CHAPTER 1

General Introduction

Greenland is one of the most poorly understood regions of the Earth due to its remoteness, harsh climate, and cover of glacial ice. The obscurity of its geology greatly limits our understanding of its geologic history and relationship to the surrounding regions. Several studies in the past have focused on smaller areas, but regional analyses have been limited due to the lack of data.

Recently, several agencies have collected and merged gravity and magnetic data sets that facilitate such regional geologic studies for Greenland (58.7 -84.2° N and 285.75 - 349.50° E). Through potential field studies, new insight on the geologic properties and tectonic history of subglacial and offshore Greenland may be inferred. Based on the limitations of these data and the anticipated processing requirements, both these data sets were upward continued to 20 km elevation using a Fourier transform operator.

The U.S. National Imaging and Mapping Agency (NIMA) has compiled several gravity data sets for the region. These include the aerogravity survey collected over Greenland by the Naval Research Laboratory [Brozena, 1995] during the Greenland Aerogeophysics Projects of 1991 and 1992. These aerogravity data were combined with other terrestrial and shipborne data [Forsberg, 1996; Forsberg, 1994] using least squares collocation to generate a 5' free-air gravity anomaly (FAGA) grid spanning the entire area of interest [Forsberg and Kenyon, 1995]. These data are draped upon a digital elevation model (DEM) determined by NIMA to represent the surface of Greenland and its surrounding environs. It was necessary to upward continue the FAGA from this surface to an elevation of 20 km to provide a FAGA grid at a uniform elevation. The processing details to perform this correction are given in Appendix A.

Another major data set for this analysis is the magnetic anomaly compilation that was produced by the Atlantic Geoscience Center (AGC) [Verhoef et al., 1996]. This grid of magnetic anomalies (MA) was compiled from multiple airborne and shipborne surveys, as well as previously gridded data sets. Due to the problematic nature of combining multiple surveys from multiple organizations, only the 400 km and shorter wavelength components were represented in the final grid. Additionally, the various data sources were provided at different survey elevations and were not reduced to a common elevation. For this reason, the data were then upward continued to 20 km to minimize the effects of these varying survey elevations. Finally, to facilitate geologic analysis and comparison with gravity data, the MA data were reduced-to-pole. Details for both of these corrections are given in Appendix B.

Terrain data that are as accurate as possible are required to fully exploit the geopotential field anomalies for subsurface information. In Chapter 2, the gravity geologic method for estimating bedrock elevation beneath unconsolidated materials is adapted for making improved bathymetric determinations. The high frequency components of the gravity field are directly related to the varying bathymetry through the Bouguer slab formula. By utilizing control depths to establish a regional trend to the FAGA, the component due to the bathymetry may be isolated. The resulting bathymetric predictions represent a significant improvement over traditional sources of bathymetry (ETOPO5U and JGP95E), as well as those derived from others [Smith and Sandwell, 1994; 1997]. These improved bathymetry estimates were used to generate better models of the depth to the ocean bottom, as well as an isopach map for the ocean thickness.

The masses implied by these and other terrain models can be used to estimate the depth to the Moho boundary. In Chapter 3, Gaussian Legendre Quadrature integration (GLQ) is used to estimate the gravity effect of the masses implied by the bedrock and ocean models. Additionally, available models for the ice surface and bottom are also modeled using GLQ integration to generate a gravity field. These three fields combined represent the terrain gravity effects (TGE) of the crust. Components of the FAGA field that are strongly correlative or anti-correlative (inversely correlative) with the TGE are assumed to reflect deviations from an Airy model of isostatic compensation. Removal of these FAGA components generates the compensated TGE that may be used in a GLQ inversion to estimate the Moho. Differencing the Moho model with the bedrock model generates a crustal thickness model. The Moho and crustal models may be used to locate intermediate to long wavelength crustal structure. This may be further refined by examing adjusted densities that may signify lateral changes in lithology.

With knowledge of the physical properties for rocks in the region, FAGA can also be compared to MA to extend knowledge of geologic features both into obscured crustal regions (subglacial and offshore) and in the mantle. In Chapter 4, the TGE were used to isolate the non-correlative components of the FAGA (TDFAGA). It is assumed that these data represent lateral density variations within the crust, as well as vertical density variations and errors. TDFAGA is then compared with the higher harmonics of an EGM96 generated FAGA field, which are more related to crustal or shallow mantle sources. The correlative portion of TDFAGA becomes the intracrustal terrain decorrelated gravity anomalies (IC-TDFAGA) that are reflective of lateral density variations in the lithosphere.

After isolating the components of FAGA most related to lateral density variations within the lithosphere (crust and uppermost mantle), a similar component is desired from the MA. Because the MA source region is likely located within the crust only [Shive et al., 1992; Wasilewski and Mayhew, 1982; 1992; Wasilewski et al., 1979], it is only necessary to separate the component of MA related to crustal thickness variations to determine the intracrustal MA (IC-RTPMA). GLQ is used to generate a gravity field from the crustal thickness model. The first radial derivative of this gravity field estimates pseudo-magnetic anomalies that can be related to the component of the MA data due to crustal thickness variations using Poisson's Relation. Removal of the most correlative components from the MA data generates the IC-RTPMA

The IC-TDFAGA and IC-RTPMA data may now be compared to find regions that are correlative, non-correlative, and anti-correlative, which can be related to the expected geophysical characteristics of the rocks in the region. The IC-RTPMA and the first radial derivative of the IC-TDFAGA (FVD(ic-TDFAGA))are first normalized so that they both have the same standard deviation (energy). This step is necessary to account for the unknown proportionality constant in Poisson's Relation, which relates these two potential fields. The local favorability indices (LFI) of these two normalized grids can be summed (SLFI) and differenced (DLFI) to highlight regions characterized by maxima and minima in the FAGA and MA. By examining the geopotential characteristics of mapped lithologies for this region and comparing with the SLFI and DLFI, these characteristics may be used to extrapolate and map the lithologic boundaries and structure into offshore continental platforms areas and in regions covered by glaciers.

Several interesting structures were determined from the maps of the Moho undulations, adjusted densities, and the extrapolations based upon the LFI including one along the southwestern Greenland margin. Its formation and significance is discussed further in Chapter 5 where these features apparently contradict a widely held kinematic model for the opening of the North Atlantic Ocean [Srivastava, 1978; Srivastava and Roest, 1986; Roest and Srivastava, 1989; Roest, 1998]. These structures are supported by several seismic surveys that determined similar results along profiles [Chian and Louden, 1994; Chian et al., 1995a, Chian et al., 1995b; Chalmers et al. 1995]. A tectonic model for the evolution of the region that is based upon the interpretations of the structures determined in Chapters 3 and 4. This model incorporates the significant results of these seismic surveys along with tectonic evolution models for other regions to determine a probable origin for the rifted crust in the Labrador Sea.

In Chapter 6, the results of this study are summarized. Conclusions from this work and recommendations for future work are also made. The significance of this work to other regions of interest including the formation of the Arctic Ocean is also discussed.