Circum-Arctic Lithosphere-Basin Evolution: An Overview

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Abstract

A new collection of papers spanning the breadth of the Arctic provides new insight into the region's geodynamic evolution. New results pertain to lithospheric structure, the link between magmatic and extension-related tectonic processes, variations in the composition and velocity structure of the lower crust in the Amerasia Basin, and provenance and paleogeography of Paleozoic to Triassic successions across the Arctic. Elucidation of geodynamic processes in the Eurasia Basin suggests new hypotheses for future research in the complex and poorly understood Amerasia Basin. New results from detrital zircon provenance studies as well as from stratigraphic facies compilations constrain the Late Paleozoic to Triassic paleogeography of the Arctic realm.

Key Words

Circum-Arctic; tectonics; geodynamics; paleogeography; magmatism

1. Introduction

This circum-Arctic lithosphere-basin Special Issue evolved from a Special Session at the Geological Society of America Annual meeting in Vancouver, Canada in 2014. The session's aim was to highlight new research across the Arctic, reflecting the breadth of lithospheric interactions that occurred over the past ~700 Myr, emphasizing thematic linkages, such as inter-regional, onshore-offshore, lithosphere-basin, magmatism-tectonism and so on. The modern Arctic is the product of a long history of plate tectonic processes that closed and opened Phanerozoic oceans, deformed sedimentary basins and created orogens, together with surface processes that produced and transported sediments from orogenic highlands into adjacent sedimentary basins. By assembling a multidisciplinary suite of papers into one Special Issue, this project attempts to facilitate greater understanding of the interdependence of the processes underlying the tectonic, magmatic and sedimentary evolution of the Arctic, to encourage new avenues for future multidisciplinary studies, and possibly to foster fresh insights into the linkages between these processes.

From the 1960s and until the 1990s, geoscientific research in the Arctic was driven largely by cyclical activity in the petroleum exploration sector, interspersed with intermittent public sector and academic programs. The Arctic's remoteness and inaccessibility was, and continues to be, an impediment to research. Although these efforts resulted in many important advances in understanding the region's geological history, it remained poorly understood. Over the past 10-15 years, the evolution of the Arctic has been increasingly a focus of geoscience research. Initially, this was driven by renewed exploration investments by the petroleum sector. However, as technological advances in petroleum production reduced the economic incentive for Arctic resource development, a new incentive for research arose in the United Nations' 1982 Convention on the Law of the Sea (UNCLOS), Article 76, which sets out how coastal states define the outer limits of their legally defined continental shelf beyond 200 NM, where one exists (e.g., United Nations, 1999). The criteria set out in Article 76 required coastal states to collect significant volumes of bathymetric and sediment thickness data across the Arctic continental margins, which provided an opportunity to acquire new crustal structure data. It was also a challenge to drive new technologies (e.g., new seismic sources designed to operate in heavy ice conditions) , data collection methods (e.g., multi-national, multi-ship ice-breaker operations) and international collaborations in order to be successful. Data for several of the contributions to this Special Issue were acquired through surveys in support of programs to define nations'extended continental shelves, as required under Article 76 of the Convention.

Meanwhile, onshore, a dramatic increase in the volume of research based on U-Pb age analyses of detrital zircon began to provide new insights into the provenance histories of multiple Paleozoic and Mesozoic depositional systems around the Arctic. In many cases, they identified previously unrealized common sources for sands deposited into sedimentary basins that were subsequently tectonically dismembered and dispersed. In a few cases, age populations occur for which no plausible sources are known. Further, as the technique has become more widespread, it is increasingly apparent that sedimentary recycling is more common than previously understood. Thus, the immediate zircon sources may be quite different from the original magmatic sources. Such cycles of inheritance can be traced back through several generations. In combination with stratigraphic and structural analyses, the use of detrital zircon geochronology continues to advance our understanding of Arctic paleogeography across the region and throughout the Phanerozoic. Three contributions in this issue are based on detrital zircon geochronology.

2.0 Thematic Overview

Altogether, the contributions in this Special Issue reflect current research in the Arctic realm encompassing multiple aspects of the geosciences: lithospheric structure, magmatic processes, rheology, tectonic evolution, and provenance and paleogeography. Geographically, the 15 presented studies span much of the Arctic region (Fig. 1). In Figure 1, they are colour coded according to two broad categories: lithospheric structure and geology. The former is largely marine and remotely sensed, further differentiated in Figure 1 based on their principal data sets (seismology vs potential field). The latter consists of land-based field studies. Here we summarize the contributions in the Special Issue. In order to facilitate the presentation, we have organized what follows into these two broad themes: Lithospheric structure and Geology (Fig. 1).

2.1. Lithospheric Structure

The first theme, lithospheric structure, is explored primarily using seismology supplemented with potential field modelling. Despite the logistical complexities of acquiring seismic data in heavy ice, these new studies determine the physical characteristics of its crust with sufficient resolution to make new inferences about tectonic setting and internal structure.

In an important and comprehensive study of the crustal structure in southern Canada Basin, Chian et al. (2016) employ a suite of sonobuoy records supported by multichannel seismic reflection profiles and potential field modelling to classify crustal types within the basin. They distinguish three crustal types mainly on the basis of their P-wave velocity analysis: thinned continental crust (5.5-6.6 km/s), oceanic crust (6.7-7.1 km/s), and high-velocity transitional crust

(7.2-7.6 km/s). A key finding is that oceanic crust occupies a broadly pentagonal area within central Canada Basin some 600 km long by 350 km wide. This publication undoubtedly will be used widely to underpin future tectonic syntheses of the basin.

In a new 400 km seismic refraction and gravity transect from the Greenland margin of Nares Strait southward into northern Baffin Bay, Altenbernd et al. (2016) present a new crustal structure model, imaging the continent-ocean transition in this area. Crustal layers are defined in the continental, transitional and oceanic portions of the transect. Velocities of 7.7 km/s characterize the sub-oceanic mantle; such low velocities are inferred to relate to serpentinization. Serpentinization as well as thin oceanic crust in this area are correlated with slow spreading rates. Moho depths vary from 34 km beneath Greenland to 13 km beneath the oceanic crust. No evidence was found to suggest significant magmatism occurred within the continent-ocean transition zone.

Anudu et al. (2016) applied a series of derivative filters to regional aeromagnetic and gravity anomaly datasets, to enhance signals of magmatic and structural features across the Canadian Polar margin adjacent to Alpha Ridge. They recognize five magnetic domains based on anomaly patterns and attributes. They infer that Cretaceous to Paleogene magmatic bodies are more prevalent than the existing mapping suggests; that the marginal basin underlying the continental shelf post-dates Cretaceous magmatism, and that most of the intrusions were emplaced in a NW-SE minimum compressive stress field, believed to correlate with Early Cretaceous High Arctic Large Igneous Province (HALIP) magmatism.

Oakey and Saltus (2016) present magnetic and gravity models along regional transects through the Alpha-Mendeleev Ridge complex, which extends over a region exceeding one million square kilometres, and compare the resulting crustal characteristics with other major large igneous provinces. They conclude that HALIP magmatism was largely or completely intruded into continental crust that was intensively intruded and underplated by mafic magmatism. They refer to the continental Kerguelen Plateau as an appropriate analogue.

Using seismology and potential field analyses, several studies focus on the magmatic processes associated with ocean basin tectonic evolution in the context of mid-ocean ridge processes and large igneous provinces (LIPs). These contributions provide detailed seismic and potential field interpretations along the Greenland continental margins and adjacent oceanic spreading ridges that elucidate the processes involved in magmatic and amagmatic formation of oceanic crust in the Eurasian Basin and north Atlantic during Cenozoic time.

A contribution by Schmidt-Aursch and Jokat (2016) uses 3D gravity modelling in parts of the Eurasian Basin to resolve variations in crustal thickness related to temporal and spatial variations in magma supply to the ultra-slow spreading Gakkel Ridge. They describe three regional domains: two that are magma-rich, separated by a central domain containing areas of sparse but focused volcanism. Magnetic anomaly amplitudes vary in complex ways, both along and across the study area. However, they appear to be uncorrelated with crustal thickness variations. In the western domain a period of more robust magmatism with well-defined anomalies is inferred to correlate with northward propagation of a chemically distinct North Atlantic mantle.

In a related study, interpretation of aeromagnetic surveys in the north Greenland, Fram Strait and Lena Trough areas, Jokat et al. (2015) have clarified multiple relationships between magmatic events and tectonic evolution adjacent to northern Greenland. First, the latest Cretaceous Kap Washington volcanics, extensively exposed onshore, are more widely preserved offshore than was previously recognized. They also recognize that the Arctic spreading centre required ~11 Myr to propagate southward from Fram Strait to the Spitzbergen Fracture zone. Also, the ultra-slow spreading centre in Lena Trough, inferred to be non-volcanic, is characterized by a subdued magnetic signature that may reflect magnetization of exhumed serpentinized mantle.

A new crustal seismic refraction transect and coincident gravity profile, of some 500 km length, extends from Kong Oskar Fjord into the Atlantic Ocean off east Greenland (Hermann and Jokat, 2016). It presents a new model of the continent-ocean transition in this area, characterized by a 3 km thick lower-crustal high-velocity zone that is inferred to indicate excess magmatism in the vicinity of the Jan Mayen Fracture Zone, dating to the separation of the Jan Mayen microcontinent from Greenland in Oligocene time. This implies that fracture zones may play an important role in the production and distribution of magma at extended continental margins.

The response of the lithosphere to applied tectonic stresses is dependent on its rheology. Local and regional variations determine if and where strain becomes concentrated, and also the mechanism(s) by which the strain occurs. External influences on rheology are the thermal environment, the lithology and the strain-rate.

In the Barents and Kara Sea region, Gac et al. (2016) employ a 3D lithospheric-scale structural and thermal model to compute an effective elastic thickness map and rheological model of the region. They illustrate the correlation between lithospheric thickness, lithospheric strength and effective elastic thickness. Also, the region has an asymmetric lithospheric structure, thinner and hotter in the west, colder and thicker in the east. Thus differing responses to imposed tectonic stresses are to be expected across the region. Computed gravitational potential energy across the region indicates that ridge-push is may be a sufficient mechanism to produce contraction on western Barents shelf.

Li et al. (2016) used backstripping and 2D subsidence modelling to reproduce the thermal subsidence history of the southern margin of Canada Basin in comparison to an analogous area within the South China Sea. Both settings involve hyperextended crust and deep basins with crustal geometry constrained by seismic reflection profiles and gravity data. The authors conclude that a weak lower crust and high heat flow led to a lower crust that extended much more than the overlying crust, implying substantial ductile thinning within the lower crust.

2.2. Geology

Studies of stratigraphic and structural history, integrated with geochronology and geochemistry of magmatic rocks provides additional information on the deeper lithospheric processes during tectonism, as well as on regional tectonic evolution, through time.

Within the context of the temporally and spatially complex mid-Paleozoic tectonic history of the Timan Range of Arctic Russia, Pease et al. (2016) attempt to resolve ambiguities in the tectonic setting of the magmatism by examining the petrology and geochemistry of Devonian basalts. Chemical (including trace and rare-earth elements) and isotopic relationships indicate that the low-potassium tholeiiteic magmas comprise two discrete groups, derived from mid-ocean ridge basalts, distinguished by differing amounts of contamination by continental crust. The magmatism is interpreted to result from local melts related to rifting of a mainly non-volcanic continental margin sampling a heterogeneous mantle source. It is distinct from back-arc extension or mantle plume-related settings and suggests a complex interplay between tectonic settings within and marginal to the East European Craton.

In an ambitious review and synthesis paper, Moore and Box (2016) distill the Phanerozoic tectonic evolution of Alaska into a suite of 14 time-slice maps summarizing the evolution of nearly two dozen discrete tectonostratigraphic terranes, in three regional domains. Alaska's location at the intersection of the Pacific and Arctic realms of the Laurentian craton has positioned it to interact with exotic terranes derived from both directions throughout Phanerozoic time. Accordingly, its stratigraphic, magmatic and tectonic evolution is complex and diverse. It incorporates terranes with affinities to the Siberian, Baltican and Laurentian cratons, as well as to various oceanic realms. Moore and Box summarizes the current state of knowledge for the bulk of Alaska and, with its extensive citation list, provides an entry point into the Alaskan geoscience literature for readers.

Studies of provenance and paleogeography provide information that permits correlations within continents and between continents and terranes. Such linkages may help to characterize terranes that are otherwise poorly understood. Four papers in this issue focus on these topics, of which three are based on detrital zircon (DZ) studies. One study synthesizes regional sedimentology and stratigraphy, supported by previously published DZ results.

Zhang et al. (2015) report on the provenance and paleogeography of a latest Mesoproterozoic and Neoproterozoic metasedimentary succession located on the northern margin of the Baltic Shield, now imbricated within Caledonian nappe complexes. Using new DZ data combined with facies analyses and an extensive dataset of paleocurrent data, they reconstruct the Neoproterozoic paleogeography of the passive margin succession on the northern (Timanian) margin of the Baltic Shield in northern Fennoscandia. By integrating multiple lines of evidence in the reconstruction, they establish that the entire succession is indigenous to Baltica and clarify aspects of the margin's geometry up to the early stages of Timanian (late Neoproterozoic) orogenesis. The DZ results also support a reliable baseline dataset documenting a Baltican cratonic signature.

In their contribution, Anfinson et al. (2016) report on the temporal and spatial variations of detrital zircon distributions in Permian and Triassic sandstones on the northern margin of Canada's Sverdrup Basin. These data, together with existing sedimentological data, indicate that sediments were derived from the recycling of remnant Ellesmerian orogenic deposits from a source area of low relief to the north. However, the eastern segment of the basin margin received a voluminous influx of Late Triassic sands containing abundant Early Carboniferous to Triassic zircon populations, which they infer to be derived from the Taimyr region of Eurasia. This localized influx is restricted to an interval of some 20 Myr. Integrating these results with existing regional sedimentological and stratigraphic data, they further propose paleogeographic reconstructions for the Permian and Late Triassic, the latter including a fluvial drainage system connecting a Taimyr provenance with the Sverdrup Basin, circumventing the coeval Barents Basin.

Ershova et al., (2016a), provide an overview of the Late Paleozoic paleogeography of Arctic Russia based on a review of the Devonian to Permian facies belts of the Taimyr region, the major island groups of the east Russian Arctic shelf and Chukotka. They recognize two distinct paleogeographic groups. The widely separated island groups on the East Siberian shelf (Severnaya Zemlya, New Siberian Islands, Wrangel) and Chukotka share stratigraphic and provenance similarities but are distinctly different from the adjacent northern Siberian margin, which suggests that Siberia experienced a distinctly different Late Paleozoic history. The authors further suggest that the New Siberian Islands-Chukotka-Wrangel region may comprise part of the distal Barents shelf, whereas the Kara terrane (Severnaya Zemlya-North Taimyr) was accreted to Siberia in the Carboniferous.

A second contribution by Ershova et al. (2016b), documents an important baseline “Siberian affinity” DZ signature, based on a study characterizing Siberia-derived Permian successions. Permian strata deposited onto the Arctic margin of Siberia contain zircon age distributions that are dominated by peaks of Late Carboniferous-Permian and Cambrian-Ordovician ages, with minor Paleoproterozoic peaks indicating a cratonic source. On the basis of these baseline data, the authors delineate two distinct lineages for Permian strata deposited into displaced terranes within the Arctic realm. One lineage is dominated by zircon grains of Late Carboniferous to Permian age similar to those studied from the northern Siberian margin and sourced from the Ural-Mongolian orogen. The second lineage contains few or no grains of these ages and is consistent with a source dominated by recycling of the Ellesmerian clastic wedge and Laurentian margin rocks.

3 Discussion

3.1. Large Igneous Provinces, Magmatic and Amagmatic Ocean Spreading

Using the results gained from studies of areas with relatively well-understood tectonic settings, such as the northern Atlantic and Eurasia basins, is it possible to gain new insights about areas such as Amerasia Basin? Several papers in the Special Issue describe crustal structure and the role of magmatic processes for areas near continent-ocean transitions along the east and north Greenland margins, as well as within the Eurasian Basin. These results can be compared to new data documenting the distribution of crustal types, including extensive areas of highly thinned continental crust, as well as the effect of regional variations in the importance of magmatism in the development of Canada Basin. Can these spatial variations perhaps be correlated with areas of high-velocity magmatic underplating? Certainly, high-velocity underplated crust is identified in the transitional zone surrounding the oceanic central part of Canada Basin, yet these areas appear in areas identified as both magma-rich and magma-poor (Chain et al., 2016).

The Cenozoic tectonic history of the Arctic is dominated by the opening of the Eurasia Basin. The initial separation of Lomonosov Ridge from the Barents Shelf and development of Gakkel Ridge occurred ~55 Ma (e.g., Brozena et al., 2003; Schmidt-Aursch and Jokat, 2016). The early history of mid-Atlantic Ridge propagation included extension and seafloor spreading in Labrador Sea and Baffin Bay during separation of Greenland from North America, and subsequent convergence with Ellesmere Island. A connection between the northward-propagating mid-Atlantic Ridge and Gakkel Ridge was established only much later with the opening of Fram Strait (Jokat et al., 2015; Hermann and Jokat, 2016).

In an ultra-slow spreading ocean-ridge system, mafic magmatism is apparently optional. Amagmatic extension is developed in places along Gakkel Ridge (Schmidt-Aursch and Jokat, 2016). This study provides insights into the development and physical characteristics of slow-spreading systems that may be instructive for other basins, in particular Amerasia Basin. Mafic volcanism was locally important prior to Amerasia Basin initiation and throughout its subsequent history, particularly in the northern part of the basin (compare Jokat et al., 2015, and Schmidt-Aursch and Jokat, 2016 *vs* e.g., Evenchick et al., 2015). However, southern Canada Basin, is identified as magma-poor (Chian et al., 2016).

The significance of large igneous provinces (LIPs) in the tectonic evolution of the Arctic has been a topic of vigorous research over the past decade (e.g., Petrov et al., 2016). The geodynamic drivers for development of LIPs and their tectonic consequences remain areas of active research (e.g., Jokat et al., 2015; Hermann and Jokat, 2016; Anudu et al., 2016).

3.2. Tectonics and Paleogeography

Over the past decade, the Paleozoic paleogeographic histories of the Arctic region have become a major focus of study. These activities have been manifest in three disparate fields, which are nonetheless interconnected through various publication feedback cycles. These broad fields are: 1) tectonics and orogens; 2) continent-scale paleomagnetic syntheses; and 3) provenance and paleogeography of displaced terranes (e.g., Cocks and Torsvik, 2007, 2011; Prokopiev et al., 2013).

An improved understanding of the provenance and facies trends of displaced terranes and deformed belts marginal to the major continents is critical to reconstructing paleogeographic evolution. The relationships between Arctic terranes and the adjacent cratons are poorly understood. However, new studies from the Arctic margins of Baltica, Russia and Canada (Ershova et al., 2016a; Anfinson et al., 2016), as well as a comprehensive overview of the Phanerozoic tectonic evolution of Alaska, comprising numerous displaced terranes inferred to derive from both the Pacific and Arctic realms (Moore and Box, 2016), have provided much new data and incorporate new results from multiple active research programs across the region. Their new insights help to clarify the paleogeography of the Paleozic and early Mesozoic strata across the Arctic.

New detrital zircon U-Pb geochronology studies, some combined with trace element and rare earth geochemistry, have provided significant insights into the provenance of Proterozoic to Triassic strata (Zhang et al., 2016; Ershova et al., 2016b). These and other studies (e.g., Kirkland et al., 2009; Anfinson et al., 2012; Lane and Gehrels, 2014) have provided baseline signatures for autochthonous successions of known provenance, whereas others document exotic sources in sedimentary successions (e.g., Rainbird et al., 1992; McNicoll et al., 1995; Miller et al. 2006; Lane et al., 2016). Such studies suggest linkages between sedimentary source areas and remote depositional basins have helped to inspire the theme of this issue. Improved understanding of inter-regional linkages, whether sedimentary (provenance to basin), structural (correlation of deformation events), or magmatic (in relation to both sedimentary and tectonic processes) will improve Phanerozoic reconstructions of Arctic paleogeography.

3.3. Progress and Problems

Previously, alternative hypotheses of Arctic tectonic evolution were based on a paucity of data and heavy reliance on speculation. Recently, due to a rapid increase in the volume of new research, new geological models are based on more substantial datasets. Although the geodynamic history of Eurasia Basin is well understood, several contributions to this volume provide new results that refine our understanding of the interplay between magmatic ocean spreading, non-magmatic spreading and the propagation of rifting. Segmentation of Gakkel ridge into magma-rich and magma-poor domains is reflected in the crustal thickness and magnetic signature of each domain. In the Amerasia Basin, similar issues may have been in play during its formation in the Mesozoic. Delineation of the extent of oceanic crust is an important new development, but so is the areal distinction of thinned continental lithosphere in some areas and high-velocity magmatic underplated crust in other areas (Chian et al., 2016; cf. Li et al., 2016). This makes clear that the role of magmatism extends beyond the question of age, extent and style associated with Alpha-Mendeleev Ridge. There remains much to learn about the interplay of magmatism and extension in the Amerasia Basin.

The Mesozoic tectonic evolution of the Amerasia Basin continues to be a topic of intense debate with a variety of multi-stage hypotheses replacing earlier simple fan-shaped spreading scenarios (e.g., Lane, 1997; Miller et al. 2006; Grantz et al. 2011; see also Lane et al., 2016, for discussion). The documentation that oceanic crust is limited to the central part of the basin (Chian et al., 2016) requires a reconsideration of the kinematics of basin formation and provides further validation of the position of the extinct spreading axis within the oceanic part of the basin.

Alpha-Mendeleev Ridge underlies much of the Amerasia Basin, yet it is understood largely through remote sensing (seismic and potential field). While these data sources provide useful structural and seismic velocity information, many of the results are ambiguous, leading to differing, sometimes conflicting interpretations. Key among them is the question of its tectonic setting and basement composition and origin (e.g., Petrov et al., 2016). Bruvoll et al. (2012) provide a concise review of the literature concerning this problem. They conclude that “the acoustic characteristics and seismic velocities compare more closely with basement on Ontong Java Plateau and Kerguelen Plateau than normal ocean crust or wedges at volcanic margins”. Oakey and Saltus (2016) provide new evidence in support of an interpretation that the Alpha-Mendeleev basement consists of highly thinned and intruded continental crust, in agreement with other recent studies (e.g., Lebedeva-Ivanova et al., 2006; Petrov et al., 2016).

Although Alpha-Mendeleev Ridge is regularly cited as a manifestation of the High Arctic Large Igneous Province (HALIP), including in papers in this issue, the age range of Alpha-Mendeleev Ridge is too poorly understood to be very confident of this correlation. The age of HALIP-related magmatism in onshore exposures is widely cited as being concentrated in two main pulses, one in Barremian-Aptian time and another in the Albian-Cenomanian (e.g., Evenchick et al., 2015). Age constraints for Alpha-Mendeleev Ridge are rare. Jokat et al. (2013) report a reliable Ar-Ar age of 89±1Ma on plagioclase from a tholeiite collected from central Alpha ridge. This is more similar to ages from Hansen Point volcanics on Ellesmere Island (88-94 Ma; see Anudu et al., 2016) and Peary Land dyke swarms on Greenland (80-85 Ma; see Jokat et al, 2015). The latter were cited as a possible early manifestation of Eurasia Basin initiation. Also, variations in the chemistry of the magmas (alkaline vs tholeiite) have led some to suggest that both plume and rifting environments may have been active (e.g., Jowitt et al., 2014). To the south, in Labrador Sea and Davis Strait, long-lived magmatism includes significant episodes of Late Jurassic to Early Cretaceous age well in advance of the dominant Paleogene events (Larsen et al., 2009). Although much progress has been made, the questions of how many magmatic events, what tectonic process(es) they were associated with, and what were their magma sources, all remain largely unresolved. Suggestions that HALIP is a single entity spanning 130-70 Ma (e.g., Petrov et al., 2016) may tend to cloud the issue rather than clarify it.

Recent technical advances in methodologies such as geochemistry and detrital zircon gechronology have generated robust research programs to elucidate provenance and to reconstruct paleogeography (Ershova et al., 2016b; Anfinson et al., 2016; and references therein). However, the increasing recognition of zircon recycling indicates that the immediate sources of distinctive age distributions may differ from the original magmatic sources (e.g., Lane and Gehrels, 2011; 2014). Furthermore, although a distinctive zircon distribution may well be derived from a particular source area, that does not imply that the source must be proximal to the destination. In addition to recycling, the evidence for long distance transportation of zircon in the sedimentary environment is well established (e.g., Rainbird et al., 1992; Anfinson et al., 2016).

4 Conclusions

The elucidation of Arctic geodynamic and tectonic history has been a gradual process whereby assumptions and speculations have been displaced by data and their interpretation. In this Special Issue, interactions of lithospheric, tectonic, magmatic and sedimentation processes have been documented and investigated. Each approach provides valuable information that can be used to constrain elements of the region's tectonic history. However, a better understanding of how these processes interact can provide additional insight that initially may not be apparent. By presenting a suite of new research that includes studies of the mantle and whole crust we hope to encourage broader consideration of multidisciplinary studies to help resolve refractory scientific questions.

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Figure Caption

Figure 1. Summary map showing the areal coverage of papers in this Special Issue. Outlines are colour coded to correspond to the themes and topics outlined in the overview. Bathymetric base map, IBCAO v3 is from Jakobsson, et al. (2012).