the Semantic Web technology stack is the Web Ontology Language (OWL). OWL is based on other languages such as the DARPA Agent Markup Language + Ontology Inference Layer (DAML + OIL). OWL builds on RDF and incorporates RDF concepts, syntax and schema while providing more expressive modelling tools including:

Cardinality: exact number allowed; max; min

Transitive: $P(x,y) \wedge P(y,z) \text{ implies } P(x,z)$

Symmetric: $P(x,y) \text{ iff } P(y,x)$

Intersection

Union

Complement

Enumeration: predetermined, closed set of members

Disjoint: guaranteed not to be a member of class

.....

(Powers, 2003)

Using a more semantically expressive language such as OWL supports the application of logic and the ability to infer new meaning, integrate information and facilitate activities such as advanced search. The standards and technologies outlined here provide the technical foundation for developing standardized formal semantic models of a domain of discourse.

4.4.3 Example: Developing an Antarctic Domain Ontology

Pulsifer and Cooper (2006) presented preliminary results on the development of a formal domain ontology of Antarctic geographic features based on the SCAR Feature Catalogue (SCAR FC) (Brolsma & Ryan, 2002; Scientific Committee on Antarctic Research, 2007). Pulsifer and Cooper demonstrated the practical and technical aspects of creating an ontology, in part through the use of textual analysis. This work, however, did not explore the nuances of establishing an ontology with respect to a particular application domain or for use by a particular information community as Chapter 5 of this thesis does. The SCAR FC (Figure 4.5) defines features and attributes of geographic features that can generally be described as domain level physical features (e.g. coastlines, glaciers, rocks, etc.).

A word within the name or synonym of a feature type	☐ Case sensitive search ☐ Highlight any matches
A word within the description	
Restrict to features within a theme	All themes
Restrict to features containing the attribute	All attributes
SCAR Composite Gazetteer of Antarctica Feature Class	All classes
Display options	Select all: ☐ Yes ☒ No ☒ Feature Type Name ☒ Definition ☐ The Themes of a feature type ☐ The Attributes of a feature type ☐ The Sources of a feature type ☐ The SCAR Class Name of a feature type ☐ Link from feature types to the Australian Antarctic Gazetteer ☐ Tick to create a text file for importing into the Geoplanner
Output Format	HTML -- If Excel or Word, enter its filename (ignoring extension) feature_types
Order the results by	Feature Type Code

Figure 4.5 Search interface to SCAR Feature Catalogue (Scientific Committee on Antarctic Research, 2007).

Each feature can have a variety of associated properties and values, for example the *certainty* property has a value list and associated definitions that help to define the vagueness related to a feature:

Approximate: In the data capture process the feature was evident but its location was not entirely clear

Connector: A line that is introduced for data completeness, e.g. a line used to close polygons, to represent missing data or data that is not visible

Definite: High level of confidence that the feature is correctly located

Inferred: In the data capture process the feature was not evident but the location of the feature was inferred

Interpolated: The location of the feature was determined by interpolation

In some cases, features might have a hierarchical definition such as the case of the feature type of *Coast*.

Types of Coastline

- Ice coastline
- Rock coastline
- Grounding line
- Rock against ice shelf
- Ice wall
- Iceberg tongue
- Floating glacier tongue
- Ice shelf and front
- Ice rumples

Pulsifer and Cooper (2006) establish that although originally designed as a reference for human consumption, the features and properties defined in the SCAR FC have the potential to be modelled using RDF (triplets) and OWL to support semantic mediation. In addition to simply converting the features and attributes captured in the SCAR FC to triplets, more detailed semantic relationships can be established through the use of the natural language definitions of features. To demonstrate, the definition of the feature *Rumple* is used to establish assertions. For simplicity a general form is used here, however the assertions can readily be translated to the RDF/OWL XML syntax.

Definition of feature type *Rumple*

A locally **grounded** area of **ice shelf** which is overridden by an **ice sheet**. Rumples are distinguished by **crevassing** together with a rise in the surface. The criterion for **distinguishing** between rumples and an ice rise is the **direction** of ice movement as shown by the **crevasse pattern**. Ice may be deflected or even halted by ice rumples, but in an ice rise, **movement is independent** of that of the ice shelf and, being in the main radial, will in places oppose it. **No** known rumples rise **more than 50 m** above ice shelf surface level, whereas ice rises may be up to **several hundred metres high**.

(SC-AGI, 2008)

Some model assertions then are:

Topological Relationships

(rumple, lies within, an ice shelf)

(rumple, is bounded by, [grounding line | rumple boundary])

Disjoint Relationships

(rumple, is not, an ice rise)

(rumple, is not, an ice shelf)

(rumple, is not, continental ice sheet)

(rumple, is not, greater than a few tens of meters high)

Association

(rumple, is similar to, an ice rise)

As suggested in Section 4.2.1 as part of the discussion on language and spatial cognition, words can be used to describe features and establish mental maps. In this example, a natural language definition of a feature has been used to establish semantic assertions about the feature that can be used in a formal ontological context. More information can be inferred if a hierarchical relationship model is established as demonstrated by Pulsifer & Cooper (2006). Figure 4.6 illustrates a conceptualized hierarchy using some features that exist in the SCAR FC (indicated by scarfc: prefix) and others that do not.

Figure 4.6 Modelling class hierarchies using mixed namespaces. Model after (Pulsifer & Cooper, 2006).

4.5 Implementation Tools

Applied formal ontologies using the RDF/OWL specifications are encoded in text base formats and so, in theory, one could develop a formal ontology with nothing more than a text editor. In practice though, tools are desirable to assist in the process of created syntactically correct and logically consistent formal ontologies. There are many tools available for use in developing various levels of formal ontology and modelling semantics and a detailed review will not be provided here. The tool used to support this research is called Protégé 2000 (<http://protege.stanford.edu>). Protégé is an open source tool that supports the input of features, properties and relationships and can output the semantic model in a number of formats, visualize the model and use an add-on inference engine to reason against the model. An inference engine is the generic control mechanism that applies the axiomatic knowledge present in the knowledge base/formal ontology to the task-specific data to arrive at some conclusion. Having a knowledge base/formal ontology alone is not of much use if there are no facilities for navigating through and manipulating the knowledge to deduce something from it. Figure 4.8 provides a screen shot of Protégé as it was used in this research.

Figure 4.7 Using Protégé 2000 to develop a formal ontology

4.6 Conclusion

This chapter began with an overview of the general goal of achieving interoperability and the challenges related to semantic interoperability. A review of various levels of ontology research was presented. The general concept of descriptive geographic ontology was discussed in terms of research in the areas of spatial cognition, categories and geographic kinds and critical theory and was followed by a review of machine-based formal ontology. Within the limits of formal logic, formal ontology approaches are seen to provide powerful information exchange and integration methods that can facilitate semantic interoperability. Combined with standards, specifications and technologies already being established (OGC, W3C etc.), semantic translation approaches have the potential to play an important role in moving towards fully interoperable geographic information systems.

What is clear from the review is the fact that while computer systems can process formal ontologies, the same machines cannot build the knowledge model on which the formal ontology is constructed. Creating the knowledge model requires the participation of members of an information community and domain experts who are familiar with the language, nature, complexities and nuances of a particular domain. A formal ontology begins with lists, glossaries, taxonomy and thesauri and then moves to metadata, extended models (schema, RDF, UML etc.), description logics or general logic as

application demands require. Regardless of the position of the ontology on the semantic continuum, all of the approaches with the exception of the 'list' approach require a strong understanding of the domain and its concepts and language. In fact, the OWL specification requires that knowledge community terms be explicitly defined and referenced as part of building an ontology (World Wide Web Consortium, 2004c). At its base, formal ontology models concepts, properties and relationships. Clearly defining these, even if logical modelling is not used, may help an information community towards improved information exchange and interoperability in the short term and the development of a formal ontology as needed in the longer term. It is at the early stage of modelling – the list creation stage - that the issues and questions raised and addressed by various research and development streams can and should be considered. In keeping with the philosophy underlying User Centered Design methodologies, community members can consider and make explicit appropriate potential uses, forms of representation, scope of the ontology, access to information policies and other aspects of the project early in the process. Various aspects of ontology construction can then be iteratively developed as the ontology development progresses.

The prospect of developing a formal ontology or description logic may seem quite overwhelming and possibly abstract to those who would ultimately be end users rather than developers of an interoperable information system (e.g. policy makers, scientists). The temptation might be to leave the construction of formal ontology to developers.

However, the review presented in previous chapters and the results of Chapter 5 suggest that reflexive and effective ontology construction requires dialogue among stakeholders such that everyone can contribute to and, ultimately, have a sense of the possibilities, limits, strengths and implications for a semantic mediation approach to interoperability. Construction of a formal ontology can be carried out in an incremental way that begins with the fundamental requirements of a formal ontology – defining features. The following chapter reports the results of a study that examined the consistency and completeness of an existing Antarctic feature catalogue in attempt to explore the development of a preliminary feature definition model and simple ontology for the AEG domain.

CHAPTER 5. TOWARDS A FORMAL ONTOLOGY FOR THE AEG DOMAIN

5.1 *Introduction*

Chapter 2 provided an overview of the AEG domain and selected information requirements of the Antarctic environmental protection regime. The diverse nature of the domain and the geographically and institutionally distributed information construction process within the domain, combined with the priority established for information exchange, environmental monitoring and state of the environment reporting by the Committee for Environmental Protection (Committee for Environmental Protection, 1998:Statement 6), suggests that the AEG would benefit from improved interoperability between the information systems supporting it (e.g. environmental monitoring, scientific databases for modeling etc.). The geographic and information and data management communities have placed priority on interoperability and the development of information systems based on a Service Oriented Architecture approach, however these developments are relatively new and thus are in the planning stages or early phases of development (JCADM, 2007; SC-AGI, 2007).

The development of a formal ontology has the potential to facilitate successful information sharing through interoperability by helping to mediate semantic

heterogeneity within the information community. As previously established, formal ontology requires the understanding of domain concepts and vocabulary to establish a model that can be used in semantic mediation processes. Efforts to establish a formal semantic model of Antarctic geography have already begun in the form of a general geographic domain vocabulary for the Antarctic called the SCAR Feature Catalogue (SCAR FC) (SC-AGI, 2008). The SCAR FC was originally conceived as the foundation for a formal ontology to be used by those developing information systems for the Antarctic region (Brolsma & Ryan, 2002). In theory, this shared geographic vocabulary can be used to develop a formal ontology for the AEG domain. What has not yet been established is whether the SCAR FC is consistent (provides semantic agreement) and complete (all concepts are captured) with respect to AEG regime semantics. This chapter reports the results of a content analysis that analyzed the SCAR FC for consistency and completeness with respect to the domain semantics of the AEG domain. Due to the geographically distributed location of stakeholders, performing focus groups or other such face-to-face approaches to analysing AEG domain semantics was beyond the scope of this research however this is being considered as a future research project. As a starting point, the body of documents that report the results of the ATCM, the ATCM corpus, were selected as a sample that would be partially representative of AEG domain geographic semantics and analysed using a content analysis approach. The aim of the study was to address the following general question:

Is a general domain vocabulary for Antarctic geography (i.e. SCAR FC) consistent and complete with respect to a vocabulary of the AEG domain as established through content analysis of the ATCM corpus?

This work uses a content analysis methodology theoretically based on work in cognitive mapping (Taylor, 2000; Tversky, 2000) and ontology construction (Kuhn, 2001) to address the stated question and develop the basis for a simple formal ontology (low resolution, low granularity)

It has been suggested in previous discussion that domain ontology is situated (in space and time) and to some extent contextually contingent. That is, that we cannot expect, for example, a policy community to have the same ontology as the science community, or one discipline to have the same ontology as another. Top level ontologies attempt to provide a semantically comprehensive framework that are applicable to a wide variety of applications as is suggested by the following description of the SCAR FC:

“The Feature Catalogue is the platform for creating understandable and accessible data to users by providing common, shareable semantics. The SCAR Feature Catalogue provides a detailed description of the nature and the structure of GIS and map information... Considerable effort has gone into ensuring that the Feature Catalogue is a unified and efficient tool that can be used with any GIS software and at any scale of geographic information (SC-AGI, 2008).

However, lacking studies examining the SCAR FC in comparison to the AEG domain specifically, it is appropriate to ground these assumptions through analysis.

The analysis is broken into two separate but related studies. Both are expected to address questions related to the relative consistency and completeness of the SCAR FC and to contribute to the overall development of a coarse geo-ontology for the AEG domain.

The first study primarily examines the completeness and semantic coherence observed when comparing the SCAR FC and the features model derived from analysis of the domains (SCAR FC, AEG). The second study examines the consistency and persistence of features over time and contributes to our understanding of the temporal stability of selected Antarctic geographic features. For example, do features emerge and possibly extinguish depending on the state of the regime?

To build on the previous discussion about the complexity and situated nature of domain ontology, the discussion provides a critical review of notable features and issues related to establishing (or not) a term as a feature. The chapter concludes by reporting on the codification of the results in the syntax of a formal ontology and proposing a method for further developing the ontology through community input.

5.2 *Methods*

Content analysis can be defined as the analysis of the manifest and latent content of a body of communicated material through classification, tabulation and evaluation of its key symbols and themes in order to ascertain its meaning and probable effect. This research analyzes content related to the Antarctic Treaty System for terms representing geographic features. A discussion of the methodological details of content analysis is not provided here. For this, the reader is directed to Krippendorff (2004). This research used

both quantitative (simple word frequencies) and qualitative (interpretation based on domain expertise) forms of content analysis to perform what is termed ‘simulation of hypothesis testing’ to test established hypotheses (Krippendorff, 2004:137-39). The method used is considered a qualitative analogue to statistical hypothesis testing but uses verbal logic to reject propositions by counterexample. Specific case studies were established to address two hypotheses as follows:

Study 1:

Null Hypothesis 1: All AEG feature terms (as established through analysis of the ATCM corpus) are semantically equivalent to the same terms in the SCAR FC

Alternative Hypothesis 1: All AEG feature terms are not semantically equivalent to the same terms in the SCAR FC

Inference if null hypothesis is rejected: The SCAR FC is not consistent relative to AEG geographic features

Null hypothesis 2: All AEG geographic features (as established through analysis of the ATCM corpus) exist in the SCAR FC

Alternative Hypothesis 2: All AEG geographic features do not exist in the SCAR FC

Inference if null hypothesis is rejected: The SCAR FC is not complete with respect to AEG geographic features

Study 2:

Study 2 does not compare the AEG corpus to SCAR FC but rather examines selected legal instruments from the corpus over time.

Null Hypothesis: Once an AEG geographic feature term is introduced to the domain of discourse, that geographic feature term (as established through analysis of the ATS corpus) will be effective and applicable throughout the lifespan of the Antarctic Treaty regime (at most, 1959 – present)

Alternative Hypothesis: Once an AEG feature term is introduced to the domain of discourse, that feature term will not necessarily be effective and applicable throughout the lifespan of the Antarctic Treaty regime (at most, 1959 – present).

Inference if null hypothesis is rejected: AEG feature terms are not necessarily stable over time.

The rationale for Study 1 is related to the theory that a formal ontology should be a consistent and complete specification of domain semantics. One can assume that a

general geographic domain ontology for the Antarctic, such as the SCAR FC, would apply to the AEG domain in terms of capturing and constraining geographic information semantics. However, without verification, we cannot be certain that 1) the feature terms used in both domain ontologies are semantically equivalent (refer to the same concept) 2) the terms in the general geographic domain ontology are sufficient to address the semantic requirements of the AEG domain. To test this, the SCAR Feature Catalogue is used as an analogue for a general geographic domain ontology – it is more accurately a partial domain glossary and partial schema (it does define attributes but not necessarily essential attributes).

Preliminary tests revealed that the SCAR FC was relevant to the ATS corpus. The SCAR FC terms were used to automatically code the ATS text, with the result that over 25,000 instances of the SCAR FC feature terms were identified. This does not tell us how many of those instances are true features due to the potential effects of context (e.g. Land can be a noun or a verb – feature in one case, not in the other), however a sample analysis of the Madrid Protocol document reveals 600 valid instances of SCAR FC features after validation through manual inspection. Accepting that the SCAR FC ontology and the AEG ontology intersect, does not establish that the SCAR FC features in the ATS documents completely overlap – i.e. SCAR FC represents all features in the ATS corpus. Hypothesis 1 of Study 1 tests the ATS corpus to establish if there are feature terms found in the ATS corpus that are not semantically equivalent to the same term in SCAR FC. If this is the case, then the null hypothesis must be rejected and the alternative accepted (i.e.

inferring semantic inconsistency). Hypothesis 2 of Study 1 tests the ATS corpus to establish if there are any features that exist in the corpus that do not exist in SCAR FC. If this is the case, then the null hypothesis must be rejected and the alternative accepted (inferring incompleteness).

For Study 1, Annexes related to Antarctic Specially Protected Area (ASPA) management plans were analysed. These management plans can apply to Protected Areas, Specially Managed Areas or Sites of Special Scientific Interest. Requirements for management plans include:

“a description of the area, including: i. the geographical co-ordinates, boundary markers and natural features that delineate the area; ii. access to the area by land, sea or air including marine approaches and anchorages, pedestrian and vehicular routes within the area, and aircraft routes and landing areas; iii. the location of structures, including scientific stations, research or refuge facilities, both within the area and near to it; (ATCM XVI, 1991: Article 5)

Based on these requirements, the management plans included in annexes were deemed a suitable source for geographic feature information.

The rationale for Study 2 is related to the observation that many high level geographic concepts (e.g. Tiers 3 & 4 in Frank, 2001) are established in the legal instruments that are

part of the ATS. It is expected that higher-level concepts resulting from human activities (including the establishment of laws) would be more likely to change over time. Thus, a sample of legal instruments representing different periods in the development of the ATS was selected for testing. If it is the case that a feature emerges and then, in some way becomes ineffective or inapplicable (e.g. feature cannot be instantiated; feature contradicts another feature), then the null hypothesis must be rejected and the alternative accepted (inferring the possibility for feature instability).

The general content analysis method used in the studies is described in subsequent sections.

5.2.1 General Methodology

The primary source of text used in the content analyses was the Antarctic Treaty System corpus of policy documents. This corpus comprises the final reports of all Antarctic Treaty Consultative Meetings. These documents were accessed using the Antarctic Treaty Searchable Database (<http://aspire.tierit.com>). Content analysis and visualization was computer assisted by a qualitative analysis tool (Atlas.ti <http://www.atlasti.com/product.html>). Various standard tools from the Unix-based operating system (e.g. GREP) were also used to facilitate quantitative aspects of the analysis.

5.2.2 Unitizing

Sampling Units: Categorical analysis was not carried out on the entire corpus. Sample documents were analysed. The top-level sampling units are individual ATCM final reports by year (e.g. Final report for ATCM I, 1961). A second tier sampling unit was also established and was dependent upon the study. For Study 1, the sampling unit was the “Annex to Measures” document type. Each ATCM final report is hierarchically divided into a number of sections (see Figure 5.1 for example). Since 1995, these sections have included Decisions, Measures and Resolutions. The documents of interest in Study 1 were selected Annexes of Resolutions (see sampling). For Study 2 the sampling unit was the legal instrument documents (e.g. Antarctic Treaty, CRAMRA etc.).

Figure 5.1 ATCM final report document hierarchy (from <http://aspire.tierit.com/search.htm>)

Recording/Coding Units and Method: The coding unit established in these analyses was a *Term* which is defined here as a word or phrase that refers to a concept. Specifically, the coding unit was referred to as a geographic feature (or feature). Please refer to Chapter 4 for a more detailed discussion of geographic features. A feature is defined here as:

“A feature is an abstraction of a real world phenomenon; it is a geographic feature if it is associated with a location relative to the Earth.” (ISO 19110) (ISO, 2005)

By design, this definition leaves significant opportunity for interpretation. However, other definitions were considered when coding. These aspects of features were also considered.

- Real world objects categorized into particular types. Features can be concrete and tangible or abstract and conceptual. A feature is described in terms of its properties which can be geometry properties (location, form, extent) or non-geometry properties for a feature (Lake et al., 2004)
- A feature can be associated with a location on the Earth using a number of methods including absolute positioning (e.g. co-ordinates), relative positioning (e.g. adjacency), by nominal reference (e.g. placename) or by conceptual reference (e.g. an administrative unit)

- In consideration of the strategy already adopted by the SCAR Feature Catalogue and the multifaceted nature of environmental governance, a feature need not be a landform. It can, for example, be an organism (e.g. plant colony) or a transportation device (e.g. ship)
- A feature can be interpreted from an information systems perspective as an external entity that produces or consumes information in the system (Lo & Yeung, 2007:426)

In practical terms, codes were applied and managed using a content analysis software package (see Figure 5.2). Quotes related to codes were then processed to create the results reported in this chapter. In addition to the coding of features, a second code (feature_definition) was assigned to text interpreted to represent feature definition concepts. Feature definition text in some way describes or provides attributes or details related to the feature. A visualization of a feature-feature definition association is presented in Figure 5.3.

Figure 5.2 Codes applied to ATS corpus documents using qualitative analysis software

Figure 5.3 Visualization of feature and feature definition code associations. Feature definitions in some way describe or define features (i.e. micro-organism type).

The coding was based on a categorical (semantic) distinction rather than a mechanical, syntactical, propositional or thematic distinction (see Krippendorff, 2004::103-109).

5.2.3 Sampling

The sampling strategy used depended upon the study.

Study 1. A sample of seven annex documents describing management plans for Antarctic Specially Protected Areas (ASPAs) from the following years were chosen:

- 1992 (ASPAs 101) (ATCM XVII, 1992),
- 1995 (ASPAs 109) (ATCM XIX, 1995),
- 1997 (ASPAs 105) (ATCM XXI, 1997),
- 1999 (ASPAs 142) (ATCM XXIII, 1999),
- 2002 (ASPAs 147) (ATCM XXV, 2002),
- 2003 (ASPAs 160) (ATCM XXVI, 2003),
- 2005 (ASPAs 163) (ATCM XXVIII, 2005a)

Note that ASPAs have recently been renumbered and therefore the historic number assigned may not agree with the currently assigned number used here. For more information on a particular ASPA, please refer to <http://cep.ats.aq/cep/apa/aspa/index.html>.

Although management plans have existed since the 1970s, they have become more comprehensive since the adoption of the Madrid Protocol in 1991 and so only management plans post-1991 were sampled. In addition, a geographic sampling approach was taken, choosing management plans from a variety of regions in the area. This was done to ensure the best chance of establishing a representative sample of feature types. Figure 5.4 is a map depicting the location of the ASPAs for which the management plans were sampled.

Figure 5.4 Map depicting identification numbers of sampled Antarctic Specially Protected Areas (ASPAs).

Study 2. A sample of four ATS legal instruments was chosen. The Antarctic Treaty itself was chosen because of its central role relative to all other instruments. In this regard it is seen as foundational. Three other instruments were chosen based on a model proposed by Berkman (Berkman, 2002:72). Berkman proposes the Antarctic treaty regime has developed in three phases: the Establishment Phase (1961 – 1976), the International Accommodation Phase (1976 – 1991) and the International Stewardship Phase (1991 – present). See Figure 5.5 for a graphic depiction of accession to the treaty. An interactive version of this visualization can be accessed at <http://atlases.gcrc.carleton.ca/antarctic/ats2/ats.xml.html>. The Agreed Measures were analysed as representative of a legal instrument adopted in the Establishment Phase. The CRAMRA (minerals convention) was analysed as representative of a legal instrument adopted in the International Accommodation Phase. The Madrid Protocol was analysed as representative of a legal instrument adopted in the International Stewardship Phase.

Figure 5.5 A spatio-temporal cartographic depiction of accession to the Antarctic Treaty over time.

The graph below the map represents the temporal development of national accession to the treaty. The x axis represents the year of accession. The y axis represents cumulative number of signatories over time. The size of a circle represents the number of signatories in a given year. The colour adheres to Berkman's phases as labelled on the graph.

5.3 Results

In this section, selected results from the analyses performed in Study 1 and Study 2 are presented in table format. In the interest of brevity, the bulk of the results are found in Appendix B. Geographic features interpreted from the analysis of the reports of the Antarctic Treaty document as acquired from the Antarctic Treaty Searchable Database (<http://aspire.tierit.com/>) are presented in tabular format. Each table provides information on:

- the geographic feature term identified
- whether the feature is included in the SCAR FC
- document reference
- textual context of the feature term
- the SCAR FC definition (if applicable) or a proposed definition from other sources, optionally followed by any author's discussion notes related to the feature

In the interest of efficiency, the author's notes found in the last column of the table provide detailed discussion text that is then synthesized in Section 5.4.

5.3.1 Study 1

Table 5.1 provides a listing of geographic features resulting from the analysis of the document ATCM XVII (1992), Annex to Recommendation XVII-2. Specially Protected Area (SPA) No. [01], Taylor Rookery, MacRobertson Land. This SPA has

since been reassigned as an ASPA and has been renumbered to 101. Henceforth it will be referred to as ASPA 101. The features identified in Table 5.1 exist in the SCAR FC and in many cases, the interpreted semantics of the features are consistent with the SCAR FC. However, in some cases, the semantics are not equivalent (e.g. *Land*) and ambiguity is observed. The discussion section (5.4) elaborates on this ambiguity. Based on this result, the stated null hypothesis:

Null Hypothesis 1: All AEG feature terms (as established through analysis of the ATCM corpus) are semantically equivalent to the same terms in the SCAR FC

is rejected, and the stated alternative hypothesis

Alternative Hypothesis 1: All AEG feature terms are not semantically equivalent to the same terms in the SCAR FC

is accepted with the stated inference also accepted

Inference if null hypothesis is rejected: The SCAR FC is not consistent with respect to AEG geographic features

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Bay	Y	Map A	Map legend or label	SCAR FC definition: Properly a smooth, comparatively gradual indentation of the coastline, the seaward opening of which is usually wider than the penetration into the land, but often applied more to loosely, cf. bight, firth, fjord, gulf, inlet.
Beach	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 2	The Area also has a raised beach which is typical of several found along the coast...	SCAR FC definition: The unconsolidated material that covers a gently sloping zone, typically with a concave profile, extending landward from the low-water line to the place where there is a definite change in material or physiographic from (such as a cliff), or to the line of permanent vegetation (usually the effective limit of the highest storm waves); a shore of body of water, formed and washed by waves or tides, usually covered by sand or gravel, and lacking a bare rocky surface.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Camp(s)	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 7 Paragraph 3	...area where all activity such as landing helicopters and installing field huts or field camps should take place	SCAR FC definition: A temporary residence, when away from the station.
Coast	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 2	The Area also has a raised beach which is typical of several found along the coast of Mac Robertson Land.	SCAR FC definition: Boundary between land and sea, applied in place-names to lengths of coastline determined partly by the history of their discovery and partly by convenient demarcation points, cf. land.
Colony	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 1, Paragraph 1	...originally designated a Specially Protected Area because it contains a colony of emperor penguins...	SCAR FC definition: A collection of animals, plants, etc., connected, in contact, or living close together.
Glacier	Y	ATCM XVII (1995), Annex to Recommendation	There is ice free terrain adjacent to the glacier on the western boundary...	SCAR FC definition: A mass of snow and ice continuously moving from higher to lower ground or, if afloat, continuous spreading.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

<i>SCAR FC Feature Types</i>	<i>Semantic Agreement with SCAR FC</i>	<i>Doc reference (Section (subsection) or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/fic)</i>
<i>Head</i>	Y	XVII-2, Item 5(a), Paragraph 1	Map legend or label	SCAR FC definition: Comparatively high, steep faced land jutting into the sea or into an ice shelf; similar to promontory but applied to a feature of lesser extent, cf. cape, point. An unnamed head is usually described as a headland.
<i>Headland</i>	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 8(a)(iii), Paragraph 1	...helicopters are authorised to land in the Area, to the North-East at the point marked "H", where a <i>headland</i> to the South obscures the colony from view.	SCAR FC definition: Comparatively high, steep faced land jutting into the sea or into an ice shelf; similar to promontory but applied to a feature of lesser extent, cf. cape, point. An unnamed head is usually described as a headland.
<i>Hill(s)</i>	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 1, Paragraph 1	The colony is ideal for counting since it is surrounded by small rocky <i>hills</i> which make it possible to observe every bird	SCAR FC definition: Natural elevation usually below 300m, but the term may be applied to much higher (although relatively low) features in mountainous areas, cf. knoll, mountain.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Ice	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	... the rock rises steeply to meet the ice of the plateau.	SCAR FC definition: The solid state of water, monomineral rock.
	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	...and the islands of corner of a bay formed by Taylor Glacier to the East.	SCAR FC definition: A land mass, especially one smaller than a continent, entirely surrounded by water.
Land	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Title	Taylor Rookery, MacRobertson Land	SCAR FC definition: Large continental area defined by natural boundaries, or partly by natural boundaries and partly by boundaries of political convenience. Outside the area covered by this work the term may be synonymous with territory. The use of land does not refer to the ground, rather it is a generic part of a toponym.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Moraine	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	...around a central flat area of exposed rock and moraine.	SCAR FC definition: A mound, ridge, or other distinct accumulation of unsorted, unstratified glacial drift, predominantly till, deposited primarily by direct action of glacier ice, in a variety of topographic landforms that are independent of control by the surface on which the drift lies.
Outcrop	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1 Map B	The rookery is located on a low lying rock outcrop...	SCAR FC definition: A detached rock mass, or group of rocks, distinctively shaped by erosion and weathering.
Peak	Y		Map legend or label	SCAR FC definition: A hill or mountain with a comparatively sharp summit.
Penguins	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 1, Paragraph 1	...originally designated a Specially Protected Area because it contains a colony of emperor penguins...	SCAR FC definition: Sea-fowl of southern hemisphere with wings developed into scaly flippers with which it swims under the water.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Plateau	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	... the rock rises steeply to meet the ice of the <i>plateau</i> .	SCAR FC definition: More or less extensive ice-covered area of relatively high and uniform elevation, which may include one or more domes and be limited by mountain walls or not so limited,
	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 2	It slopes upwards from the shoreline to a well defined <i>platform</i> several meters broad and 3 to 6 m above sea level.	SCAR FC definition: A small plateau or flat rock massif.
Protected Area	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 1, Paragraph 1	The area was originally designated a Specially <i>Protected Area</i> because it contains a colony of emperor penguins (<i>Aptenodytes forsteri</i>)...	SCAR FC definition: An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity and/or of natural and associated cultural resources. The area is managed through legal or other effective means.
Range	Y	Map A	Map legend or label	SCAR FC definition: Row of mountains, or groups of mountains broken by glaciers, extending over a considerable distance.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Refuge	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(c), Paragraph 1	...structures including scientific stations, research and refuge facilities...	SCAR FC definition: A shelter from extreme or dangerous environmental conditions such as those posed by the weather.
Ridge	Y	Map B	Map legend or label	SCAR FC definition: Long narrow hill or mountain top or spur leading to a summit; the term may also be applied to submarine features.
Ridge(s)	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	The sides of the horseshoe are rounded ridges of rock	SCAR FC definition: Long narrow hill or mountain top or spur leading to a summit; the term may also be applied to submarine features.
Rock	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	The Area consists of the whole of the northernmost rock exposure on the east side of Taylor Glacier...	SCAR FC definition: Any aggregate of minerals that makes up part of the earth's crust. It may be unconsolidated, such as sand, clay, or mud, or consolidated, such as granite, limestone, or coal.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Rookery	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Title	The rookery is also important because of long-term monitoring...	SCAR FC definition: Nesting and breeding places of a penguin colony, usually of Emperor penguins.
Route(s)	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 7, Paragraph 2 / Map B	Map B shows the location of the field hut on the Colbeck Archipelago, and access routes to the Area; (examination of Map B reveals route types of: Vehicle Approach Helicopter Approach.)	SCAR FC definition: Any established or selected course for passage or travel.
Sea ice	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 1, Paragraph 1	Almost all other emperor penguins rookeries are located on sea ice.	SCAR FC definition: Any form of ice found at sea which has originated from the freezing of seawater.

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Snow	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	This Area is covered with snow in winter and is occupied by the emperor penguins.	SCAR FC definition: Atmospheric precipitation of ice crystals.
	Y	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(c), Paragraph 1	Location of structures including scientific station(s)	SCAR FC definition: A place where there is permanent human habitation and infrastructure serving as a base for scientific research.
Tongue	Y	Map A	Map legend or label	SCAR FC definition: A projection of the ice edge up to several km in length caused by wind and current.
Land	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 1, Paragraph 1	of the known colonies of this species located wholly on land.	SCAR FC definition: This usage of Land conflicts with the first usage of Land (see above)

Table 5.1 Features derived from analysis of management plan for ASPA 101 (ATCM XVII, 1992).

Features listed here are captured by the SCAR FC but do not necessarily agree with the SCAR FC definition as indicated by the 'Semantic Agreement' column

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (Section (subsection) or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Marker(s)	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 3	There are no boundary markers since the area is easily defined by its natural features.	SCAR FC definition: Marker/s around boundary of area of dangerous rocks (See also <i>Boundary Marker</i> in Table 5.2)

Table 5.2 provides a list of features, interpreted from the management plan for ASPA 101 that are not captured in the SCAR FC or are sufficiently inconsistent with the SCAR FC definition to be considered an independent feature. All of the features listed in Table 5.2 are unique to the ATS corpus, that is, they are not captured in the SCAR FC. For a complete listing of new features established through the Study 1 content analysis, please refer to Appendix B. Based on the sample results provided (ASPA 101), the stated null hypothesis:

Null hypothesis 2: All AEG geographic features (as established through analysis of the ATCM corpus) exist in the SCAR FC

is rejected, and the stated alternative hypothesis

Alternative Hypothesis 2: All AEG geographic features do not exist in a general Antarctic geographic feature ontology.

is accepted with the stated inference also accepted

Inference if null hypothesis is rejected: The SCAR FC is not complete with respect to AEG geographic feature terms

Table 5.2 Features established through the review of the management plan for ASPA 101 (ATCM XVII, 1992).

These features are not captured in the SCAR FC. In most cases, a proposed definition is provided in the rightmost column of the table

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Hut (field)	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 7, Paragraph 2	Map B shows the location of the field <i>hut</i> on the Colbeck Archipelago, and access routes to the area	Definition: a small, simple, single-storey house or shelter (Soanes, 2004).
Ice Cap (Polar)	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	The rookery is located on a low lying rock outcrop in the South-West corner of a bay formed by Taylor Glacier to the West, the <i>polar ice cap</i> to the South and the islands of corner of a bay formed by Taylor Glacier to the East.	Definition: A covering of ice over land. ...ice-cap is frequently used to describe a dome-shaped cover in a highland massif during a mountain glaciation. But accepted usage also includes reference to the.. 'polar ice-caps' which are of much greater dimension (Whittow, 2000:258). SCAR FC defines Ice Cap as part of the definition of <i>ice sheet</i> : Ice sheets of less than about 50,000 square km resting on rock are called ice caps. SCAR FC does not account for 'polar ice-cap' usage and does not have an <i>ice cap</i> feature type.

Table 5.2 Features established through the review of the management plan for ASPA 101 (ATCM XVII, 1992).

These features are not captured in the SCAR FC. In most cases, a proposed definition is provided in the rightmost column of the table

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Access points	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(b), Paragraph 1	"Restrictions apply to the mode of transport to and within the Area, and access points are prescribed;"	An abstract concept that would generally be instantiated with another feature type such as SCAR FC <i>pontoon</i> , or SCAR FC <i>beach</i> . However, this term is regularly used to refer to a more general concept and thus is part of the ontology. Can also be seen as having a topological relationship (terminus point) to the feature <i>route</i> .
Arch	N	Map A	Labeled feature on Map A	Definition: A natural opening through a mass of rock or boulder clay (Whittow, 2000:26).

Table 5.2 Features established through the review of the management plan for ASPA 101 (ATCM XVII, 1992).

These features are not captured in the SCAR FC. In most cases, a proposed definition is provided in the rightmost column of the table

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Bird	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 1, Paragraph 1	The colony is ideal for counting since it is surrounded by small rocky hills that make it possible to observe every <i>bird</i> without entering the breeding area.	Definition: a warm-blooded egg-laying vertebrate animal of a class distinguished by the possession of feathers, wings, and a beak, typically able to fly. • Class Aves. (Soanes, 2004). May also derive definition from Agreed Measures definition of <i>native bird</i> : "native bird" means any member, at any stage of its life cycle (including eggs), of any species of the Class Aves indigenous to the Antarctic or occurring there through natural agencies of dispersal; (ATCM, 1964: Agreed Measures for the Conservation of Antarctic Fauna and Flora, Article II, (b))
Cracks	N	ATCM XVII (1995), Annex to Recommendation	"Otherwise the terrain is rough and dissected with <i>cracks</i> and fissures."	No definition found in specialized dictionaries (e.g. Park, 2007); Whittow, 2000). Raises question - at what point is a feature definition considered

Table 5.2 Features established through the review of the management plan for ASPA 101 (ATCM XVII, 1992).

These features are not captured in the SCAR FC. In most cases, a proposed definition is provided in the rightmost column of the table

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Fissures	N	XVII-2, Item 5(a), Paragraph 2	"Otherwise the terrain is rough and dissected with cracks and fissures."	Definition: A crack or open break in rocks (Whittow, 2000:189)
Ice free terrain	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 2	"There is <i>ice free terrain</i> adjacent to the glacier on the western boundary and to the south the rock rises steeply to meet the ice of the plateau."	Definition: An area of terrain not covered by ice (from author). Seems an obvious definition, however, supporting machine interpretation requires precise definition. Also introduces question: is this feature equivalent to the second instance of Land in Table 5.1 or could it simply be defined as negation of ice as an attribute of a feature <i>terrain</i> ?

Table 5.2 Features established through the review of the management plan for ASPA 101 (ATCM XVII, 1992).

These features are not captured in the SCAR FC. In most cases, a proposed definition is provided in the rightmost column of the table

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Lake	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	"The compressed snow melts in summer to form a shallow lake and stream which exits to the North-East."	Definition: 1) An enclosed body of water, usually but not necessarily fresh water, from which the sea is excluded. 2) A standing body of a relatively fluid substance, e.g. water, oil, asphalt (Whittow, 2000:292); SCAR FC has more general feature of <i>water body</i>
Melt Lake	N	Map C/ ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	Labeled feature on Map C + feature inferred from "The compressed snow melts in summer to form a shallow lake and stream which exits to the North-East."	A lake formed from water resulting from the melting of glacier ice and/or snow (Whittow, 2000:327). A specialization of <i>lake</i> and/or SCAR FC <i>water body</i> . Important to note that <i>melt lake</i> has different persistence properties when compared to other types of <i>lakes</i> - it only exists for a limited period of time.

Table 5.2 Features established through the review of the management plan for ASPA 101 (ATCM XVII, 1992).

These features are not captured in the SCAR FC. In most cases, a proposed definition is provided in the rightmost column of the table

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Pathway(s)	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 8(a)(i)	"Persons in the vicinity, not approaching the colony, should also be aware of the penguins <i>pathways</i> , and take care to cause as little disturbance to them as possible."	Definition: Path - A way or track formed by the continued treading of pedestrians or animals, rather than one deliberately planned and made. Pathway - A way that constitutes or serves as a path; a path, a track. (Soanes, 2004)
Shoreline	N	ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 2	"It slopes upwards from the <i>shoreline</i> to a well defined platform several meters broad and 3 to 6 m above sea level."	Definition: A line of contact between a land surface and a lake or ocean surface. Differs from the term coastline, which is not normally used to describe a lake shore. (Whittow, 2000:478)
Stream	N	Map C/ ATCM XVII (1995), Annex to Recommendation XVII-2, Item 5(a), Paragraph 1	"The compressed snow melts in summer to form a shallow lake and <i>stream</i> which exits to the North-East."	Definition: A natural body of running water that flows along a channel (Park, 2007:430). SCAR FC has a more general feature of <i>water course</i> .

As stated, the establishment of geographic features from analysis of the ATS corpus rejects the proposed null hypothesis and accepts the alternative hypothesis which infers that the SCAR FC is not complete with respect to AEG geographic feature terms. Thus, content analysis as reported here has the potential to support the expansion of the SCAR FC in the short term and the development of a domain ontology in the longer term. Study 2 examines the persistence of features over time and is reported in a format similar to Study 1.

5.3.2 Study 2

The results of Study 2 are presented here in table format. An analysis of the Antarctic Treaty and the three sampled Antarctic Treaty instruments (Agreed Measures, CRAMRA, and Madrid Protocol) are presented. In the interest of a concise presentation, selected features are reported as they emerge. For example, the feature *Treaty Area* is established through the analysis of the Antarctic Treaty, however, it also occurs in the three instruments analysed and many other corpus documents but is not reported in the other results tables. To help summarize the results in terms of feature persistence, a timeline visualization is provided in the discussion section (5.4.2)

Antarctic Treaty (1959)

The Antarctic Treaty of 1959 is the core agreement in the Antarctic Treaty System and all other instruments. For this reason, the Antarctic Treaty was analysed to explore the fundamental geographic features that exist within the text of the treaty. The Antarctic

Treaty is a relatively short, high-level document as opposed to the other instruments analysed (e.g. does not address implementation details as with other instruments) and as such, the features observed are few in number and mostly abstract. Nevertheless, the discussion provided in Section 5.4.2 reveals that these features are nuanced and important to the establishment of a domain ontology.

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ftc/) / Notes
Claim	Y	Antarctic Treaty (1959), Article IV(1)	prejudicing the position of any Contracting Party as regards its recognition or non-recognition of any other State's rights of or <i>claim</i> or basis of claim to territorial sovereignty in Antarctica.	SCAR FC: An area claimed by a country as an external territory of that country. / In this case, 'claim' is considered an inherently geographic term in that a geographic location is inherently associated with the 'territory'. Interesting that the term claim comes up in AT, CRAMRA, CCAMLR but few other documents in the corpus. Seems to be a high level concept that is only used in the AT and selected instruments.
Ice Shel(f)(ves)	Y	Antarctic Treaty (1959), Article VI	The provisions of the present Treaty shall apply to the area south of 60° South Latitude, including all <i>ice shelves</i> ,	SCAR FC: A floating ice sheet of considerable thickness attached to a coast. Ice shelves are usually of great horizontal extent and have a level or gently undulating surface. They are nourished by the accumulation of snow and often by seaward extension of land glaciers. Limited areas may be aground. The seaward edge is termed an ice front. / An example of strong semantic coherence between context of usage in ATS corpus and SCAR FC

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc) / Notes
Ship(s)	Y	Antarctic Treaty (1959), Article VII(3)	including all stations, installations and equipment within those areas, and all <i>ships</i> and aircraft	SCAR FC has an undefined feature type of <i>ship</i> . / Whether to establish a ship as a feature is an interesting and debatable question. It can certainly be argued, that in the era of GPS tracking and telemetry and location based services, that a <i>ship</i> can be a feature in an information systems (e.g. navigation and safety related tracking systems). Going to Lo & Yeung (2007:327), a feature is partly defined as "external entities that produce or consume information in the system". <i>Ship</i> could be defined as a feature under this definition. From a functional perspective, a <i>ship</i> may also serve the same purpose as a <i>station</i> i.e. a base for scientific research. Regardless, would be worth discussing in that <i>ships</i> will play an important role in collecting information related to AEG (e.g. compliance activities). In this regard, it may be an important geographic agent that affords certain AEG activities.

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc) / Notes
Station(s)	Y	Antarctic Treaty (1959), Article III(1)	...scientific personnel shall be exchanged in Antarctica between expeditions and stations;	SCAR FC: A place where there is permanent human habitation and infrastructure serving as a base for scientific research. / An example of strong semantic coherence between context of usage in ATS corpus and SCAR FC
Territory	N	Antarctic Treaty (1959), Article VII(5)	all expeditions to and within Antarctica, on the part of its ships or nationals, and all expeditions to Antarctica organized in or proceeding from its territory;	SCAR FC: Extent of land under the jurisdiction of a sovereign state. / Interesting discussion as to whether this definition is appropriate in relation to this particular quote: " Considering the text of article IV, a more appropriate definition might be something to the effect of: An area for which one has certain rights or for which one has responsibility with regard to a particular type of activity. In terms of similar usage, there is a context in biology where the term is used as: "Most pairs have observation points close to petrel nests, from which they can observe their food territory on the bird cliffs." 2005, Measures, Annex to Measure XXVIII-2 ASPA 103

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc) / Notes
[Antarctic] Treaty Area	N	Antarctic Treaty (1959), Article VI	Inferred from quote: "...present Treaty shall apply to the area south of 600 South Latitude"	Proposed definition: Area falling within the jurisdiction of the Antarctic Treaty (from author). See Section 5.4.2 for more detailed discussion.
Aircraft	N	Antarctic Treaty (1959), Article VII(3)	All areas of Antarctica, including all stations, installations and equipment within those areas, and all ships and <i>aircraft</i> at points of discharging or embarking cargoes or personnel in Antarctica,	Proposed definition: Flying-machines collectively; a flying-machine. (Soanes, 2004) / Interestingly, this feature is not included in SCAR FC in active form, however <i>aircraft wreckage</i> is defined. SCAR FC does define a potentially similar term <i>ship</i> , which raises the question of why <i>aircraft</i> is not included in SCAR FC.
Antarctica	N	Antarctic Treaty (1959), Preamble	Recognizing that it is in the interest of all mankind that <i>Antarctica</i> shall continue for ever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord;	Proposed definition: The continent of Antarctica. (from the author) / Can be interpreted as being somewhat synonymous with the <i>treaty area</i> , however this usage may imply a more physiographic intention as opposed to administrative/legal.

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (*Parties to the Antarctic Treaty, 1959*)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ftc) / Notes
Areas of Antarctica	N	Antarctic Treaty (1959), Article VII(2)	Each observer designated in accordance with the provisions of paragraph 1 of this Article shall have complete freedom of access at any time to any or all areas of Antarctica.	<p>Proposed definition: Sub-regions of the Antarctic <i>treaty area</i>. May include administrative territory or physiographic region. (from the author) / Very abstract concept related to mereology of the domain. Examining the context of usage implies that although there is a container area (<i>treaty area</i>), this <i>treaty area</i> is subdivided into regions, places or local areas that contain features such as <i>stations, installations, equipment</i> etc. These <i>areas of Antarctica</i> may implicitly refer to <i>claims</i> or perceived territories (e.g. British Antarctic Territory) although this text makes it clear that no signatory can prevent an observer from entering such <i>areas of Antarctica</i>. Context examination of 5 other instances reveals that the feature is also used in a very generic sense such as "... few ice-free <i>areas of Antarctica</i>" presenting potential ambiguity.</p>

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) / Notes
Equipment	N	Antarctic Treaty (1959), Article I(2)	The present Treaty shall not prevent the use of military personnel or <i>equipment</i> for scientific research or for any other peaceful purpose.	Proposed definition: Anything used in equipping; scientific instruments, camp gear, survival gear ; necessities for a research expedition or other operations. (Derived from Soanes, 2004) / This feature is established based on inference from SCAR FC. A number of equipment types are included in SCAR FC (e.g. <i>AWS, Apparatus, Repeater, Rack</i>) however no general parent class exists. A general class may be important for integration. In subsequent document analysis it is revealed that the characteristics and location of <i>equipment</i> (general class) must be established as part of a protected area management plan or an environmental impact assessment.

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) / Notes
High Seas	N	Antarctic Treaty (1959), Article VI	... but nothing in the present Treaty shall prejudice or in any way affect the rights, or the exercise of the rights, of any State under international law with regard to the <i>high seas</i> within that area.	Proposed definition: General term for international areas of the oceans that lie beyond the legal control of any nation. Similar to open sea. (Park,2007:211) Open sea - that part of the ocean that lies beyond the continental shelf. (Park, 2007:319). / High seas south of 60s are geometrically contained with the <i>treaty area</i> , however the legal relationship is fuzzy at best. Context of the quote defines the feature of <i>treaty</i> <i>area</i> by effectively excluding (or at least making fuzzy) the inclusion of the <i>high seas</i> . Nevertheless, <i>high seas</i> are part of the domain of discourse. SCAR FC does not have definition of <i>high seas</i> . It does have a definition of <i>sea</i> , however this is from a physiographic perspective - "A body of salty water that covers much of the Earth" - rather than an administrative or legal perspective

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic) / Notes
Installations	N	Antarctic Treaty (1959), Article VII(3)	All areas of Antarctica, including all stations, <i>installations</i> and equipment within those areas,	Proposed definition: A mechanical apparatus set up or put in position for use; a large piece of permanent equipment installed for use or a military or industrial establishment (derived from Soanes, 2004). / Noted because it is explicitly differentiated from a <i>station</i> or <i>equipment</i> . Clearly similar to equipment in this instance context. Definition would probably entail level of permanence - station defined as permanent, installation may be more permanent than Equipment or possible related to SCAR FC <i>apparatus</i>

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ftc) / Notes
Point(s) of discharging	N	Antarctic Treaty (1959), Article VII(3)	All areas of Antarctica, including all stations, installations and equipment within those areas, and all ships and aircraft at <i>points of</i> <i>discharging</i> or embarking cargoes or personnel in Antarctica,	Proposed definition: The place in the Antarctic <i>treaty area</i> at which ships or aircraft discharge personnel or cargo. (from author) /. This is a functional feature. Node in logistical/operational transportation network and as such of interest to AEG process. An abstract feature with an instantiation being e.g. <i>airfield</i> or <i>harbour</i> , <i>wharf</i> etc. Note: SCAR FC contains a feature <i>point</i> , however it is defined as: Sharp and often comparatively low piece of land jutting out from the coast or forming a turning point in the coastline. This presents potential ambiguity.

Table 5.3 Selected geographic features derived from the analysis of the Antarctic Treaty (1959) (Parties to the Antarctic Treaty, 1959)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic) / Notes
Point(s) of embarking [cargoes personnel]	N	Antarctic Treaty (1959), Article VII(3)	All areas of Antarctica, including all stations, installations and equipment within those areas, and all ships and aircraft at <i>points of</i> discharging or <i>embarking</i> cargoes or personnel in Antarctica,	Functional feature. The place in the Antarctic <i>treaty area</i> at which personnel or cargo embark on a journey aboard a ship or aircraft. (from author) / Same discussion point as <i>points of discharging</i>

Agreed Measure (1964)

With the exception of Article IX 1(f) which mentions the preservation and conservation of living resources in Antarctica as a matter of common interest between parties, the Antarctic Treaty does not comprehensively address environmental or conservation issues. The Agreed Measures for the Conservation of Antarctic Fauna and Flora (1964), an instrument of the Antarctic Treaty, began the process of specifically addressing environmental and conservation issues and concerns. Analysis of the Agreed Measures reveals a number of features that reflect this focus. In many cases, the features identified may not be perceived as a geographic features (e.g. *native bird*), however the analysis follows the precedent set by the SCAR FC in this regard. As can be seen from the results, the content analysis used here can reveal inconsistencies in existing information resources such as the SCAR FC.

Table 5.4 Features derived from the analysis of the 'Agreed Measures' (1964) (ATCM III, 1964)

Feature Types	Exists in		"Context" from ATS corpus	Notes	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/)
	SCAR FC	Doc reference, Article (section)			
Protected Area(s) [Specially]	Y	Agreed Measures, (1964), Article VIII(2)	In addition to the prohibitions and measures of protection dealt with in other Articles of these Agreed Measures, the Participating Governments shall in Specially Protected Areas further prohibit: a) the collection of any native plant, except in accordance with a permit; b) the driving of any vehicle.	SCAR FC: An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity and/or of natural and associated cultural resources. The area is managed through legal or other effective means. / An example of strong semantic coherence between context of usage in ATS corpus and SCAR FC	
(Native) Bird	N	Agreed Measures, (1964), Article II(b)	"native bird" means any member, at any stage of its life cycle (including eggs), of any species of the Class Aves indigenous to the Antarctic or occurring there through natural agencies of dispersal;	SCAR FC: Has <i>Flying Bird</i> - Feathered vertebrate with two wings and two feet. / This is a general class that would contain the more specific feature of native bird	

Table 5.4 Features derived from the analysis of the 'Agreed Measures' (1964) (ATCM III, 1964)

Feature Types	Exists in		Doc reference, Article (section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic) / Notes	
	SCAR	FC				
(Native) Mammal	N	N	Agreed Measures, (1964), Article II(a)	"Native mammal" means any member, at any stage of its life cycle, of any species belonging to the Class Mammalia indigenous to the Antarctic or occurring there through natural agencies of dispersal, excepting whales;	SCAR FC: Mammal - Any animal of the Mammalia, a large class of warmblooded vertebrates having mammary glands in the female, a thoracic diaphragm, and a four-chambered heart. The class includes the whales, carnivores, rodents, bats, primates, etc. / This is a general class that would contain the more specific feature of native mammal	

Table 5.4 Features derived from the analysis of the 'Agreed Measures' (1964) (ATCM III, 1964)

Feature Types	Exists in		SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) /
	SCAR FC	Doc reference, Article (section)	Notes
(Native) Plant	N	Agreed Measures, (1964), Article II(c)	<p>"Context" from ATS corpus</p> <p>"native plant" means any kind of vegetation at any stage of its life cycle (including seeds), indigenous to the Antarctic or occurring there through natural agencies of dispersal;</p> <p>Suggested definition: Any kind of vegetation at any stage of its life cycle (including seeds), indigenous to the Antarctic or occurring there through natural agencies of dispersal (text)</p>
Circumpolar Range	N	Agreed Measures, (1964), Preamble	<p>the unique nature of these fauna and flora, their circumpolar range, and particularly their defencelessness and susceptibility to extermination;</p> <p>Having a habitat range round or about the entire polar region (from author)</p>

Table 5.4 Features derived from the analysis of the 'Agreed Measures' (1964) (ATCM III, 1964)

Feature Types	Exists in SCAR FC	Doc reference, Article (section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/) / Notes
Non-indigenous animal	N	Agreed Measures, (1964), Article IX(1)	of any species of animal or plant not indigenous to that Area, except in accordance with a permit.	Related to SCAR FC Introduction of animal species: Animals which have been translocated by human agency into lands or waters where they have not lived previously, at least during historic times. Such translocation of species always involves an element of risk if not of serious danger. Newly arrived species, depending on their interspecific relationships and characteristics, may act as or carry parasites or diseases, prey upon native organisms, display toxic reactions, or be highly competitive with or otherwise adversely affect native species and communities. / This reveals potential inconsistency problem with SCAR FC – in most cases, object is defined, in some cases process is defined.

Table 5.4 Features derived from the analysis of the 'Agreed Measures' (1964) (ATCM III, 1964)

Feature Types	Exists in SCAR FC	Doc reference, Article (section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc) / Notes
Non-indigenous plant	N	Agreed Measures, (1964), Article IX(1)	of any species of animal or plant not indigenous to that Area, except in accordance with a permit.	Related to SCAR FC: Introduction of plant species: Plants which have been translocated by human agency into lands or waters where they have not lived previously, at least during historic times... On the other hand many plants introduced into modified or degraded environments may be more useful than native species in controlling erosion or in performing other positive functions. / This reveals potential inconsistency problem with SCAR FC – in most cases, object is defined, in some cases process is defined

Table 5.4 Features derived from the analysis of the 'Agreed Measures' (1964) (ATCM III, 1964)

Feature Types	Exists in SCAR FC	Doc reference, Article (section)	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) /	
			"Context" from ATS corpus	Notes
Protected species	N	Agreed Measures (1964), Article VI(5)	The species of native mammals and birds listed in Annex A of these Measures shall be designated "Specially Protected Species", and shall be accorded special protection by Participating Governments.	Suggested definition: Species of native mammal or native bird within the Treaty Area that is protected from being killed, wounded, captured, molested, subjected to harmful interference or any attempt at being subjected to harmful interference (derived by author from text)

CRAMRA (1988)

The situation leading to the current 'legal limbo' status of the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) (1988) was discussed in Chapter 2. The historic context of the described events of 1988-1991 is important from a geographic conceptualization perspective. The selected geographic features presented in Table 5.5 reveal a conceptually rich proposed geography constructed from the visions and procedures established in CRAMRA. Some of the features established in the convention have persisted beyond the 'CRAMRA Crisis' while others remain in limbo along with the instrument itself. Regardless of the status of a feature, the results presented here provide insight into the potentially dynamic nature of the descriptive and formal ontology of the AEG domain.

Table 5.5 Features derived from the analysis of CRAMRA (1988)(CRAMRA, 1988 #285)				
Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/) / Notes
Deep seabed	N	CRAMRA (1988), Article 5(3)	1988 - For the purposes of this Convention 'deep seabed' means the seabed and subsoil beyond the geographic extent of the continental shelf as the term continental shelf is defined in accordance with international law.	Concept first introduced and formally defined as a feature in CRAMRA .
Dependent or associated ecosystems	N	CRAMRA (1988), Preamble	Recognising that Antarctic mineral resource activities could adversely affect the Antarctic environment or <i>dependent or associated ecosystems</i> ;	This is an abstract feature in that it is a concept that has geographical implications in terms of the areal extent of jurisdiction. Although the feature was first introduced in CRAMRA (preamble), it has survived to present day.

Table 5.5 Features derived from the analysis of CRAMRA (1988)(CRAMRA, 1988 #285)

Feature Types	Exists in		Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/) / Notes	
	SCAR	FC				
Mineral resource deposits	N		CRAMRA (1988), Article I(8)	aimed at identifying and evaluating specific mineral resource occurrences or deposits,....	The physical entity that is the object of exploration and development	
Mineral Exploration Area	N		CRAMRA (1988), Article 21(d).	Antarctic Mineral Resources Recognizing that available information is insufficient reliably to assess the possible environmental effects of many activities in the area of exploration and exploitation of mineral resources in Antarctica,... / to determine, in accordance with Article 41, whether or not to identify an area for possible exploration and development, and to perform the related functions assigned to it in Article 42;"	This feature defines where mineral exploration activities can take place. The feature is refined in other articles of CRAMRA.	

Table 5.5 Features derived from the analysis of CRAMRA (1988)(CRAMRA, 1988 #285)

Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/) / Notes
Mineral Prospecting area	N	CRAMRA (1988), Article I(8)	'Prospecting' means activities, including logistic support, aimed at identifying <i>areas of mineral resource potential</i> for possible exploration and development, including geological, geochemical and geophysical investigations and field observations, the use of remote sensing techniques and collection of surface, seafloor and sub-ice samples	This feature defines where mineral prospecting activities can take place. The feature is refined in other parts of CRAMRA.
Mineral Development area	N	CRAMRA (1988), Article I(8)	CRAMRA - Article I(8) ... aimed at identifying <i>areas of mineral resource potential</i> for possible exploration and <i>development</i> , including geological, geochemical and geophysical investigations and field observations, the use of remote sensing techniques and collection of surface, seafloor and sub-ice samples.	This feature defines where mineral development activities can take place. The feature is refined in other parts of CRAMRA.

Table 5.5 Features derived from the analysis of CRAMRA (1988)(CRAMRA, 1988 #285)				
Feature Types	Exists in SCAR FC	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) / Notes
Prohibited area	N	CRAMRA (1988), Article 13(1)	Antarctic mineral resource activities shall be <i>prohibited in any area</i> designated as a Specially Protected Area or a Site of Special Scientific Interest under Article IX(1) of the Antarctic Treaty. Such activities shall also be prohibited in any other area designated as a protected area in accordance with Article IX(1) of the Antarctic Treaty, except to the extent that the relevant measure provides otherwise.	Although similar to a protected area, under CRAMRA a prohibited area designated outside the Antarctic Treaty protected area designation process. However, an Antarctic Specially Protected Area is typically a Prohibited Area under CRAMRA.
Regulated Area	N	CRAMRA (1988), Article 12(1)	Aerial inspection may be carried out at any time over the <i>area</i> in which Antarctic mineral resource activities are <i>regulated</i> by this Convention.	Feature defining jurisdictional extent

Table 5.5 Features derived from the analysis of CRAMRA (1988)(CRAMRA, 1988 #285)

Feature Types	Exists in		Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/) / Notes
	SCAR	FC			
Seabed	N	N	CRAMRA (1988), Article 5(2)	...this Convention shall regulate Antarctic mineral resource activities which take place on the continent of Antarctica and all Antarctic islands, including all ice shelves, south of 60° south latitude and in the <i>seabed</i> and subsoil of adjacent offshore areas up to the deep seabed.	Although a recognizable physical feature, Seabed initially emerges as an AEG feature only in the context of mineral exploration and development. Reference to the seabed continues after the signing of Madrid protocol.
Seafloor	N	N	CRAMRA (1988), Article I(8)	... field observations, the use of remote sensing techniques and collection of surface, <i>seafloor</i> and sub-ice samples.	Although a recognizable physical feature, Seafloor initially emerges as an AEG feature only in the context of mineral exploration and development. Reference to the seafloor continues after the signing of Madrid protocol.

1991 Madrid Protocol

In May of 1989, representatives of France and Australia announced that they would not ratify CRAMRA, the convention that they had signed in November of 1988 (Joyner, 1998:78). This led to the abandonment of CRAMRA and the move towards a comprehensive environmental protection regime for the Antarctic region. The subsequent Madrid Protocol (1991) has resulted in a new geography for the region that is still evolving today. The results presented in Table 5.6 reveal a number of features laid out in the Madrid Protocol. In some cases, these features are established in the protocol or Recommendation XV-1 from ATCM XV (1989) that called for the development of a comprehensive environmental protection regime. In other cases, features were established many decades before are affirmed in the Madrid Protocol. More detailed discussion on the evolution of features is provided in Section 5.4.2.

Table 5.6 Features derived from the analysis of the Madrid Protocol (1991) (ATCM XVI, 1991)

Feature Type	Exists in SCAR FC?	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic) / Notes
Crashed aircraft	Y	Madrid Protocol (1991), Annex III: Article 8(3)	Each such Party shall, as far as is practicable, also prepare an inventory of locations of past activities (such as traverses, field depots, field bases, crashed aircraft) before the information is lost	SCAR FC contains Aircraft Wreckage which is defined as "The remnants or remains of an aircraft such as an aeroplane or helicopter.". Crashed Aircraft as found in Madrid Protocol can be seen as a synonym of Aircraft Wreckage.
Pedestrian routes	Y	Madrid Protocol (1991), Annex V: Article 5(3.e.ii)	access to the area by land, sea or air including marine approaches and anchorage, pedestrian and vehicular routes within the area,	SCAR FC has general feature route defined as: Any established or selected course for passage or travel./ A linear feature that highlights emergence of a series of 'human activity' features in Madrid Protocol. May be an important feature when analysing impact of tourism in Antarctica.

Table 5.6 Features derived from the analysis of the Madrid Protocol (1991) (ATCM XVI, 1991)

Feature Type	Exists in SCAR FC?	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) / Notes
Waste storage	Y	Madrid Protocol (1991), Annex III: Article 1(3)	Waste storage, disposal and removal from the Antarctic Treaty area, as well as recycling and source reduction, shall be essential considerations in the planning and conduct of activities	SCAR FC has a specialized feature waste disposal site defined as: A place for depositing rubbish./ SCAR FC does not account for all forms of waste. Abstract feature that might be instantiated as features such as dump site, tank etc.. Highlights emergence of a series of 'human activity' features in Madrid Protocol
Abandoned work sites	N	Madrid Protocol (1991), Annex III: Article 1(6)	Past and present waste disposal sites on land and abandoned work sites of Antarctic activities shall be cleaned up by the generator of such wastes and the user of such sites.	Abstract feature that would likely be instantiated as features such as Hut, Refuge, Installation etc.. Highlights emergence of a series of 'human activity' features in Madrid Protocol

Table 5.6 Features derived from the analysis of the Madrid Protocol (1991) (ATCM XVI, 1991)

Feature Type	Exists in SCAR FC?	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) / Notes
Areas of Significance [biological scientific historic aesthetic wilderness]	N	Madrid Protocol (1991), Article 3(2bvi)	activities in the Antarctic Treaty area shall be planned and conducted so as to avoid... vi. degradation of, or substantial risk to, areas of biological, scientific, historic, aesthetic or wilderness significance;	A prominent feature with respect to establishing protected areas. Interesting that the concept was actually first established in CRAMRA but persisted through Madrid Protocol and is used in subsequent years (e.g. 1997,98,2003,04,05)
Environmental Indicators	N	Madrid Protocol (1991), Article 5	Procedures shall be put in place, including appropriate monitoring of key environmental indicators, to assess and verify the impact of any activity that proceeds following the completion of a Comprehensive Environmental Evaluation.	Abstract feature that would be instantiated instantiated through other features related to environmental monitoring (e.g. point data used to map temperature, salinity, toxicity etc.).

Table 5.6 Features derived from the analysis of the Madrid Protocol (1991) (ATCM XVI, 1991)

Feature Type	Exists in SCAR FC?	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/) / Notes
Field bases	N	Madrid Protocol (1991), Annex III: Article 8(3)	Each such Party shall, as far as is practicable, also prepare an inventory of locations of past activities (such as traverses, field depots, field bases, crashed aircraft) before the information is lost	As with Abandoned Work Sites, Crashed Aircraft etc., highlights emergence of a series of 'human activity' features in Madrid Protocol
Ice pit(s)	N	Madrid Protocol (1991), Article 4(2)	generated by stations located inland on ice shelves or on the grounded ice-sheet may be disposed of in deep ice pits where such disposal is the only practicable option.	Referred to in relation to human activity of waste disposal. An ice-pit is a vague description and thus is considered a fiat object. Does not have strong commitment to SCAR FC definition of Pit "A small covered hole generally to give access to communication and electrical networks."

Table 5.6 Features derived from the analysis of the Madrid Protocol (1991) (ATCM XVI, 1991)

Feature Type	Exists in SCAR FC?	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) / Notes
Marine area	N	Madrid Protocol (1991), Annex V: Article 2	any area, including any marine area, may be designated as an Antarctic Specially Protected Area or an Antarctic Specially Managed Area. Activities in those Areas shall be prohibited	A specialization or attribute of more general feature Protected Area. Referred to in future ATS corpus documents I.e. ATCM xxvi (2003) Annex To Measure XXVI-2 [Antarctic Specially Protected Area No 161 - Terra Nova Bay, Ross Sea]
Micro-organisms [viruses, bacteria, parasites, yeast, fungi]	N	Madrid Protocol (1991), Annex II: Article 4(6)	Each Party shall require that precautions, including those listed in Appendix C to this Annex, be taken to prevent the introduction of micro-organisms (e.g., viruses, bacteria, parasites, yeasts, fungi) not present in the native fauna and flora.	A specialization of the Agreed Measures feature Non-indigenous [plant animal]. Indicates evolution of the perceived risk related to non-indigenous species.

Table 5.6 Features derived from the analysis of the Madrid Protocol (1991) (ATCM XVI, 1991)

Feature Type	Exists in SCAR FC?	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc/) / Notes
Natural Reserve	N	Madrid Protocol (1991), Article 2	The Parties commit themselves to the comprehensive protection of the Antarctic environment and dependent and associated ecosystems and hereby designate Antarctica as a natural reserve, devoted to peace and science.	A high level feature that is a recognized concept in the conservation community. Natural Reserves or Natural Area Preserves are defined by (Park, 2007:297) as an area of land designated by a private or public agency to preserve a representative sample of an ecological community primarily for scientific and education purposes. Commercial exploitation is generally not allowed and public use is discouraged. If natural reserve were added to an AEG ontology, would need to be defined specific to Antarctic context.
Oil spill(s)	N	Madrid Protocol (1991), Annex IV: Article 12(1)	...fixed sites or of ships) operating in the Antarctic Treaty area, particularly ships carrying oil as cargo, and for oil spills, originating from coastal installations, which enter into the marine environment.	Infers the creation of a feature that represents the areal extent of an oil spill.

Table 5.6 Features derived from the analysis of the Madrid Protocol (1991) (ATCM XVI, 1991)

Feature Type	Exists in SCAR FC?	Doc reference, Article(section)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic/) / Notes
Particulate deposition	N	Madrid Protocol (1991), Annex III: Article 3(2)	allowance shall be made for the wind direction and speed and the type of wastes to be burnt to limit <i>particulate deposition</i> and to avoid such deposition over areas of special biological, scientific, historic, aesthetic or wilderness significance	Infers a particulate deposit or sewage plume area feature.
Special Conservation Area	N	Madrid Protocol (1991), Preamble	Recalling the designation of Antarctic as a <i>Special Conservation Area</i> and other measures adopted under the Antarctic Treaty system to protect the Antarctic environment and dependent and associated ecosystems;	Originally introduced in Agreed Measures, reiterated in 1989 and then reaffirmed in Madrid Protocol. An example of a persistent small scale, fiat feature.

The results of Study 2 reveal that there were a number of features (e.g. Prospecting Area, Development Area) established within the CRAMRA instrument that were made ineffective (at least until 2048) with the signing and subsequent entry into force of the Madrid Protocol. Specifically, Article 7 states simply:

“Any activity relating to mineral resources, other than scientific research, shall be prohibited.” (Madrid Protocol, 1991: Article 7)

Considering the effect of Article 7, the hypotheses proposed for this study are evaluated as follows:

Null Hypothesis: Once an AEG geographic feature term is introduced to the domain of discourse, that geographic feature term (as established through analysis of the ATS corpus) will be effective and applicable throughout the lifespan of the Antarctic Treaty regime (at most, 1959 – present)

is rejected, and the stated alternative hypothesis

Alternative Hypothesis: Once an AEG feature term is introduced to the domain of discourse, that feature term will not necessarily be effective and applicable throughout the lifespan of the Antarctic Treaty regime (at most, 1959 – present).

is accepted, and the stated inference is accepted

Inference if null hypothesis is rejected: AEG feature terms are not necessarily stable over time.

5.4 Discussion

5.4.1 Study 1

Study 1 provides a number of interesting points of discussion in terms of the features established and the inconsistency and incompleteness observed when comparing the AEG corpus features with features contained in the SCAR FC. For example, Table 5.7 presents two examples of homonyms revealed through the analysis of the 1992 management plan presented for ASPA 101. The feature *land* is an interesting one in that the AEG feature commits to what might be considered a more common usage of the term. The SCAR FC definition is more closely associated with place name assignment during the heroic age of exploration and, subsequently, the territorial claims established in the early 20th century. Consultation with the maintainers of the SCAR FC (Personal Communication, Henk Brolsma, July 8, 2006) suggests that the current SCAR FC definition will remain as the authoritative semantics although establishment of a synonym could be considered. This suggests that in the case of the feature *land*, the geopolitical interpretation of the term takes priority over the physical interpretation of the term. This has important implications for semantic mediation in support of interoperability. Under the described situation, information resources using the feature term *land* would be interpreted under the geopolitical interpretation. Moreover, the physical interpretation

would be explicitly established as a disjoint (is not) relationship within a formal ontology due to the component of the SCAR FC that states “The use of land does not refer to the ground, rather it is a generic part of a toponym.”.

Table 5.7 Example of feature homonyms found using content analysis

<i>ATS Corpus</i>	<i>Definition or Usage</i>	<i>SCAR FC</i>	<i>Definition</i>
Land	The part of the Earth that is not covered by water as opposed to the sea or the air	Land	Large continental area defined by natural boundaries, or partly by natural boundaries and partly by boundaries of political convenience. The term was formally used by explorers for newly discovered lengths of coastline, cf. coast. Outside the area covered by this work the term may be synonymous with territory. The use of land does not refer to the ground, rather it is a generic part of a toponym.
<i>Marker(s)</i>	There are no boundary <i>markers</i> since the area is easily defined by its natural features.	<i>Marker</i>	SCAR FC definition: Marker/s around boundary of area of dangerous rocks (See also <i>Boundary Marker</i> in Table 5.2)

Although the analysis of the management plan for ASPA 101 establishes a significant level of agreement between features interpreted from the ATS corpus and those defined in the SCAR FC, the identification of homonyms identifies feature ambiguities or disagreement that would need to be resolved if full interoperability were to be achieved.

The results presented in Appendix B, Tables B.1 and B.3 provide other examples of

feature ambiguity. While the number of ambiguous features is small relative to number of features with semantic agreement, it is important to note that 1) the sample size of 7 documents was relatively small – for example, in 2005 and 2006 alone, 25 management plans were submitted to the ATCM. Increasing sample size may reveal more examples of ambiguity. 2) each ambiguous feature type would result in a failure with respect to the achievement of semantic interoperability making the identification of each ambiguity important. Moreover, the analysis examines feature types or classes rather than individual feature instances that exist in geographic databases. A feature type such as *structure* (see Table B.3) could represent many hundreds of feature instances.

Although the aforementioned ambiguous terms present a problem with respect to achieving semantic interoperability, some ambiguity cannot be easily eliminated. There are, in fact, two meanings for the geographic feature of *land*, each representing a valid geographic concept. In the case of the AEG domain, the physical interpretation would be more representative of AEG community semantics, however this does not make the geopolitical interpretation less valid. In this case, it appears that multiple meanings would need to be assigned to the feature term with a qualification indicating the context of usage on a feature-by-feature basis. This type of qualification can be modeled using formal ontology, however it is the community that must first establish the ambiguity and associated qualifications using methods such as those applied here.

The second test performed as part of Study 1 reveals a significant level of incompleteness when comparing the AEG corpus features to the SCAR FC. Incompleteness appears to be primarily a function of three factors:

1. Scale
2. Disciplinary specificity
3. Level of abstraction

Many of the new features established are most appropriate for analysis and representation at large scale (e.g. *fissures*). Although the SCAR FC aims to be relevant at all scales, the catalogue was developed based primarily on reference to medium and small-scale maps (Brolsma & Ryan, 2002) and GIS applications. In contrast, ASPAs are typically very small areas and are thus mapped, surveyed and described at large scales. This can explain the incompleteness in this regard. Other features established are discipline specific (e.g. *melt lake* – glaciology) and may not be appropriate for inclusion in the more general SCAR FC. However, within a disciplinary domain, the feature is valid. This is an example of the relationship between a Project World (i.e. the discipline) and the Information Community. In this case, discipline level features can be included in an application level ontology with explicit relationships to higher level concepts (i.e. *water body*) made. The SCAR FC was developed as a ‘flat catalogue’ and by design no hierarchical structure is established. For this reason, many higher-level abstractions are omitted from the catalogue, as they do not have bona fide qualities. This is another case

where newly proposed features that have a high level of abstraction (e.g. *high seas*) may not be suitable for inclusion in the SCAR FC. However, in the case of building a domain ontology, feature hierarchies are typically used to link and integrate disparate levels of information. It is for this reason that a sample hierarchical semantic model was established in the experimental SCAR FC ontology as described in Chapter 4 (Pulsifer & Cooper, 2006). To make use of the inferential capabilities of a formal ontology as processed by an inference engine, a hierarchical model is highly desirable if not necessary. The results of the analysis suggest that such a model could be constructed for the AEG domain.

5.4.2 Study 2

The following section provides a discussion of selected features from the results of the Study 2 content analysis. Although Study 2 was intended to focus on the temporal qualities of geographic feature in the AEG domain, the analysis revealed many interesting points of discussion and nuances that relate to the consistency, completeness, structure and content of an ontology. Thus much of this discussion relates to semantic modelling in general rather than strictly dynamic aspects of features.

Figure 5.6 illustrates the evolution of selected features over time. We see features such as *treaty area* established early and persisting. Other features such as *mineral exploration area* have short life spans and are made ineffective in relation to particular

Figure 5.6 Timeline of selected AEG Features.

Feature such as Treaty Area were established early and are persistent, while features such as Mineral Development Area and Mineral Exploration Area were established much later and have a relatively short lifespan. The events related to the emergence and extinction of features are indicated as points. An interactive version of this timeline can be accessed at: http://devel0.gcrc.carleton.ca/~peterpulsifer/aeg_feature_evolution/aeg_feature_evolution.html

events (i.e. CRAMRA inert).

1959 Antarctic Treaty

Many points of discussion are provided in the results related to Study 2 (Tables 5.3 -5.6).

A few points are highlighted here to elucidate the nuances and complexity involved in establishing geographic information ontology.

Seemingly simple features such as *treaty area* can prove to be complex features when considered beyond simple geometric description. As a term, *treaty area* occurs more than 300 times in the ATS corpus starting with Article VIII of ATCM I in 1961.

However, the term was first defined by inference in Article VI of the Antarctic Treaty (1959).

“The provisions of the present Treaty shall apply to the area south of 60[d] South Latitude, including all ice shelves, but nothing in the present Treaty shall prejudice or in any way affect the rights, or the exercise of the rights, of any State under international law with regard to the high seas within that area.”

While this text defines the geographic extent of *treaty area*, it also provides us with information defining the properties of the feature. Specifically, in administrative terms *ice shelves* are part of the *treaty area*, while the *high seas* are not (or at least are a limited part). The uncertainty related to the treaty area and other international conventions related to the high seas (Joyner, 1998:241) suggests that while the *treaty area* feature can

be readily defined in terms of geometry (south of 60[d] South Latitude), the semantics of that feature cannot be fully captured and constrained as the semantics with respect to jurisdiction are not entirely clear. Moreover, establishing the geometry of the *treaty area* is not entirely unproblematic depending upon which ATS legal instrument is considered. The Convention on the Conservation of Marine Living Resources (CCAMLR, 1980) for example, uses a slightly different jurisdictional area (see Joyner:137) that is based on the ecosystem concepts related to the biological Antarctic convergence (Joyner, 1998:135) rather than an arbitrary geographic grid location (see Figure 5.6).

Figure 5.7 Map of CCAMLR Statistical Reporting Subareas and the Polar Front (also known as the Antarctic Convergence). Map constructed using data from (Orsi & Ryan, 2001; Australian Antarctic Division, 2002)

Both the jurisdictional uncertainty and the geometric variability in relation to *treaty area* poses potential challenges to geographic information interoperability that would need to be considered as part of constructing a formal ontology for the AEG domain.

Interestingly, despite the apparent importance of the *treaty area* feature to the AEG domain, the SCAR FC provides a definition of *treaty* (the legal document) but does not define the corresponding geographic feature of *treaty area*.

In terms of feature persistence, the development of the CCAMLR *treaty area* boundaries establishes that the feature can change over time. Similarly, the uncertainty around the relation of the Southern Ocean and international maritime law relates to the stability of the feature to international legal processes. Of course, changes in the Antarctic Treaty regime itself can also change the nature and/or extent of the feature. All of this makes the overall treaty geography contingent, which can in turn affect descriptive and formal ontologies of the AEG domain – i.e. jurisdiction of environmental protocol.

1964 Agreed Measures

As suggested in Chapter 2, the Antarctic Treaty did not place a primary focus on conservation values and procedures. In examining the content of the Agreed Measures, we find an emergence of conservation principles and values and as a result, interesting additions to the geographic ontology. In some cases, these features are found in SCAR FC, however in other cases, there are related concepts but the semantics are quite different.

The features *native bird* and *native mammal* emerge from the analysis of the Agreed Measures. While the SCAR FC has related concepts, there is incongruity in terms of level of abstraction. The SCAR FC features of *flying bird* and *mammal* are more general terms. Supporting semantic mediation within the AEG domain would require the establishment of more specialized features.

The results also reveal inconsistency in the nature of the features defined in the SCAR FC. In most cases, the SCAR FC defines objects, however in some cases processes are defined. The SCAR FC provides a definition for *introduction of animal species* and then goes on to define both object (animals) and process “translocated”. In this analysis, the ATS corpus contains the object feature *non-indigenous animal*. Failure to address this seemingly arbitrary mixing of objects and process as features would make it difficult to establish a consistent AEG domain ontology.

1988 CRAMRA

The CRAMRA analysis presents clear examples of non-persistent features. Specifically, features such as *regulated area*, *prospecting area*, *exploration area*, *development area*, and *prohibited area* emerged from CRAMRA, but as a result of the CRAMRA crisis (see Chapter 2) these features fail to become active geographic features. Article 7 of the Madrid Protocol effectively suspends the validity of these features until the middle of the 21st century at least. Interestingly, CRAMRA resulted in a number of new marine features (e.g. deep seabed, seabed, seafloor) added as a result of the very different

perspective that the proposed mineral exploration sub-regime brought. These features are not invalidated and they may actually be useful additions to the ontology although they may be less relevant in the absence of the CRAMRA regime. Other features – typically related to environmental assessment - exist in CRAMRA and are still valid and highly relevant (i.e. *dependent [and][or] associated ecosystems*). This suggests that at some level, CRAMRA had a conservationist approach to mineral resource development and that particular concepts and features of the CRAMRA ontology are persistent.

Effectively, the analysis of the CRAMRA instrument relative to the subsequent Madrid Protocol instrument resulted in the rejection of the Null hypothesis established for Study 2. This result reveals that the overall AEG domain context (e.g. politics) can have an affect on the geographic ontology for the domain. Moreover, the AEG domain can be affected by the overall global environmental governance context (Elliott, 1998). This finding has implications for the need to establish a temporally expressive and dynamic formal ontology for the AEG domain.

1991 Madrid Protocol

While Article 7 of the Madrid protocol effectively results in the rejection of the null hypothesis for Study 2, the content analysis of the protocol results in an interesting descriptive geographic ontology. We see the emergence of some new concepts and features with more comprehensive definitions. In some cases, much higher granularity in terms of starting to establish essential attributes and move toward a more expressive formal ontology. To date (2007), features are persistent. In some cases, features

emerged in the Madrid Protocol or related documents (e.g. *environmental indicators*, *oil spills*, *waste storage*) while others such as *special conservation area* were first used in the Agreed Measures of 1964. In fact, an updated version of the Agreed Measures is essentially what constitutes Annex II of the Madrid Protocol. Therefore, features from the Agreed Measures and other instruments like CCAMLR (not formally analysed here) are inherited by the Madrid Protocol, establishing the enduring nature of those features

5.5 FORMALIZING THE RESULTS

The results of these analyses are in the process of being formalized using the Protégé 2000 ontology editor. Although the resolution and granularity of the source information is not appropriate for developing a fully expressive formal ontology (i.e. description logic), this approach is forward looking in that the knowledge is now, and will increasingly be in a form that can be easily exchanged or translated. For example, the author is working to develop a method that will support conversion from ontology form to spatially enabled relational database form.

5.6 DEVELOPING THE RESULTS

The author has established an AEG ontology “repository”. Unlike repositories that post a published version of ontologies for download (e.g. Marine Metadata Initiative, 2008), the strategy used for the emerging AEG ontology is to provide a means for members of the community to contribute directly to the ontology development process. To this end, an online repository has been established at <http://polarknowledge.selfip.org/svn/ontology/aeg> using a program that is typically

applied to managing programming source code. Using a Subversion client program (see <http://subversion.tigris.org>), contributors can ‘check out’ the most recent version of the ontology, inspect and modify it using tools such as Protégé 2000 and then ‘check in’ (commit) any changes back to the shared repository. All of these changes are tracked and optionally can be accepted or rejected by ontology managers (depending on the governance model that is established). This model can support the idea of an ‘actively negotiated formalism’ – that is, a formal ontology that can quickly adapt to changes in domain semantics and provide the opportunity for a large number of distributed stakeholders to participate in the ontology construction. Conceivably, other tools such as the Nunaliit Cybercartographic Atlas framework (<http://nunaliit.org>) could be adapted to make this method simpler for those not familiar with the tools mentioned. Making the ontology editing process more accessible to those without expertise in formal ontology tools and methods is an active area of research for the author.

5.7 Conclusion

The results of the content analysis presented in this chapter infers a number of assertions as follows:

- The SCAR FC is not consistent with respect to AEG geographic features
- The SCAR FC is not complete with respect to AEG geographic feature terms
- AEG feature terms are not necessarily stable over time.

These statements must be qualified of course. The results presented suggest that there is, in fact, a great degree of consistency between the AEG features established and the

SCAR FC. There are however some examples of inconsistency that would affect the potential to develop a consistent and complete formal ontology for the purposes of semantic mediation. Similarly, many AEG features are captured by the SCAR FC, however there are many others that are not. To determine which of the newly identified features would be appropriate for inclusion in the SCAR FC and which would be included in a an ontology specific to the AEG domain would need to be established through consultation with both the AEG and the SCAR geographic information communities. Lastly, the analysis revealed that some features are quite stable over time while others have a short lifespan within the domain of discourse.

The partial perspective provided by the reported content analysis reveals a domain where semantics are not always in agreement with or complete with respect to domain semantic established within the larger Antarctic community. We also see geographic conceptualizations and language changing over time – thus the analysis presented in this chapter suggests an ontology is not, or at least should not be, simply a snapshot of what exists but rather a model of what has been and what is becoming in terms of the language of geographic features for a particular domain. The discussion section established that semantic inconsistency, incompleteness and dynamism cannot be easily reconciled in all cases. In some cases, imprecision or ambiguity is the result of imprecision and ambiguity inherent to the domain of discourse rather than simply a function of ineffective formalization or communication of domain concepts. Thus, it is argued in the next chapter that developing interoperable geographic information systems requires an

ongoing process of ‘geographic mediation’ that considers not only the information and technology involved but also the context of information production, processing and use at a variety of levels (technical, methodological, social etc.).

Finally, it is suggested here that the most important result of this analysis was not the acceptance or rejection of the hypotheses, but rather, it was the knowledge gained from the *process* of performing the content analysis. Analyzing the ATS corpus to identify features for the purpose of developing a formal ontology has provided a deeper understanding of the complexities and nuances of the AEG domain. The analytical process used was, in itself, a form of *geographic mediation* as defined in Chapter 6.

CHAPTER 6. GEOGRAPHIC MEDIATION IN ANTARCTIC ENVIRONMENTAL GOVERNANCE

6.1 *Introduction*

Previous chapters in this thesis have established that effective information exchange is a central value and requirement of the Antarctic Environmental Governance regime. In fact, the regime mandates the free and open exchange of information as a means of promoting better results in scientific research, operational and fiscal efficiency. The advent of new technologies, methods and theory in the geographic information domain presents the opportunity to greatly improve information exchange. New data models enabled by Web Services established within a Spatial Data Infrastructure paradigm can support greatly improved information delivery. Ontological approaches to information integration hold the promise of semantic interoperability within and among domains.

In the case of the AEG domain, the end users of exchanged information are policy makers, managers, operations practitioners and scientists. In many cases, these users may not have extensive expertise in the area of geographic information processing. Thus, it makes little sense to deliver the information to the defined user group in potentially difficult to understand technical formats e.g. GML wrapped in RDF/OWL. An interface that provides usable information is a critical element in achieving effective information

exchange. At the same time, an easy to use interface should not come at the expense of having access to relevant and necessary information. The development approach used must adopt an information and technical architecture that can support the needs of end users at a number of levels (e.g. primary, secondary, tertiary).

For centuries, cartographers have focused on developing innovative methods for representing geographic information in a way that supports optimum access by users. This chapter presents a model architecture that brings together multilevel, distributed, information resources for the purpose of providing information representation that is meaningful to an end user. The proposed geographic mediation approach has the potential to integrate many 'streams' of research and development taking place in the contemporary, geographic information domain (distributed systems, formal ontology, cybercartography etc.). It is argued that this approach can be the basis for developing effective environmental information systems for the AEG domain and the environmental governance domain in general. It is important to recognize that the proposed model is not intended to be a detailed technical design, but rather a general design pattern that recognizes the multilevel, multifaceted, distributed and ultimately complex nature of domains such as Antarctic Environmental Governance.

6.2 *Mediation of Geographic Information*

This section proposes that the concept of geographic mediation may be useful in conceptualizing a system that supports the exchange of geographic information for the

purposes of developing geographic information systems useful in the domain of Antarctic Environmental Governance.

6.2.1 Geographic Mediation

The terms mediation and mediator have many definitions. A dictionary defines mediator as ‘one that mediates, especially one that reconciles differences between disputants’. Currently, the term mediator is widely used within the disciplines of Computer Science, Information Engineering, Interoperable GIS, and Cartography (Wiederhold, 1999; Fonseca et al., 2002; Zaslavsky, 2003). In this context, the machine-based mediator accesses multiple heterogeneous information sources and services, retrieves different pieces of the result and seamlessly assembles these pieces into a composite response. These software components have embedded knowledge that is derived and maintained by experts. Wiederhold (1999) discusses mediation in terms of a model for interoperability. In Wiederhold’s model, the mediator is seen as an intermediate element between digital sources of information and the end user interface in a (typically) networked infrastructure. Much of this work focuses on computational and resource efficiencies for this type of model.

Another definition of mediation sees the map as a form of ‘mediated seeing’ (Fremlin & Robinson, 1998). In this model, mediated seeing permits observers to see in times and places in which they are not physically present, or perhaps cannot possibly be, and in projections other than that supplied by the lens of the eye. Mediated seeing can be applied beyond maps, i.e., television. In the case of a map, ‘lateral inputs’ such as

projection, scale, generalization and others are part of the process of producing a mediated representation on the retina which in turn projects a representation onto user mentality. Although this work focused solely on the paper map, some interesting ideas are put forward that may be applied to digital cartography.

Gumpert and Carthcart (1990) examine mediation with respect to the role of technology in communication and human information processes and the nature of the relationship between mass and personal communication processes. They posit that all forms of mediation produce unique forms of information which in turn have potent effects on producers, programmers, messages, receivers and the social construction of reality. In more recent works, cartographers and GIS researchers have discussed the effects of mediation (in a 'media' sense) on various forms of geographic information (Peterson, 1995; Sui, 2001).

6.2.2 The Cartographer as Mediator

Informed by the various definitions of mediation/mediator discussed, the present work proposes the abstract concept of *geographic mediation* (geo-mediation) and a discipline specific extension of *cartographic mediation* as useful for the development of cartographic practice and theory. The concept of geo-mediation proposes that a mediator is the nexus between observations of the real world and representations based on those observations. In this definition, the mediator forms a representation of geographic phenomena based on processes of abstraction and integration applied to heterogeneous

sources of [geographic] information². The goal of geographic mediation is to produce a representation that is meaningful to an end user. The term is used in the broader sense in an attempt to integrate discourse in the domains of applied cartography, cartographic theory and critical social theory. This abstract term can be used in the multiple but related contexts often experienced in cartography and Geographic Information Science. Figure 6.1 provides a generalized illustration of the geo-mediation process.

² In this context information is defined as spatially referenced observations of the world accompanied by contextual data after Masser (1998). This can include (i) The actual world (ii) A way that the actual world might be arranged, (iii) An interpretation (iv) A possible world.

Figure 6.1 Geographic mediation applies processes of Abstraction, Integration and Representation to heterogeneous information sources with the end result being a representation of the real world that is meaningful to an end user.

In many ways, the geo-mediation process describes an element of what cartographers have practiced and studied for some time. However, the end result of contemporary geographic information processing is not necessarily a map. For example, some forms of atmospheric modeling can be seen as geo-mediation with a strictly numerical output. Similarly, modern in-vehicle navigation systems use an audio (voice) representation to convey geographic information. Thus, a distinction is made between geographic and cartographic mediation. *Cartographic mediation*, as defined here, is a specific instance of geographic mediation whereby cartographic knowledge is applied to produce some form of graphic representation of geographic phenomena. Considering the non-expert user profile established at the beginning of this chapter, cartographic mediation is of particular interest in this discussion.

In the case where a cartographer manually produces a map, cartographic knowledge is applied directly to form a representation. Knowledge embedded in a machine-based mediator or mediators such as a formal ontology can be used by an entity other than the original cartographer to create representations. In the latter case, the cartographic knowledge will be reused as part of a process. For cartographers in a digital environment, knowledge is often embedded even if it is simply through the process of assigning a line weight in a desktop mapping environment. As long as the file exists, it can be reused. It should be noted, however, that in some cases (i.e., expert systems)

cartographic mediators formalize knowledge such that it can be applied to more than one application or instance of cartographic mediation.

Although the idea of the cartographer as mediator is central to the present work, it is important to recognize the distinction and relationships between geographic mediation and cartographic mediation. Geographic mediation is a general term that may describe a variety of individual and collective mediation processes including the production of art (i.e., graphic and literary) and the construction of geographic narratives (Doubleday, 1993). Cartographic mediation assumes the result to be some form of cartographic representation. Thus, cartographic mediation is a form of geographic mediation focused on a particular type of representation. To expand on some of the implications for developing systems based on the concept of cartographic mediation, the following section outlines the use of geographic and cartographic mediation in an applied setting.

6.3 *A Mediator Based Development Model*

This section presents a development model in which the concepts of geographic and cartographic mediation are used. Current and emerging development approaches inform the architectural design. The present work builds on previous work detailed elsewhere (Pulsifer, 2003; Pulsifer & Taylor, 2003).

Conceptually, the model design uses a four level approach to describe elements of the system. Figure 6.2 illustrates the general relationships between the top levels of Infrastructure, Mediator, Interface and User. In a contemporary applied sense, the

Infrastructure level is modeled after SDI programs and thus comprises data, technology, standards and management policies. Standards and policies are typically embedded within systems at the Infrastructure level. That is, technologies are based on standards and typically incorporate elements that manage policies (e.g. security). Generally, the Mediator level is the level at which domain specific geographic and cartographic knowledge is applied to information acquired from the Infrastructure level and results in the formation of a representation of the real world presented at the Interface level. An interface can be defined as a boundary across which two independent systems meet and act on or communicate with each other. It is important to note that the proposed model considers two types of interfaces, user and software. The Interface level depicted in Figure 6.2 refers to the user interface or the point at which a human user interacts with a given representation.

Figure 6.2 The levels of geographic mediation.

The information infrastructure is built upon observations of the real world and serves the mediator level. At the mediator level, the process of geographic mediation produces a meaningful representation of the world that the user accesses via the interface level. Once accessed, the representation is mediated by the end-user's mental processes. The column on the left indicates how levels are constrained in relation to other levels.

Software interfaces are also an important element of the model and are discussed in subsequent sections. The User level refers to human cognitive processes and is not discussed in detail here, although some discussion of spatial cognition was presented in Chapter 4.

From the previous discussion, we see that the information flow between Infrastructure, Mediator, Interface and User is a bidirectional and nested process that occurs at various levels of the system. The following sections provide a high level description of a system architecture that could be applied to information exchange in the AEG domain. The intent is to present a concrete example of how a system might incorporate the concepts of geographic and cartographic mediation.

6.3.1 The Open Cartographic Framework

A conceptual architecture labelled the Open Cartographic Framework (OCF) was designed for use in the Cyberbercartography and the New Economy (CNE) project (Taylor, 2003). This section provides a necessarily high level discussion of the design and selected components of the OCF. The OCF is established on an Internet-based, distributed database and computing approach and is enabled by emerging agent-based computing and Web service strategies. Agent based computing and Web Services were discussed in more detail in Chapter 3.

Open Cartographic Framework Architecture

Figure 6.3 provides a graphic depiction of the OCF architecture. As seen on the left of the diagram, the design incorporates the Infrastructure-Mediator-Interface chain previously described (Figure 6.2). The ‘cycling arrow’ graphic on the left of the diagram denotes that the cycle is nested within the system – i.e. it occurs at more than one level. This is discussed in more detail in subsequent sections. The OCF is discussed in reference to Figure 6.3 and the numeric labels to the left of the diagram denoted in a square box and square brackets in related text (e.g. [1]).

Figure 6.3 The Open Cartographic Framework:

A potential implementation of a mediator-based development model. Infrastructure elements are below mediator elements which in turn are below interface elements. Mediation occurs at many levels of the system, however the process may be predominant in middleware applications at the “mediator level”. Semantic mediation using formal ontology could conceivably be applied at all levels.

In the interest of facilitating information sharing within the system, and in the spirit of the Antarctic Treaty, wherever possible open standards such as those developed by the OGC and ISO and the World Web Consortium are proposed.

6.3.2 Infrastructure Level

Generally, the infrastructure level is where data and descriptions of data are stored and managed. The data are distinct pieces of factual information derived from observations of the real world [1]. At this level, contextual data is stored and associated with the data that it references. In practical terms, data [2], metadata and catalogue services [3] exist in this layer. A semantic mediator could be implemented at this level to mediate information flowing to the mediator level. If the data stored in the infrastructure are primary or secondary level data, then a top-level or domain ontology is typically employed. Although not yet well developed, inclusion of near real-time sensor data from in-situ sensors existing in a Sensor Web is possible (see Chapter 3). Given the context in which the system has been developed, a number of data types not typically identified, as spatial data are included at this level. Data types include sound, video and olfactory.

Within the Infrastructure level, geographic data are stored in a variety of forms and formats [2]. Standard, file-based layers using a geo-relational data model (e.g. .shp: ESRI shapefiles) are stored on a network accessible drive and accessed by higher level processes through Web services such as the OGC service models previously outlined. Alternatively, data are stored in a spatial relational database management system such as

ESRI's ArcSDE (ESRI, 2004) or the open source PostGIS (Refractions, 2004) referred to in Figure 6.3 as a geographic database. In the case of the OCF, the WMS capabilities of the University of Minnesota's open source Mapserver (University of Minnesota, 2004) have been proposed to provide necessary Web Services. Imagery radiometry and gridded data are delivered through a Web Coverage Service (WCS).

Text and typical multimedia data (images, sound) are stored as files or in a database and are designed to be accessed through Internet HyperText Transfer Protocol (http) protocol requests. Current research is attempting to establish the best approach to developing a self-describing, geospatially enabled media service. The strategy is based on the development of multi-namespace XML documents embedded within media files. The XML document can include metadata from various standards (i.e. Dublin Core, MPEG7, ISO19115) coupled with location data encoded in Geography Markup Language (GML). In this strategy, multimedia data are treated very much like a geographic feature rather than an aspatial data entity. Other types of data such as streaming media would be delivered using appropriate server software i.e. Apple's Quicktime or Microsoft's Windows Media Server. Again these are not yet defined as spatially enabled Web Services.

At present, there is not strong software or hardware support for providing multi-sensory media services to deliver haptic or olfactory signatures that are reproduced by force feedback and scent producing devices respectively. In terms of developing a Web

Services approach, this may be an area where discussions with a group such as the OGC would be warranted.

To facilitate data discovery and subsequent mediation, metadata, catalogue and possibly formal ontology services are required [3]. Metadata services manage detailed contextual information about individual datasets while catalogue services record information about data collections and point to metadata services. In the case of geographic data, OGC Web Services include metadata services. For example, a request to a Web Feature Server will return metadata for the holdings in that service. Thus, if data services related to a collection are registered within a catalogue server, detailed metadata can be retrieved by a user or agent as needed. Catalogue services use a standard protocol called Z39.50.

Developed by the American National Standards Institute's (ANSI), Z39.50 is a computer-to-computer communications protocol designed to support searching and retrieval of information, full-text documents, bibliographic data, images and multimedia in a distributed network environment. During the early years of SDI development, a profile specifically designed to deal with metadata for geographic data was developed (Z39.50 FGDC/GEO profile search protocol)(Nebert, 2000). The Z39.50 protocol is recognized in the catalogue interface standards of the OGC and is incorporated in the OCF design.

In examining the cycle represented by [1], [2] and [3] in Figure 3, we see the emergence of a nested process. *Real World Observations* can be seen as a form of information

infrastructure [1] (e.g. field observations with contextual data in the form of logs etc.). These observations are abstracted, integrated and then represented as a file or in a database [2]. Thus, in this discussion, the process of creating data structures is a form of geo-mediation. The infrastructure-mediator-interface chain is completed through the establishment of a (software) interface in the form of Web Services [3].

The data, metadata and catalogue services at the Infrastructure level can be seen as autonomous *agents* within the system. These agents can be used by human users or other agents through requests and resulting responses. Given the increasing number of Infrastructure services available, combined with the necessity to access them using standard request/response formats, these infrastructure agents are not typically useful to a human user. While the user can access the infrastructure agents directly using a Web browser or programming language, the resulting XML documents may not provide a representation that is meaningful to a human user. To create a meaningful representation, processes of abstraction, integration and cartographic representation are performed by mediator agents at the Mediator level of the system.

6.3.3 Mediator Level

In a system that supports new forms of dynamic cartography underpinned by various multimedia and map content from distributed sources, much of the processing required to generate these new forms of representation may be most efficiently executed at the Mediator level (Figure 6.3). In the case of the OCF, the Mediator level handles encoded information from the Infrastructure level [4] using mediator agents for Geographic [5]

and Cartographic mediation [6]. Geo-mediation does not consider cartographic representation, but rather is concerned with data modeling, manipulation of semantics etc.. These operations (e.g. semantic translation using formal ontology) can take place using information and a knowledge base related to the real world phenomena. An ontology for the AEG domain would operate at this level. Operations here need not consider elements related to cartographic representation. This separation is a logical construct, however, in a cartographic system such as the OCF, the two types of mediator agents (geographic and cartographic) are tightly integrated.

Although Figure 6.3 depicts the Mediator level as contained, agents may be distributed. For example, geo-mediation [5] may take the form of modeling and may take place on a server or peer separate from that which performs the cartographic mediation [6]. A geographic mediator [5] abstracts and integrates information from infrastructure level services to create a representation in the form of model output, for example. In response to a request, the model output is delivered over the Internet in standards encoded XML to a cartographic mediator agent, which in turn applies cartographic knowledge embedded within that particular agent. The cartographic mediator may be receiving input from a variety of agents (e.g. a multi-sensory media agent, a video agent, a legend agent etc.) and thus will execute a process of abstraction and integration with the purpose of generating a meaningful representation for use in the Interface level of the system.

Mediation strategies can be implemented using a wide variety of tools. For cartographic mediation [6], the OCF proposes a set of server-based technologies including a Web Map Server (e.g. UMN Mapserver), high-speed geo-imagery servers and multimedia servers. Application logic and knowledge are embedded using the open source server side scripting languages such as Java Server Pages and the XML Stylesheet Language Transformations (XSLT) (see Lehto, 2003). Geographic mediation carried out separately from the cartographic mediation, may be performed with a variety of tools including open source GIS packages such as GRASS (<http://grass.itc.it>), commercial packages such as ArcGIS, ENVI, PCI etc. or possibly using high level programming languages such as JAVA. For research related to semantic translation, open source Semantic Web toolkits such as the Jena Semantic Web Framework (<http://jena.sourceforge.net>) can be used to process and evaluate RDF/OWL ontology constructs. Results of the various mediation processes (e.g. an integrated database created from two source databases) executed at the Mediator level are delivered to the Interface level using the open source Apache Web server [7].

At the mediator level we again see a nested infrastructure-mediator-interface cycle with responses from the Infrastructure level becoming the infrastructure layer of the Mediator level [4]. Processes of geographic [5] and cartographic [6] mediation are applied and the resulting representation is passed to a (software) interface [7] which in turn responds to requests from the Interface level.

6.3.4 Interface Level

The Interface level is the level at which a human end user interacts with the information system. The user requests information and responses are delivered at this level.

Depending on the type of mediator strategy being used, the Interface level can simply render what is produced at the Mediator level (i.e. HTML + multimedia) or provide interactive functions for the user. In the first case, much of the cartographic mediation will have been accomplished using limited HTML functionality such as hyperlinks. For more responsive, interactive applications the use of dynamic server side scripts can be used. While this approach provides extended functionality, there are several potential limitations to maintaining a strictly server-side architecture. First, HTML provides very limited native support for interactive operations thus reducing the potential for developing advanced cartographic applications. Second, processing application functions on the server side using scripting may result in unacceptable delays while results are returned from the server to the user's client application. Lastly, the use of server side scripting may be outside the skill set of the cartographer or may not be supported by the server infrastructure hosting an application.

Alternatively, mediation can occur outside of the Mediator level, nested within the Interface level. In this case, the cartographer incorporates elements of abstraction, integration and representation at the Interface level within the client environment (e.g. Web browser). The use of client side scripting (i.e. JavaScript) with SVG graphics is an example of this methodology. In this way, a local cartographer (one without access to

Mediator level processes) can implement cartographic mediation with the added performance efficiency eliminating unnecessary requests to the server. This approach also allows the cartographer to take advantage of powerful client side authoring tools such as Macromedia's Flash. In this case, the mediation functions are embedded within the Flash application file. A limit to this method is the inability to easily update information from the Mediator or Infrastructure levels.

Also available to support mediation at the Interface level is the use of emerging OGC specifications. Certain specifications allow the cartographer to modify cartographic elements of the representation at the Interface level. The Styled Layer Descriptor (SLD) specification is a means of controlling the portrayal of data that is rendered from OGC Web Services. In this way, a cartographer who may not have control of the styles defined at the Infrastructure or Mediator level can override with local settings. Similarly, OGC Web Map Context (WMC) documents can be used to provide Interface level control of the user interface state and layout (map layers, position of legends, multimedia etc.).

In summary, a nested infrastructure-mediator-interface chain at the Interface level is identified. Responses from the Mediator level effectively become infrastructure within the Interface level. At the Interface level, in some cases, no mediation is required or perhaps allowed. However, mediation at this level is possible [8]. This point of mediation may be one of the most important, as it provides the opportunity for the 'local'

cartographer to incorporate cartographic knowledge into the representation presented to the user. Although some development effort would be required, semantic mediation could potentially take place, or at least be initiated at the Interface level. This may be necessary if ‘on the fly’ translation is required in a dynamic (e.g. real-time) application. Depending on the system design, the end user can be included in the category of local cartographer. Increasingly, the end user has the opportunity, and in some cases is required to perform abstraction, integration and representation processes.

To support this type of user mediation, some products now support on-line, multi-author, collaborative map data publication and map design (e.g. Mapbuilder, 2004).

6.3.5 Implications of a Mediator Based Development Approach

The review presented in Sections 6.3.2 – 6.3.4 reveals an architecture where information is exchanged and processed by a variety of agents at many levels. Within the parent levels of Infrastructure, Mediator and Interface are nested elements of the same chain (infrastructure-mediator-interface). In general, the expectation from those in environmental governance, government, industry and parts of the GI Science community is that such a system can provide ‘single window’ access to and relatively easy integration of geographic information. The potential power to form new representations afforded by improved information access and integration is, however, coupled with increasing complexity and a lack of structure relative to previously existing forms of cartography. No standard methods exist to establish the allocation of various components and processes (i.e. mediation) within the system. In an agent-based approach, the designers of an application system may not have control of how or where particular

service agents are implemented. Moreover, the potential for multiple authors (including end users) presents research, design, and implementation realities not present in previous generations of cartographic systems.

Distributed Web Services such as those proposed in the architecture, can be chained to create what is known as cascading services. In this scenario, data are delivered from one service agent to another. The information is in some way processed and then passed to another agent and so on. This service chaining presents powerful possibilities in terms of data access and integration. However, through this chaining process information can be *re-mediated* as it moves from agent to agent. In situations where multiple agent re-mediation takes place, establishing information lineage may be difficult or impossible. This can impede a user's ability to evaluate information quality and fitness for use resulting in a 'black box' information resource. Ensuring that the Semantic Web previously discussed includes a collective process that manages information lineage is important for modern cartographic systems development.

A standard or typical usage scenario no longer exists (and thus none was presented) for a system like the Open Cartographic Framework. Particular usage scenarios are defined by negotiations between stakeholders that may include policy makers, environmental managers, field scientists, data collectors (human and otherwise), database designers, application developers, archivists, librarians, graphic designers, logicians, computer scientists, cartographers, human computer interaction specialists and end user/producers.

The last stakeholder in the list is of particular interest. Poore (2003) suggests that users of SDI and mediator-base systems, including people who build and integrate data should also be characterized as designers of the infrastructure. In her view, this 'bottom up' approach contrasts the formalist, 'top down' approach adopted by most SDI programs and, presents possibilities for more effective geographic information integration. In Poore's view, integration is a process of negotiation rather than technical translation. She recognizes that the negotiation process necessary to create effective systems is difficult, heterogeneous, diffuse and unstable. If we accept Poore's account, then building the negotiation process into development will be a requirement if we are to design and implement effective cartographic information systems.

6.4 Conclusion

Cartographers are conceptualizing an emerging cartography that produces adaptable, dynamic, and interactive products. This cartography incorporates multimedia and integrates map information from distributed sources using systems built by teams comprised of a variety of stakeholders and linked through new forms of partnership (Taylor, 2003; Zaslavsky, 2003). This approach can facilitate the development of very integrative and expressive, cartographically based environmental information systems. While maps are central in this vision, other forms of representation (e.g. model animations, sound, video etc.) can allow the user to explore and understand the nuances of past, present and future environments.

The previous sections provided a broad overview of a system architecture that may support these visions. Moreover, the paper identifies challenges and implications for developing such systems. Historically, a limit for cartographers in terms of producing meaningful representation of the world has been limited access to geographic information. With the advent of SDIs, this reality is changing and a new challenge is emerging - how to mediate the massive amounts of heterogeneous information made available through SDIs. The need for abstraction and integration of heterogeneous sources of information will be increasingly relevant given the visions outlined above. Semantic mediation will almost certainly be a component of the geo-mediation process.

All of these new possibilities provide the cartographer with opportunities but also new technical and theoretical challenges. In terms of creating products that are useful beyond the validation of technological methods, it will become increasingly important for cartographers and system developers to recognize the human context within which their work is situated. While this point has been well established through academic discourse, emerging social and technical structures (i.e. SDIs) may have implications for the cartographer's ability to effectively evaluate these contexts.

Using the concept of cartographic mediation as a practical and conceptual framework may contribute to organizing and understanding emerging cartographic theory and practice. Understanding the mediation process in addition to system components is critical both in terms of establishing data quality, fitness for use etc. and understanding

the human context(s) from which representations are constructed. In this chapter, the mediation process is one that is described as resulting in a 'meaningful representation'.

Meaning may be defined in at least two ways:

Conventional: common, or standard sense of an expression, construction, or sentence in a given language, or of a non-linguistic signal or symbol.

Literal: non-figurative, strict meaning an expression or sentence has in a language by the virtue of the formal (dictionary) meaning of its words and the import of its syntactic constructions.

The use of formal ontology requires a literal interpretation of the term meaning and goes beyond the definition provided here to one where essential attributes and formal logical associations are declared as part of the definition of terms. While this type of formalization can support powerful integration strategies, it may present significant challenges when attempting to implement systems where ambiguity, domain specificity and semantic evolution exist and will continue to exist.

The term "meaningful" is deliberately left undefined in this thesis to represent the multiplicity of perspectives facing modern cartographers and information system developers. Technical problems will be identified and addressed in turn. However, if contemporary cartographic systems are to address a variety of topics, beyond products

used for simple location finding or describing (as opposed to understanding) the environment (Taylor, 2003), then both stated definitions for meaning will need to be considered. If mediation processes within distributed systems are to provide meaningful representation, then the related questions and challenges that arise through the representation process will necessarily be heterogeneous and diffuse.

To address these challenges in the context of Antarctic Environmental Governance, an applied research approach is being adopted. The Nunaliit Cybercartographic Atlas Framework (Pulsifer et al., 2008) is an atlas development tool that fits within the mediator-based development approach. Nunaliit is not an infrastructure level tool, but rather it draws information from a standards-based infrastructure, applies expert knowledge at the mediator level (in a process known as compiling) and results in a modular, interactive atlas information system that can be installed to a Web server or, conceivably, migrated to a DVD or print atlas. Nunaliit was used to create an introduction module (see Figure 6.4) for the prototype Cybercartographic Atlas of Antarctica (Pulsifer, 2005). While this module was designed for a general public audience, the design principals are applicable to the AEG domain. The module is designed to provide a current view of the state of the continental and local Antarctic environment. The map presents temperature information acquired from a near real-time data source precise to within 6 hours of the present. An aggregator mediator agent developed by the author acquires the temperature data from other sensor agents and processes the information so that it can be included in the data infrastructure and accessed

by the Introduction module. Conceivably, the aggregator mediator agent can draw information from a variety of environmental sensors (e.g. oceanographic buoys, tide gauges, wind gauges etc.) and other geographic information resources (bathymetric data, human activity data etc.). This disparate information could, in turn, be processed by a semantic mediator that processes various data resources using a formal ontology and inference engine. In the case where semantics cannot be automatically processed, a domain expert would intervene to establish an approach to semantic mediation.

In addition to the dynamic map, the module includes a dynamically updated (every 10 minutes) image of Mawson station (compliments of the Australian Antarctic Division). Aside from the general interest of seeing an image of the station, this image also provides us with environmental information – it was a clear sunny day at Mawson when the screen capture for Figure 6.4 was created. The information mediation methods supported by the Nunaliit framework are extensive and a number of application requirements can be addressed.

From the context of information exchange, the design of the module presented is based on well-defined semantics. The information ‘currency’ is XML and thus the various information elements presented (map features, images, sensor data) are explicitly defined within the Nunaliit model. However, although the information elements are explicitly defined, they are not defined on the basis of a community developed semantic model. To do this, the preliminary AEG ontology knowledge developed as part of this research (see

Chapter 5) will need to be further developed and formalised. The module, as presented, is a starting point in an ongoing research program being developed by the author and the Geomatics and Cartographic Research Centre at Carleton University (<http://gcrs.carleton.ca>)

Figure 6.4 A high level example of a cartographic application for monitoring the Antarctic Environment

CHAPTER 7. CONCLUSION

7.1 Summary

At the highest level, this thesis dealt with integration in geography. More specifically, the thesis examined the integration of digital geographic information in a machine environment in the context of Antarctic Environmental Governance (AEG).

It was established that the concept and practice of full and open information exchange is central to the Antarctic Treaty System (ATS) and the domain of Antarctic Environmental Governance (AEG). The AEG domain is distributed, multi-level and heterogeneous.

The domain draws on information from a variety of communities including international law, science, logistics and operations and environmental management to name a few.

The diverse nature of the domain presents challenges in terms of information exchange.

While information is increasingly available in digital form and can be readily transmitted across networks, achieving true integration of information assumes a certain level of shared understanding that may or may not exist within the domain.

A variety of developments in the geographic information domain (including technology, methods and theory) have the potential to facilitate more effective information exchange

in the AEG domain. While established and emerging standards, formats and technologies are making the transport of information easier, a key remaining challenge is that of semantic interoperability – the ability to effectively exchange meaning between information systems. The general study of ontology and the more specific study and application of formal ontology has the potential to facilitate improved semantic interoperability.

Developing a semantic interoperability strategy based on formal ontology requires an understanding of the theoretical, methodological and technological concepts and details related to ontology development and application. Developing a consistent, complete and expressive formal ontology is a complex undertaking requiring collaborative effort. Collaborative effort is required because, at the foundation of formal ontology is a presupposition of ontological and epistemological agreement among actors within an information community and agents within an information system. Developing an effective strategy where the goals and expectations of stakeholders are achieved also requires an understanding of the limits of a formal ontological approach. Formal ontology and the inference engines that are used to reason with them are based on formal (typically first order predicate) logic and all that that entails including the requirement to evaluate an assertion as True or False. These requirements must be considered when designing an information system for a heterogeneous and sometime diffuse domain such as AEG.

The starting point for developing a formal ontology is to establish terminology used within the domain of discourse. Members of the Antarctic science community have established a general geographic feature vocabulary with descriptive semantics (definitions) for use in sharing information between Geographic Information Systems. The SCAR Feature Catalogue was used as a simple reference ontology to establish its suitability as a base for an AEG domain ontology.

A content analysis of the Antarctic Treaty System corpus revealed that, geo-semantically, the AEG domain (as represented by the ATS corpus) is not entirely consistent with the SCAR FC. Additionally, AEG domain semantics overlap but do not entirely intersect the SCAR FC semantics – that is the SCAR FC is incomplete with respect to the AEG. Additionally, it was revealed that geo-semantics in the AEG domain are not necessarily persistent. Features extinction appears to be related to the overall dominant worldview existing within the regime. The major implications of content analysis are that: 1) ontology is contextually specific – one ontology does not fit all 2) ontology is dynamic 3) ontology development is complex and nuanced. In addition to the results of the study, the method used was an effective means for improving knowledge of AEG domain geo-semantics. The analysis has resulted in a preliminary, low resolution, low granularity formal ontology that is being developed for release to the community using a collaborative repository system.

To be meaningful and usable for an end user, individual developments in the geographic information domain need to be integrated within a larger application architecture. The design of this architecture must consider the various levels of information and representation that are part of the system as well as the processes of mediation acting on system information. The thesis is concluded with a discussion of how this type of mediator-based architecture, that has both human and machine-based mediators, can be used to develop end-user interfaces that can form the basis of an environmental information system.

Finally, from the perspective of the author, perhaps the most important insight coming from this research is the recognition that developing a semantic model for domains such as AEG is an inherently complex process. We must recognize, and embrace, the fact that modelling what is currently in the domain of human intellectual and emotional processes is not a simple task, and the extent to which this can (or should) be achieved is uncertain. This statement echoes the ideas put forward by Schell and Taylor (2008) in their call to establish *Interoperability Science* to develop the knowledge required to construct interoperable systems that can provide meaningful results to end users.

7.2 Future Work

This thesis presents a preliminary ontological exploration of the Antarctic Environmental Governance domain with the objective of moving towards a model for geographic information mediation. To move forward in this research program will require additional research in a number of areas, including:

- Development of a functional formal ontology prototype to test the effectiveness of semantic mediation between at least two AEG information resources
- Using a critical social theory approach, further examine the implications of applying semantic mediation to AEG domain information
- Using visualization techniques, explore the possibilities for making ontologies more accessible to non-expert end users
- Investigate the possibilities for using participatory and User Centred Design methods in the construction of formal ontologies
- Defining the boundaries of an information community and the relationship to concepts such as communities of practice. e.g. is the AEG domain really an information community? If so, how does it relate to the 'Antarctic Science' community or the 'Antarctic logistics' community?

The author is aiming to address some of these questions through a pending post-doctoral fellowship funded by the Canadian International Polar Year program.

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Appendices

Appendix A: GIS Representation

The nature of computers dictates that data must be represented and stored as discrete digital values. Thus, a field-like phenomenon must be sampled and converted to discrete values that are then stored in a grid or 'raster' (Figure A.1). While a raster is more computationally efficient in terms of representing field-like objects, the representation can be difficult to use for some types of modeling and results in relatively large files potentially requiring enormous amounts of disk storage space. For efficiency, raster representations are often converted to discrete shapes using software operations with the result being a vector layer as subsequently described.

Figure A.1 A typical GIS raster representation of a field-like phenomena. Discrete, typically numeric values (denoted as j), are assigned to each grid cell and referenced by a grid coordinate (x,y)

A vector-based, layer model typically results in significantly smaller files relative to a raster representation. Moreover, a vector based layer model can support more efficient data editing and is more suitable for the data modeling activities required for many practical applications (i.e. utilities management, geo-demographics). For these reasons, the leading commercial GIS software packages have used a layer model since the inception of the products (i.e. ESRI's popular ArcInfo). It is important to note that in this model, location is a dominant component of feature definition, an object must have a well-defined location with similar geometric types (e.g. points, lines) being stored in the same layer to the exclusion of other geometry types.

Historically, geo-object-like phenomena have been represented in GIS by geometric shapes defined by vector geometry³ and then associated with a table of related attribute values (Figure A.2). This *layer model* is central to most of the popular GIS systems available today.

A vector-based, layer model typically results in significantly smaller files relative to a raster representation. Moreover, a vector based layer model can support more efficient data editing and is more suitable for the data modeling activities required for many

³ cartesian coordinates used to define points, lines or polygons

practical applications (i.e. utilities management, geo-demographics). For these reasons, the leading commercial GIS software packages have used a layer model since the

Figure A.2 A layer based model has typically been used to represent object-like phenomena in GIS. The object has a single geometric representation and the potential for multiple descriptive attributes stored in an associated table.

inception of the products (i.e. ESRI's popular ArcInfo). It is important to note that in this model, location is a dominant component of feature definition, an object must have a well-defined location with similar geometric types (e.g. points, lines) being stored in the same layer to the exclusion of other geometry types.

More recently, object-oriented⁴ data models have moved to the forefront of development in GIS. An object-oriented approach segments a geographic entity into an object (Figure 3) that falls within a class definition (i.e. a category such as road, tree etc.). Class definitions are ordered hierarchically. The class definition (similar to a template) is used to create or instantiate new objects. Each database object has associated properties and operations that apply to the object. These property categories and operations are *inherited* from the class definition. The properties and operations are *encapsulated* in a discrete object that is stored in what is known as an object-oriented database. These objects are then organized and manipulated using a particular model that defines object relationships and processes. The object-oriented approach may have significant advantages over the layer model in its ability to efficiently represent complex relationship and dynamic processes (Yapa, 1998; Wachowicz, 1999) and has thus attracted a great deal of attention in IGIS research and development. Moreover, the spatial component of an object is not a mandatory element as with the vector geo-object. In the case of an

⁴ it is important to note that the concept of a geographic object and object-oriented databases are distinct. Object-oriented databases are based on a formally defined system of modeling and design now pervasive in computer science and programming.

object-oriented model, the location of the object is an attribute like any other - this has important implications in that the object-oriented model can support multiple geometric representations (including no geometry) of an object providing a more flexible modeling environment. There are however implications to using an object-oriented model. Depending on one's perspective, the approach may limit flexibility in how the world can be represented in the GIS.

Figure A.3 Object-oriented GIS:

Some newer Geographic Information Systems use an object-oriented database approach to represent geo-object-like phenomena. The object is a member of a well-defined class (i.e. TREE). Attributes are stored as properties along with related operations that can act on the object

APPENDIX B: Addendum to Content Analysis Results

Additional Result for Study 1 Content Analysis

Table B.1 Results of content analysis of ASPA 109 (ATCM XIX, 1995). Features that are semantically equivalent to SCAR FC features or have some level of ambiguity.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Bay	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 7	... and leopard seals (Hydrurga leptonyx) are found in the bays on the west side of the island.	Properly a smooth, comparatively gradual indentation of the coastline, the seaward opening of which is usually wider than the penetration into the land, but often applied more to loosely, cf. bight, firth, fjord, gulf, inlet.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Beach	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(iii), Paragraph 1	at the back of the small shingle beach in the northeast corner	The unconsolidated material that covers a gently sloping zone, typically with a concave profile, extending landward from the low-water line to the place where there is a definite change in material or physiographic form (such as a cliff), or to the line of permanent vegetation (usually the effective limit of the highest storm waves); a shore of body of water, formed and washed by waves or tides, usually covered by sand or gravel, and lacking a bare rocky surface.
Bird(s)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 6	Numerous other birds breed on the island, notably about 2000 pairs of cape petrels	May be synonymous with SCAR FC Flying Bird defined as: Feathered vertebrate with two wings and two feet.

<i>SCAR FC Feature Types</i>	<i>Semantic Agreement with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/fic)</i>
Camp(s)	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(iv), Title	Location of field camps	A temporary residence, when away from the station.
Channel	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 1	off the southwestern extremity of Signy Island, from which it is separated by Fyr Channel.	A comparatively deep and narrow, navigable waterway between an island and the mainland, or between islands, or navigable route through shoals, cf. strait, although the distinction between the two terms has not always been the mainland application.
Coast	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	There is a thin bed of undifferentiated amphibolite on the northeastern coast.	Boundary between land and sea, applied in place-names to lengths of coastline determined partly by the history of their discovery and partly by convenient demarcation points, cf. land.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Colon(y)(ies)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 6	There were five colonies of chinstrap penguins	A collection of animals, plants, etc., connected, in contact, or living close together.
Contour	Y	Map 2	Legend item on map	SCAR FC Contour Line Imaginary lines, or lines on a map or chart, that connect points of equal value, e.g. elevation of the land surface.
Cove	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 3, Paragraph 2	This action would most likely consist of the erection of a seal-proof fence at the head of the gully at the northeast of Landing Cove.	Small coastal indentation, commonly circular or semi-circular in shape and with a restricted entrance, or a small bay.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Fence	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 3, Paragraph 2	This action would most likely consist of the erection of a seal-proof fence at the head of the gully at the northeast of Landing Cove.	A mesh, railing, hedge, or the like for preventing free access to an area.
Gully	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 3, Paragraph 2	This action would most likely consist of the erection of a seal-proof fence at the head of the gully at the northeast of Landing Cove.	Glacier-worn or water-worn ravine in a hill or a mountain side.
Headland	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 7	the terrain will restrict these animals to this small <i>headland</i> where damage may intensify.	Comparatively high, steepfaced land jutting into the sea or into an ice shelf; similar to promotory but applied to a feature of lesser extent, cf. cape, point. An unnamed head is usually described as a headland.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Hill(s)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 2	and lower <i>hills</i> on each of three promontories on the western side above Corral Point (92 m),	Natural elevation usually below 300m, but the term may be applied to much higher (although relatively low) features in mountainous areas, cf. knoll, mountain.
Ice	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Permanent <i>ice</i> remain on the east- and south-facing slopes with late snow lying on the steeply dipping western slopes.	The solid state of water, monomineral rock.
Island	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 2, Paragraph 3	... the differences between the ecology of an undisturbed <i>island</i> and that of an adjacent occupied and fur seal perturbed island.	A land mass, especially one smaller than a continent, entirely surrounded by water.

<i>SCAR FC Feature Types</i>	<i>Semantic Agreement with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/fic)</i>
Landing point	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(i), Paragraph 3	It is forbidden to overfly the Area below 250 m altitude above the highest Point except for access to the <i>landing point</i> specified above.	SCAR FC Any locality either on land, water or structures, including airports/helipads and intermediate landing fields, which is used, or intended to be used, for the landing and takeoff of aircraft. Landing areas may or may not have facilities for the shelter and servicing of aircraft, or for receiving or discharging passengers or cargo.
Mast	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(iii), Paragraph 2	There is a cairn and the remains of a survey <i>mast</i> , erected in 1965-66	An upright post or lattice-work structure for supporting radio antennas or similar features. Usually supported by guys. (Non directional beacons are stored under beacons)

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Peak	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 2	The island rises precipitously on the northeastern and southeastern sides to Snipe Peak (226 m altitude).	A hill or mountain with a comparatively sharp summit.
[Pedestrian] routes	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(i), Paragraph 4	No pedestrian routes are designated	Any established or selected course for passage or travel.
Penguin(s)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 6	There were five colonies of chinstrap penguins	Sea-fowl of southern hemisphere with wings developed into scaly flippers with which it swims under the water.

SCAR FC Feature Types	Seman- tic Agree- ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Point	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 2	...a subsidiary summit above South <i>Point</i> (102 m altitude)...	Sharp and often comparatively low piece of land jutting out from the coast or forming a turning point in the coastline, but usually applied to a less prominent or less navigationally significant feature than a cape. The term may also be applied to a rock feature at a little distance from a low ice-covered coast.
Promontory(ies)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 2	and lower hills on each of three <i>promontories</i> on the western side above Corral Point (92 m),	Similar to a headland, but of larger extent, that may be above open sea, above an ice piedmont or above an ice shelf.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Protected Area	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Title	Management Plan for Specially Protected Area (SPA) No. 13, Moe Island, South Orkney Islands	An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity and/or of natural and associated cultural resources. The area is managed through legal or other effective means.
Rock(s)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	The <i>rocks</i> are metamorphic quartz mica schists	Any aggregate of minerals that makes up part of the earth's crust. It may be unconsolidated, such as sand, clay, or mud, or consolidated, such as granite, limestone, or coal.
Sand(s)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Soils are predominantly immature deposits of fine to coarse clays and <i>sands</i> intermixed with gravels, stones and boulders.	A loose material consisting of small mineral particles, or rock and mineral particles, distinguishable by the naked eye; grains vary from almost spherical to angular, with a diameter range from 1/16 to 2 millimeters.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Scree	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Much of the island is overlain with glacial drift and scree.	A slope or base of a cliff consisting of broken rock fragments.
Sea	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(i), Paragraph 1	There are no restrictions on landing from the sea, which is the preferred method.	A body of salty water that covers much of the earth.
Sign-boards	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 3, Paragraph 1	Moe Island is adequately monitored, preferably by non invasive methods, and that the <i>sign-boards</i> are serviced.	Synonymous with SCAR FC sign defined as: A plate or a label carrying important textual or graphical information.

SCAR FC Feature Types	Seman- tic Agree- ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Slope(s)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Permanent ice remain on the east- and south-facing <i>slopes</i> with late snow lying on the steeply dipping western slopes.	A stretch of rising or falling ground; an inclined plane or gradient.
Snow	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Permanent ice remain on the east- and south-facing slopes with late <i>snow</i> lying on the steeply dipping western slopes.	Atmospheric precipitation of ice crystals.
Soil(s)	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	<i>Soils</i> are predominantly immature deposits	The top layer of the land surface of the earth that is composed of disintegrated rock particles, humus, water and air.

<i>SCAR FC Feature Types</i>	<i>Semantic Agreement with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)</i>
Spot height	Y	ATCM XIX (1995), Annex A to Measure XIX-1, Map 2	Legend item on map	Altitude of a point on the land surface
Vegetation[terrestrial]	Y	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 2, Paragraph 2	avoid major changes to the structure and composition of the terrestrial vegetation,	Synonymous with SCAR FC vegetation type defined as: community of plants or plant life that share distinguishable characteristics./ The 'terrestrial' attribute could potentially be included in the SCAR FC attribute Veg_Mapping, however the current enumeration is too specific

<i>SCAR FC Feature Types</i>	<i>Semantic Agreement with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)</i>
Bank(s)	N	ATCM XIX (1995), Annex A to Measure XIX-1, Item 2, Paragraph 2	avoid major changes to the structure and composition of the terrestrial vegetation, in particular the moss turf banks;	Sea area of positive bottom relief where the water is relatively shallow, but normally sufficient for safe navigation. / SCAR FC also has feature embankment defined as: A linear structure, usually of earth or gravel, shaped as to extend above the natural ground surface. However, the definition of embankment is identical to the feature Man-made embankment. The 'man-made' specialization introduces semantic disagreement in this context. Embankment is is closer semantically than SCAR FC bank which is clearly an oceanographic feature

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Equipment	N	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(iii), Paragraph 1	No structures are to be erected in the Area, or scientific equipment installed	May be considered synonymous with SCAR FC Apparatus defined as: A scientific instrument.
Pool(s)	N	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	There are no permanent streams or pools.	Related to SCAR FC feature pool which is defined as: A man-made area for holding water for a specific purpose such as swimming./ Note that the meaning is significantly different. The context suggests natural pools.
Structure(s)	N	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(iii), Title	Location of structures within the Area	Related to SCAR FC feature structure which is defined as: A structure of unknown type./ The meaning established by SCAR FC feature is too vague to assert semantic consistency

Table B.2 Results of content analysis of ASPA 109 (ATCM XIX, 1995). New features.

SCAR FC Feature Types	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Animal(s)	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(v), Paragraph 1	No living animals or plant material shall be deliberately introduced into the Area.	Any member of the animal kingdom , which comprises all multicellular organisms that obtain energy, actively acquire their food and digest it internally, have well-developed nervous systems, have cells organized into tissues, and reproduce sexually. (Park, 2007:24)
Boulder(s)	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Soils are predominantly immature deposits of fine to coarse clays and sands intermixed with gravels, stones and boulders.	A large, rounded or subangular piece of rock lying on the surface of the ground, embedded in the soil or within a layer of boulder clay. (Whittow, 2000:62)

<i>SCAR FC Feature Types</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Cairn	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(iii), Paragraph 2	There is a cairn and the remains of a survey mast, erected in 1965-66	An artificial pile of stones erected on a mountain summit or along a path as a guide. (Whittow:2000:69)
Clay(s)	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Soils are predominantly immature deposits of fine to coarse clays and sands intermixed with gravels, stones and boulders.	1. A natural argillaceous substance of soft rock which develops plastic properties with the addition of a small amount of water 2. A article size term in which the size fraction is less 0.002mm. (Whittow, 2000:88)
Col	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(i), Paragraph 2	Helicopters may land only on the col between hill 89 m and the western slope of Snipe Peak	The lowest point on a mountain ridge between two peaks.

<i>SCAR FC Feature Types</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Depot(s)	ATCM XIX (1995), Annex A to Measure XIX-1, Item 7(v), Paragraph 4	Permanent depots are not permitted.	A place where goods are deposited or stored. (Soanes, 2004)
Ecosystem	ATCM XIX (1995), Annex A to Measure XIX-1, Item 1, Paragraph 1, Paragraph 3	on the grounds that Moe Island provided a representative sample of the maritime Antarctic ecosystem, that intensive experimental research on the neighbouring Signy Island might alter its ecosystem and that Moe Island should be specially protected as a control area for future comparison. (Para 1); near-pristine example of the maritime Antarctic terrestrial and littoral marine ecosystems (Para 3).	The natural interacting biotic and abiotic system in a given area, which includes all of the organisms (plants, animals, fungi, and micro-organisms) that live in particular habitat, along with their immediate physical environment. (Park, 2007:139)

<i>SCAR FC Feature Types</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Glacial drift	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Much of the island is overlain with glacial drift and scree.	A glacial deposit, consisting of unsorted boulders and smaller particles in a matrix of clay, that is laid down beneath a glacier or ice sheet. Also known as drift, glacial diamicton, boulder clay, and till. (Park, 2007:197)
Gravel(s)	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Soils are predominantly immature deposits of fine to coarse clays and sands intermixed with gravels, stones and boulders.	A general term for an accumulation of loose compacted, coarse, stony materials. (Whittow, 2000: 229)
Ice-free area	Map 2	Legend item on map	Areas not covered by ice in an area otherwise covered with ice (author)
Marker(s)	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Title	Geographical coordinates, boundary markers and natural features	An object, etc., that serves to mark or distinguish something and boundary in particular; an indicator. (derived from Soanes, 2004)

<i>SCAR FC Feature Types</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Peat	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	There are deep accumulations of peat	Partially decomposed vegetable matter that forms in boggy ground and can be cut and dried for use as a fuel and in gardening. It forms in the initial stages of the coal series. (Park, 2007:332)
Plant communities	ATCM XIX (1995), Annex A to Measure XIX-1, Item 1, Paragraph 2	Plant communities on nearby Sipy Island have been physically disrupted by trampling by fur seals	A group of plants (such as broadleaved woodland) that grows together in a particular area, under given environmental conditions (soil, climate, etc.). (Park, 2007:343)
Seal(s)[Fur, Weddell, Leopard]	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 7	...in the low altitude terrestrial system as a result of the rapidly expanding Antarctic fur seal (Arctocephalus gazella) ; Increasing numbers of fur seals (Arctocephalus gazella), mostly juvenile males, come ashore on the north side...	A member of the family Phocidae, sub-order Pinnipedia, of aquatic carnivorous mammals, with limbs developed into flippers and adapted for swimming, and having an elongated body covered with thick fur or bristles and terminated by a short tail. (Soanes, 2004)

<i>SCAR FC Feature Types</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Splash zone	ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(iii), Paragraph 1	beyond the splash zone on top of a flat rock,	The area possibly affected by the act, of water dashing or falling forcibly. (derived from Soanes, 2004)
Stone(s)	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	Soils are predominantly immature deposits of fine to coarse clays and sands intermixed with gravels, stones and boulders.	A small piece of rock. (Whittow, 2000:507)
Stream(s)	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 3	There are no permanent streams or pools.	A natural body of running water that flows along a channel. (Park, 2007:430)

<i>SCAR FC Feature Types</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Summit	"ATCM XIX (1995), Annex A to Measure XIX-1, Item 6(i), Paragraph 2	There is a subsidiary summit above South Point (102 m altitude) and lower hills	The topmost point or ridge of a mountain or hill. (Soanes, 2004)
Survey station	Map 2	Legend item on map	The physical location or site at which observations and measurements are made.

Table B.3 Results of content analysis of ASPA 105 (ATCM XXI, 1997). Features semantically equivalent to SCAR FC or having some level of ambiguity.

SCAR FC Feature Types	Sem 'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Beach	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	up to 50 m wide and 5-7 metres above the <i>beach</i> on the north of the island.	The unconsolidated material that covers a gently sloping zone, typically with a concave profile, extending landward from the low-water line to the place where there is a definite change in material or physiographic form (such as a cliff), or to the line of permanent vegetation (usually the effective limit of the highest storm waves); a shore of body of water, formed and washed by waves or tides, usually covered by sand or gravel, and lacking a bare rocky surface.

SCAR FC Feature Types	Sem' tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fc)
Bench	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	area of vegetation previously unrecorded on an ice-cored moraine <i>bench</i>	Similar to a terrace but usually applied to a high-level rock feature.
Camp	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 7(i), Paragraph 1	may be found at the nominated northern <i>camp</i> site at the western end of northern beach	A temporary residence, when away from the station.
Cliff(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	rugged <i>cliffs</i> on the eastern slopes.	A high, very steep to perpendicular or overhanging face of rock or ice.

SCAR FC Feature Types	Sem 'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Coast	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	and small meltwater streams draining to the coast	Boundary between land and sea, applied in place-names to lengths of coastline determined partly by the history of their discovery and partly by convenient demarcation points, cf. land.
Colon(y)(ies)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	but there exists a large Adelie penguin (<i>Pygoscelis adeliae</i>) colony	A collection of animals, plants, etc., connected, in contact, or living close together.
[Cinder, spatter] Cone	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	there is evidence of layered ash-fall tuffs and welded spatter flows from local subsidiary cinder and spatter cones.	SCAR FC feature cone defined as: A conical mass of which the base is a circle and the summit a point. The term is used frequently in connection with a volcano.

SCAR FC Feature Types	Sem'itic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Ice field(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	moderately sloping <i>ice fields</i> covering much of the west side	Flat glaciated area, underlying topography is not completely levelled out
Invertebrate(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 4	The moss community is known to support significant populations of mites, but a detailed survey of <i>invertebrates</i> on Beaufort Island	Any animal lacking a backbone, including all species not classified as vertebrates.
Island	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	The <i>island</i> comprises a variety of terrain and habitats:	A land mass, especially one smaller than a continent, entirely surrounded by water.

SCAR FC Feature Types	Sem 'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Landing site	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 7(i), Paragraph 1	Should snow conditions at the designated <i>landing site</i>	Synonymous with SCAR FC landing area defined as: Any locality either on land, water or structures, including airports/helipads and intermediate landing fields, which is used, or intended to be used, for the landing and takeoff of aircraft. Landing areas may or may not have facilities for the shelter and servicing of aircraft, or for receiving or discharging passengers or cargo.
Moraine	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	area of vegetation previously unrecorded on an ice-cored <i>moraine</i> bench	mound, ridge, or other distinct accumulation of unsorted, unstratified glacial drift, predominantly till, deposited primarily by direct action of glacier ice, in a variety of topographic landforms that are independent of control by the surface on which the drift lies.

SCAR FC Feature Types	Sem'lic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Outcrop(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	This ice field is punctuated mid-way by a 2 km line of rocky <i>outcrops</i> at an elevation	A detached rock mass, or group of rocks, distinctively shaped by erosion and weathering.
[Helicopter]Pad	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 5, Paragraph 5	out from the preferred <i>Helicopter Pad</i> at an azimuth	SCAR FC feature pad defined as: A levelled ground surface.
Peak	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 1	The 7 km by 3.2 km island rises to 771 m at Paton <i>Peak</i> .	A hill or mountain with a comparatively sharp summit.

<i>SCAR FC Feature Types</i>	<i>Sem'tic Agrmee -ment with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)</i>
Penguin(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	but there exists a large Adelie penguin (<i>Pygoscelis adeliae</i>) colony	Sea-fowl of southern hemisphere with wings developed into scaly flippers with which it swims under the water.
Platform(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	Sub-tidal (abrasion) platforms and massive boulders are found below	A small plateau or flat rock massif.
Pond(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	with summer ponds and small meltwater streams draining to the coast	Low-lying muddy or damp place where animals gather.

SCAR FC Feature Types	Sem 'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Ridges	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	A series of beach <i>ridges</i> , which are generally occupied	Long narrow hill or mountain top or spur leading to a summit; the term may also be applied to submarine features.
Sand	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	each layer vertically separated by around 50-100 cm of gravels and <i>sand</i> ,	A loose material consisting of small mineral particles, or rock and mineral particles, distinguishable by the naked eye; grains vary from almost spherical to angular, with a diameter range from 1/16 to 2 millimeters.
Sea	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6, Paragraph 1	With steep and inaccessible cliffs rising straight from the <i>sea</i> .	A body of salty water that covers much of the earth.

SCAR FC Feature Types	Sem'tic Agrment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Sign(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 3, Paragraph 2	Markers, <i>signs</i> or structures erected within the Area for scientific or management purposes shall be secured	A plate or a label carrying important textual or graphical information.
Signpost	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(iii), Paragraph 1	Only structure known to exist on the island is a <i>signpost</i> on a prominent rock	Synonymous with SCAR FC sign defined as: A plate or a label carrying important textual or graphical information.
Slope(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	rugged cliffs on the eastern <i>slopes</i> .	A stretch of rising or falling ground; an inclined plane or gradient.

SCAR FC Feature Types	Sem'itic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Snow	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 7(i), Paragraph 1	Should <i>snow</i> conditions at the designated landing site	Atmospheric precipitation of ice crystals.
Soil(s)	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 2, Paragraph 4	plant communities, avifauna and <i>soils</i> in the Area provided it is for compelling reasons	The top layer of the land surface of the earth that is composed of disintegrated rock particles, humus, water and air.
Sound	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	area of mosses yet known for the McMurdo <i>Sound</i> region.	A strait between two sea areas or an extensive, partly enclosed sea area, including an area that may be covered by ice shelf.

<i>SCAR FC Feature Types</i>	<i>Sem' tic Agrmee -ment with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/fic)</i>
Spit	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	comprises a beach foreland and cuspsate <i>spit</i> , backed by steep basaltic cliffs	Long narrow shoal (where submerged) or a tongue of land (where above water) projecting into the sea.
Station	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 5, Paragraph 1	and the location of McMurdo <i>Station</i> (US) and Scott Base (NZ).	A place where there is permanent human habitation and infrastructure serving as a base for scientific research.
Terrace	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	Above the beach, a raised ice-cored moraine <i>terrace</i>	A shelf or bench of relatively flat, sometimes slightly inclined, ground.

<i>SCAR FC Feature Types</i>	<i>Sem'tic Agrmee -ment with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/fic)</i>
Valley	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 4	progressively entrained into rivulets that have eroded narrow valleys in the edge of the terrace	SCAR FC feature valley defined as: Long depression running from a higher level to a lower level (or to the coast), with a glacier completely filling the feature, partly filling it or terminating within it; rarely a valley may be ice-free with a seasonally stream running through it. The term may be applied also to submarine features.
Vegetation	Y	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	area of <i>vegetation</i> previously unrecorded on an ice-cored moraine bench	Synonymous with SCAR FC vegetation type defined as: A community of plants or plant life that share distinguishable characteristics.

SCAR FC Feature Types	Sem'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Alien animal	N	ATCM XXI (1997) Annex to Measure XXI-1, Item 2, Paragraph 5	minimise the possibility of introduction of <i>alien</i> plants, <i>animals</i> and microbes to the Area;	Related to SCAR FC Introduction of animal species: Animals which have been translocated by human agency into lands or waters where they have not lived previously, at least during historic times. Such translocation of species always involves an element of risk if not of serious danger. Newly arrived species, depending on their interspecific relationships and characteristics, may act as or carry parasites or diseases, prey upon native organisms, display toxic reactions, or be highly competitive with or otherwise adversely affect native species and communities

SCAR FC Feature Types	Sem'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Alien microbes	N	ATCM XXI (1997) Annex to Measure XXI-1, Item 2, Paragraph 5	minimise the possibility of introduction of <i>alien</i> plants, animals and microbes to the Area;	Related to SCAR FC Introduction of animal species. See alien animal above

SCAR FC Feature Types	Sem'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Alien plant	N	ATCM XXI (1997) Annex to Measure XXI-1, Item 2, Paragraph 5	minimise the possibility of introduction of <i>alien plants</i> , animals and microbes to the Area;	Related to SCAR FC: Introduction of plant species: Plants which have been translocated by human agency into lands or waters where they have not lived previously, at least during historic times. Such translocation of species always involves an element of risk if not of serious danger. Newly arrived species may be highly competitive with or otherwise adversely affect native species and communities. Some may become a nuisance through sheer overabundance. They may become liable to rapid genetic changes in their new environment. Many harmful introductions have been made by persons unqualified to anticipate the often complex ecological interaction which may ensue.

SCAR FC Feature Types	Sem'tic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
				On the other hand many plants introduced into modified or degraded environments may be more useful than native species in controlling erosion or in performing other positive functions.

SCAR FC Feature Types	Sem'itic Agrmee -ment with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Base	N	ATCM XXI (1997) Annex to Measure XXI-1, Item 5, Paragraph 1	and the location of McMurdo Station (US) and Scott Base (NZ).	Synonymous with SCAR FC station which is defined as: A place where there is permanent human habitation and infrastructure serving as a base for scientific research. / Note that feature term (symbol) is different while the concept (referent) of station is the same.
Equipment	N	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 6	abandoned <i>equipment</i> was removed from among the Adelie colony at Cadwalader Beach.	May be considered synonymous with SCAR FC Apparatus defined as: A scientific instrument.
Structure(s)	N	ATCM XXI (1997) Annex to Measure XXI-1, Item 3, Paragraph 2	Markers, signs or <i>structures</i> erected within the Area for scientific or management purposes shall be secured	SCAR FC : A structure of unknown type. / The SCAR FC definition does little to establish meaning or essential properties related to the feature type structure

Table B.4 Results of content analysis of ASPA 105 (ATCM XXI, 1997). New features.

New Feature Type	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Aircraft	ATCM XXI (1997) Annex to Measure XXI-1, Item 7(i), Paragraph 1	Land vehicles are prohibited within the Area and access shall be by small boat or by aircraft.	Flying-machines collectively; a flying-machine. (Soanes, 2004) / Interestingly, this feature is not included in SCAR FC in active form, however Aircraft Wreckage is defined. SCAR FC does define a potentially similar term Ship
Algae	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	As a result there is also a diverse community of algae,	A group of primitive plants with no leaves, flowers or vascular system. They include single-celled plants (diatom) and multi-celled seaweeds. (Whittow, 2000:12)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Avifauna	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 1	on the grounds that it "contains substantial and varied avifauna,	The birds of a particular region, habitat, or geological period. (Soanes, 2004)
[Bird]breeding area(s)	ATCM XXI (1997) Annex to Measure XXI-1, Item 7(i), Paragraph 2	Overflight of bird breeding areas lower than 750 m (or 2500 ft) is normally prohibited	An area consistently used by animals for the sexual activity of conceiving and bearing offspring. (Author)
[Small]boat	ATCM XXI (1997) Annex to Measure XXI-1, Item 7(i), Paragraph 1	Land vehicles are prohibited within the Area and access shall be by small boat or by aircraft.	A small open vessel in which to traverse the surface of water, usually propelled by oars, though sometimes by a sail or small motor. (derived from Soanes, 2004)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Boulder(s)	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	Sub-tidal (abrasion) platforms and massive boulders are found below	A large, rounded or subangular piece of rock lying on the surface of the ground, embedded in the soil or within a layer of boulder clay. (Whittow, 2000:62)
Breeding ground(s)	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 1	one of the most important breeding grounds in the region,	See breeding area(s)
Community [of algae]	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	As a result there is also a diverse community of algae,	An organized group of plants or animals, generally of distinctive character and related to a particular set of environmental requirements. (Whittow, 2000:98)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
[Basaltic]dikes	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	have been intruded by a series of late stage basaltic dikes,	A sheet-like body of intrusive igneous rock which rises upwards from a magma chamber and cuts discordantly through the bedding planes or any existing structures of the country-rock (Whittow, 2000:152)
	ATCM XXI (1997) Annex to Measure XXI-1, Item 2, Paragraph 3	preserve the natural ecosystem as a reference area largely undisturbed by direct human activities;	The natural interacting biotic and abiotic system in a given area which includes all of the organisms... that live in a particular habitat, along with their immediate physical environment. Examples include a lake, forest, or drainage basin (Park, 2007:139)
Fast-ice	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	extended to include fast-ice occupied by breeding birds.	An extensive, unbroken sheet of sea-ice formed by the in-situ freezing of sea water when water temperature falls below -2d C in calm weather (Whittow, 2000:181)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Flush	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 4	Initially the water forms a diffuse flush but becomes progressively entrained into rivulets that have eroded narrow valleys in the edge of the terrace.	An area of soil enriched by transported materials, either dissolved mineral salts or rock particles. (Whittow, 2000:194)
Gravel(s)	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	each layer vertically separated by around 50-100 cm of gravels and sand,	A general term for an accumulation of loose compacted, coarse, stony materials. (Whittow, 2000: 229)
Hummock(s)	ATCM XXI (1997) Annex to Measure XXI-1, Item 6, Paragraph 4	at the base of the ice cliff, and more continuous mats (hummocks) occur in the middle	A low mound of earth, rock or ice. (Whittow, 2000:250)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Mean high water mark	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 1	encompasses the whole of Beaufort Island (76'58'S, 167'00'E Map A) above the mean high water mark, and includes adjacent fast-ice	Boundary between the land and sea based on the average plane of high tide using tidal information collected over a long period of time. (author)
[Moss] community	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	the moss community is dominated by a single species	An organized group of plants or animals, generally of distinctive character and related to a particular set of environmental requirements. (Whittow, 2000:98)
Plant Community(y)(ies)	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 3	The exceptional plant communities at this site are fragile	A group of plants (such as broadleaved woodland) that grows together in a particular area, under given environmental conditions (soil, climate, etc.). (Park, 2007:343)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
[Astronomical]Survey station	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(iii), Paragraph 2	An astronomical survey station is recorded on a map of the island compiled in 1960,	The physical location or site at which observations and measurements are made.
	ATCM XXI (1997) Annex to Measure XXI-1, Item 1, Paragraph 2	with summer ponds and small meltwater streams draining to the coast	A natural body of running water that flows along a channel. (Park, 2007:430)
Stream(s)			
Tuff(s)	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	there is evidence of layered ash-fall tuffs and welded spatter flows from local subsidiary cinder and spatter cones.	A volcanic rock composed of compacted, medium-to fine-grained pyroclastic material (Whittow, 2000:549).

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
[Land]vehicle(s)	ATCM XXI (1997) Annex to Measure XXI-1, Item 7(i), Paragraph 1	Land vehicles are prohibited within the Area and access shall be by small boat or by aircraft.	A means of conveyance provided with wheels or runners and used for the carriage of persons or goods; a carriage, cart, wagon, sledge, motorcar or similar contrivance. (derived from Soanes, 2004)
Volcanic vents	ATCM XXI (1997) Annex to Measure XXI-1, Item 6(i), Paragraph 2	is one of a series of late Tertiary volcanic vents that developed along a line	The orifice of a volcano, consisting of a vertical passage leading down from the surface into the magma chamber (Whittow, 2000:563)

Table B.5 Results of content analysis of ASP A 142 (ATCM XXIII, 1999). Features not previously identified that are semantically equivalent to SCAR FC features or have some level of ambiguity

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Building(s)	Y	ATCM XXIII (1999) Annex to Measure XXIII-1, Item 6(i), Paragraph 2	The station, including a 10 metre buffer zone around the station buildings, is excluded	A permanent walled and roofed construction or the ruin of such a construction.
Erratic(s)	Y	ATCM XXIII (1999) Annex to Measure XXIII-1, Item 6(i), Paragraph 5	There are a few lichen species on glacier-borne erratics 1-2 km away from the bird colonies	Glacially transported stones and boulders. Erratics may be embedded in till or occur on the ground surface. They range in size from pebbles to huge boulders weighing thousands of tons. Their transport range from less than 1 km to more than 800 km. Erratics composed of distinctive rock types can be traced to their point of origin and serve as indicators of glacial flow direction.

<i>SCAR FC Feature Types</i>	<i>Semantic Agreement with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/ftc)</i>
Mountain	Y	ATCM XXIII (1999) Annex to Measure XXIII-1, Item 6(i), Paragraph 3	Extending 240 metres upwards from the base of the mountain at about 1600 metres above sea level.	Natural elevation rising to a relatively great height. Mountain, hill and knoll are terms indictating various degrees of heights in descending order, varying with the general configuration of the vicinity. The term mountains may be used for a grouping within a range.
Nunatak	Y	ATCM XXIII (1999) Annex to Measure XXIII-1, Item 6(i), Paragraph 1	consists of the ice-free areas of the Svarthamaren nunatak, including the areas in the immediate vicinity of the ice-free areas naturally belonging to the nunatak (i.e. rocks)	A small mountain, rocky crag or outcrop projecting from a glacier, ice shelf or snowfield.
Site	Y	ATCM XXIII (1999) Annex to Measure XXIII-1, Item 3,	allow erection of signs/posters, border markers, etc. in connection to the site, and ensure that these are serviced and maintained in good condition.	In this context, synonymous with SCAR FC scientific site which is defined as: allow erection of signs/posters, border markers, etc. in connection to the site, and ensure that these are serviced and maintained in good condition.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
		Paragraph 3		

Table B.6 Results of content analysis of ASPA 142 (ATCM XXIII, 1999). New features not previously identified.

New Feature Type	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
[Rock]Amphitheatre(s)	ATCM XXIII (1999) Annex to Measure XXIII-1, Item 6(i), Paragraph 3	The major features of this area are two rock amphitheatres inhabited by breeding Antarctic petrels.	A natural rock feature consisting of a level surrounded in whole or part by rising slopes. (derived from Soanes, 2004)
Ice front	ATCM XXIII (1999) Annex to Measure XXIII-1, Item 6(i), Paragraph 1	The distance from the ice front is about 200 km.	Applicable only to the vertical cliff which forms the seaward limit of a floating glacier or an ice-shelf. The term is also used commonly to describe the distal limit of an ice- sheet on a land surface (Whittow, 2000:259)

Table B.7 Results of content analysis of ASPA 147 (ATCM XXV, 2002). Features not previously identified that are semantically equivalent to SCAR FC feature or have some level of ambiguity

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Bluff	Y	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 4	The presence of exposures of the Fossil Bluff Formation, which is of prime geological importance	A headland or short stretch of cliff with a broad nearly vertical face, or a similar feature at the margin of a glacier or an ice piedmont.
Fish	Y	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 7	The presence of marine biota, including the fish Trematomus bernacchii,	Cold-blooded aquatic vertebrates.

<i>SCAR FC Feature Types</i>	<i>Semantic Agreement with SCAR FC</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>SCAR FC definition (from http://data.aad.gov.au/aadc/ftc)</i>
Heights	Y	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 1	Ablation Point - Ganymede Heights (latitude 70°48' S, longitude 68°30' W, approximately 180 km ² ,	Relatively high hills or mountains.
Massif	Y	ATCM XXV (2002) Annex to Measure XXV-1, Item 6(i), Paragraph 1	with the smaller permanent ice fields and valley glaciers within the massif representing	Compact group of mountain heights, which may be partly or almost entirely ice-covered.
Patterned ground	Y	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 2	a wide range of geomorphological features including raised beaches, moraine systems and patterned ground.	Well-defined features, such as circles, polygons, nets, steps and stripes, characteristic of areas at some time subject to intensive frost action

Table B.8 Results of content analysis of ASPA 147 (ATCM XXV, 2002). New features not previously identified.

New Feature Type	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Ablation areas	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 2	one of the largest ablation areas in West Antarctica	An area of ablation where ablation is defined as: the wastage or removal of surface snow or ice by melting and evaporation... (Whittow, 2000:1)
(hydrological) Catchment	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 13	defined on the basis of prominent geographical features and the regional hydrological catchments.	British: the total area from which a single river collects surface runoff. American: the intake area and all areas which contribute surface water to the intake area of an aquifer (Whittow, 2000:77)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Dry lake bed(s)	ATCM XXV (2002) Annex to Measure XXV-1, Item 7(i), Paragraph 9	Avoid walking in stream or dry lake beds, or on moist ground, if practical, to avoid disturbance to the hydrology and / or damage to sensitive plant communities.	The floor of a water body (Whittow, 2000:49)
	ATCM XXV (2002) Annex to Measure XXV-1, Item 6(i), Paragraph 2	As a "dry valley" area it is extremely rich in biota and serves as a valuable contrast to the more extreme and biologically impoverished ablation areas on the Antarctic continent	Valleys that are mostly ice-free and are characterized by low humidity and harsh conditions for life (author)
Dunes	ATCM XXV (2002) Annex to Measure XXV-1, Item 7(i), Paragraph 9	where practical walk on rocky or ice-covered terrain, and avoid sensitive geomorphological features such as dunes.	A mound or ridge of wind-blown sand, rising to various heights up to 50m (Whittow, 2000:150)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Mélange	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 2	The base of the succession is formed of a spectacular mélange, including large blocks of lava and agglomerate.	A jumbled mass of fragments from a wide range of rock types now cemented into a sedimentary rock (Breccia) (Whittow, 2000:327)
Oas(is)(es)	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 2	unique moss and liverwort-dominated community type being restricted to 'oases' where water issues from otherwise dry barren hillsides	1. An area of any size in the midst of a desert which has sufficient water to support plant growth (Whittow, 2000:362) 2. Ice free areas that can support life in an area otherwise covered with ice (author)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Seepage area	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 11	In the sheltered seepage area assemblages of terricolous species develop communities	Area of seepage where seepage can be defined as 1. The gradual soaking away of surface water into the soil 2. The slow emission of groundwater at the surface when the rock structures (joints, bedding planes) permit but with insufficient volume for it to constitute a spring. (Whittow, 2000:472)
Stand(s) (of vegetation)	ATCM XXV (2002) Annex to Measure XXV-1, Item 1, Paragraph 11	the Area has the most extensive stands of vegetation on Alexander Island.	An area occupied by a collection of plants or trees which are structurally and floristically homogeneous (Whittow, 2000:502)

Table B.9 Results of content analysis of ASPA 160 (ATCM XXVI, 2003). Features not previously identified that are semantically equivalent to SCAR FC features or have some level of ambiguity

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Bedrock Depression	Y	ATCM XXVI (2003) Annex to Measure XXVI-2, Item 6(i) Paragraph 7	Surface sediments consist of fine gravelly sand located in bedrock depressions	A poorly defined sunken area of the bedrock surface, not indicated by contours

Table B.10 Results of content analysis of ASPA 160 (ATCM XXVI, 2003). New features not previously identified.

New Feature Type	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Nest	ATCM XXVI (2003) Annex to Measure XXVI-2, Item 6(i) Paragraph 3	three colonies were recorded on the northwest ridge of Nelly Island with a total of 554 nests.	A structure in which animals (particularly birds) lay eggs or give birth to their young (Park, 2007:302)

Table B.11 Results of content analysis of ASP A 163 (ATCM XXVIII, 2005). Features not previously identified that are semantically equivalent to SCAR FC features or have some level of ambiguity

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/ffc)
Blue ice	Y	ATCM XXVIII (2005) Annex to Measure XXVIII-2, Item 6(i), Paragraph 3	The southernmost ice-sheet is bare 'blue ice', descending from 180 m contour to 10 m contour	Bands of transparent ice containing no air bubbles, its mass acquiring a blueish tint.
Crevasse(s)	Y	ATCM XXVIII (2005) Annex to Measure XXVIII-2, Item 6(i), Paragraph 5	Area comprises shelf ice with pressure ridges, fractures and crevasses.	A fissure formed in a glacier. Crevasses are often hidden by snow bridges.

SCAR FC Feature Types	Semantic Agreement with SCAR FC	Doc reference (line start number or map reference)	"Context" from ATS corpus	SCAR FC definition (from http://data.aad.gov.au/aadc/fic)
Fault(s)	Y	ATCM XXVIII (2005) Annex to Measure XXVIII-2, Item 6(i), Paragraph 7	Two sets of faults (N30E and N50E) are quite prominent.	A fracture in earth materials, along which the opposite sides have been relatively displaced parallel to the plane of movement.

Table B.12 Results of content analysis of ASPA 163 (ATCM XXVIII, 2005). New features not previously identified.

New Feature Type	Doc reference (line start number or map reference)	"Context" from ATS corpus	Proposed definition/ Notes
Fracture	ATCM XXVIII (2005) Annex to Measure XXVIII-2, Item 6(i), Paragraph 5	Area comprises shelf ice with pressure ridges, fractures and crevasses.	A clean break in rock or ice due to strain or stress from extension or compression of rock or ice (derived from Whittow, 2000:200)
Linaement	ATCM XXVIII (2005) Annex to Measure XXVIII-2, Item 6(i), Paragraph 5	The contact between shelf ice and eastern rocky slopes is marked by a prominent 3-km long, NNE-SSW trending lineament.	A large scale linear topographical feature reflecting an underlying structure (Whittow, 2000:307)

<i>New Feature Type</i>	<i>Doc reference (line start number or map reference)</i>	<i>"Context" from ATS corpus</i>	<i>Proposed definition/ Notes</i>
Snout	ATCM XXVIII (2005) Annex to Measure XXVIII-2, Item 6(i), Paragraph 3	descending from 180 m contour to 10 m contour at the snout of the Glacier.	Synonymous with glacier terminus (Whittow, 2000:488)