

Exploring the Arctic margins and the Central Arctic Ocean: An introduction

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The Arctic is one of the few underexplored frontiers on the Earth. The present NJG issue consists of papers presented at the Arctic Conference Days in Tromsø in September 2007. The 10 papers presented herein are from the ICAM V sessions of the conference, and thus represents a continuation of proceedings from the previous ICAM conferences held in 1992 in Anchorage, 1994 in Magadan, 1998 in Celle and in 2003 in Dartmouth.

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Introduction

The Arctic is one of the few remaining underexplored frontiers on the Earth, but as hydrocarbon and mineral exploration are moving north into high latitudes, more data have been collected and made available from the margins bordering the Arctic Ocean (Smith 2007). However, the Arctic Ocean is four times the size of the Mediterranean Sea, and yet our total inventory of seismic data in this large ocean is equivalent to what a single vessel would acquire during a 3-month cruise in the open ocean (Kristoffersen 2008). Data collection and operations in the Arctic are challenging and require substantial resources. Consequently, answers to many of the key scientific questions related to the geological history and the evolution of the Arctic can only be addressed through international cooperation. An important step was the Arctic Coring Expedition (ACEX), the first IODP mission-specific platform operation managed by ESO (ECORD Science Operator). The ACEX drilling was located on the Lomonosov Ridge, at a point only 250 km from the North Pole (Backman et al. 2006, 2008). Another step has been the international effort to compile Circum-Arctic geophysical and bedrock data into uniform, cross-border maps, a project which is currently being conducted by several national agencies from Russia, the Nordic countries, Germany, Canada and USA (Gaina et al. 2008; Petrov & Smelror 2007).

The present issue of NJG consists of papers presented at the Arctic Conference Days in Tromsø in September 2007 (Brekke et al. 2007). The Arctic Conference Days was a special event which combined three conferences into one; namely the triennial *Arctic Geology, Resources and Environment (AGREE)*, the *5th International Conference on Arctic Margins (ICAM V)* and

a Conference on Shelf Edge and Shoreline Trajectories (SEST). More than 250 papers were presented by the approximately 300 participants of the Arctic Conference Days. The papers presented herein are from the ICAM V sessions of the conference, and thus represent a continuation of the scientific proceedings from the previous ICAM conferences; i.e., those held in 1992 in Anchorage (Alaska, USA), 1994 in Magadan (Russia), 1998 in Celle (Germany) and in 2003 in Dartmouth (Canada).

ICAM was initiated and founded by the U.S. Department of Interior, Mineral Management Service (MMS) in 1991, with the objective and as an instrument for 1) Arctic understanding and 2) International cooperation in Arctic research. It has now become a well established and authoritative forum for ongoing geoscientific research in the Arctic.

Arctic Russia

One major problem in unravelling the geological history of the Arctic basins is the lack of regional seismic data. *Franke et al.* present new information on the development on the Anyui Basin and the South Anyui suture in western Chukotka. Based on multichannel seismic data acquired around the New Siberian Islands, they have identified distinct, 50 km-wide, high-reflectivity zones in the lower crust offshore of the mouth of the Indigirka River (~150°E). The dip of the reflections fits well with the previously proposed trend of the South Anyui suture, and they are interpreted as related to the closure of the Anyui ocean basin. In the eastern Laptev Sea, Frank et al. have identified high-reflectivity zones in the lower crust, which are analogous to those identified in the basement of the East Siberian Shelf. These structures are consid-

ered to form the western continuation of the South Anyui suture. The suture trends E-W along the shoreline south of the New Siberian Islands, and continues in a northerly direction to the west of these islands.

In addition to regional geophysical data, information on the age of the various geological units is needed to reconstruct the geological history. The paper of *Miller et al.* addresses the question of the paleogeographic origin of the Chukotka region. They found that U-Pb datings of detrital zircon suites show that sandstones in the New Siberian Islands have nearly identical sources to those in Chukotka and the South Anyui Zone (SAZ). These include abundant Precambrian and Late Palaeozoic, and less common Mesozoic ages, and the youngest zircons are most likely derived from the Main Belt granites in North Verkoyansk. According to Miller et al., the foreland basin and its counterpart, the orogenic highlands, either extended continuously for ~1400 km along strike, or the localities studied were once much closer together. They further hypothesize that rifting (extension) associated with formation of the Makarov Basin and development of the SAZ as a transform fault might be one way of explaining the present separation of the study sites.

Petrov et al. presents an overview of the Palaeozoic and Mesozoic evolution of the East Barents and Kara sedimentary basins, with focus on the tectono-stratigraphic and depositional histories. The geodynamic and paleogeographic reconstructions are based on results from regional geological investigations, seismic surveys, stratigraphic studies of offshore and on-shore sections and cores, as well as isotopic and geochemical data. The geological history of the region can be separated into the following main phases: 1) Ordovician to Early Devonian passive continental margin, 2) Early Devonian (Lochkovian to Eifelian) shelf destruction, 3) Middle to Late Devonian (Givetian to lower Frasnian) pericontinental rifting, 4) Late Devonian to Early Carboniferous development of marginal basins, 5) Carboniferous to Permian collision, 6) Late Permian to Triassic orogeny, followed by 7) formation of epicontinental basins from the Early Jurassic and onwards. The marginal sedimentary basins on Novaya Zemlya developed from peri-cratonic rifting at the Middle-Late Devonian boundary. Petrov et al. interpret the East Barents Basin as a fore-deep caused by the Uralian collision and orogeny.

Lorenz et al. have sampled the Neoproterozoic to Devonian sedimentary successions of Severnaya Zemlya for detrital zircon provenance studies. They found that most of the samples show a similar Precambrian age spectrum, including a strong, prominent peak in the Late Vendian to Early Cambrian, and well defined Mesoproterozoic populations reaching back into the Late Palaeoproterozoic. They also found that only a few older zircons are present, composing a minor population at c. 2.7 Ga. The study demonstrates that younger samples (Ordovician and Devonian) also contain an Early-Mid Ordovician

population, probably related to local igneous activity. Lorentz et al. conclude that the detrital zircon age spectrum of Severnaya Zemlya constitutes a strong link to the Timanian margin of northwestern Russia, and provides support for the interpretation that this part of the high Arctic was a northern continuation of Baltica's eastern passive margin in the Early Palaeozoic.

Along with data from isotopic analyses, biostratigraphy provides the main key for determining the ages of the various sedimentary units. In addition to information on the stratigraphic ages, fossils are very useful for paleoenvironmental studies and for paleogeographic reconstructions. *Basov et al.* document that Early and Middle Jurassic microfaunal assemblages in the Barents Sea Shelf and northeastern Siberia have similar taxonomic compositions, and that the Siberian microfaunal zones can be applied in the Barents Sea region. Based on the similarity of the microfaunal assemblages and the lithostratigraphic successions, Basov et al. conclude that during the Early and Middle Jurassic time there was presumably a high degree of regional homogeneity in the depositional regimes of the Barents Sea region and Siberia.

Nikitenko et al. have found that, lithologically, the Lower Jurassic succession is very similar throughout the Arctic regions. Many of the deposits contain rich assemblages of foraminifers, ostracods and palynomorphs, as well as less abundant ammonites and bivalves, providing a mean for correlation of the lithostratigraphic units. Nikitenko et al. argue that the Lower Jurassic biostratigraphic zonal subdivision of northern Siberia, which is based on ammonites, bivalves, foraminifers and ostracods, may be considered as the Boreal Zonal Standard. Based on an analysis of biotic and abiotic events, as well as on the geographic distribution of microbenthos, Nikitenko et al. define different foraminifera and ostracod biogeographic realms and provinces for the Early Jurassic and Aalenian. Based on the geographic distribution of the different microfaunal groups, they found that the configurations of the boundaries between provinces and realms changed during the Early Jurassic.

Based on palynological analysis of Lower Cretaceous (Berriasian-Barremian) sections from North Siberia, *Pestchevitskaya* defines detailed dinocyst and spore-pollen zonation, which are calibrated against the established ammonite biostratigraphic schemes of Siberia. Most of the boundaries of the palynological zones are reliable correlative markers, which can also be recognised elsewhere in East and West Siberia (the spore-pollen zonation) and in NW Europe, Canada and Siberia (the dinocyst zonation). Pestchevitskaya finds that changes in the microphytoplankton associations reflect both trends related to the dynamic evolution of the Siberian palaeobasin and trends of the dinocyst evolution. She further suggests that the diversity and abundance of the Early Cretaceous Siberian microphytoplankton associations were to a large extent determined by seawater tempera-

ture and nutrients.

Svalbard

The Svalbard Archipelago forms the sub-aerially exposed north-western margin of the Barents Shelf. The archipelago represents an important window into the geology of the entire region, and has for decades been a key site for geological research workers from many countries. Several overviews of the geology and geological history of Svalbard have been published, including the monograph of Harland (1997) and the recent synopsis of Worsley (2008). A comprehensive lithostratigraphic lexicon of Svalbard was published by Dallmann (1999).

The present study of *Midtkandal et al.* has demonstrated the need to revise the current lithostratigraphy of the upper part of the Rurikfjellet and the Helvetiafjellet formations. In the present revision, the Ullaberget Member is suggested to be abandoned as a lithostratigraphic name, and substituted by designation of the Kikutodden Member as the uppermost sand-dominated segment of the Rurikfjellet Formation, with the stratotype on Kikutodden in Sørkapp Land and hypostratotypes on Strykjernet, Torell Land. Midtkandal et al. define the Ullaberget section in Nathorst Land as the stratotype for their new Louiseberget Bed of the Festningen Member, which they interpret to represent a bay-head delta formed by an initial transgression inundating a local depression in the regional erosional surface at the base of the Helvetiafjellet Formation. Midtkandal et al. further suggest that the Festningen Member should be re-established as a formal lithostratigraphic unit from its previous informal status. They also propose that the Glitrefjellet Member should be retained as a formal member in the upper part of the Helvetiafjellet Formation, thus cancelling the proposed abandonment of this name by Mørk et al. (1999).

The Central Arctic Ocean

The IODP Arctic Coring Expedition (ACEX) carried out in 2004 on the Lomonosov Ridge represents a milestone in the exploration of the Arctic Ocean. The study of *Strand et al.* covers the Middle Miocene to Recent succession at site Site M0002 of the IODP Expedition 302, and in addition provides a revision of the Middle Pliocene core data from the ODP Site 911 (Yermak Plateau). Both these sites consist of siliciclastic sediments characterised by low organic carbon concentrations. Strand et al. document that mineralogical characteristics of the sediments in the Arctic Ocean can be used to evaluate critical climate transitions, based on a close relationship between initiations of icesheets, ice rafting and sea-ice cover changes. The Middle Miocene transition marks the start of further cooling during the Late Cenozoic. Strand et al. find that this transition seems to coincide with a decreasing smectite content and a significantly fluctuating kaolin-

ite occurrence in the central Arctic Ocean, which again relate to continental ice generation and increased glacial erosion on land. They also report that a periodic high content of smectite indicates changes to inter-glacials and more open marine conditions. These authors further suggest that the increased content of smectite, pyroxenes and amphiboles of the Middle Pliocene sediments on the Yermak Plateau indicate that during inter-glacials, transport mechanisms were a combination of sea-ice and oceanic currents, reflecting also a significant freshwater input from the great Siberian rivers.

Kristoffersen et al. studied sub-bottom sediments within a 200 x 600 km area on the crest and south slope of the submarine Alpha Ridge in the central Arctic Ocean. Here they found that the bottom sediments locally have been disrupted down to at least 500 metres below the seabed, have suffered intensive local current erosion, and show evidence of abundant mass wasting. Kristoffersen et al. find that there appears to be a westward progression along the ridge from an eastern area of chaotic and eroded sub-bottom sediments to proximal intense erosion of an undisturbed section and a more distal occurrence of mass wasting and minor erosion. As a working hypothesis, they propose that the observed, dramatic, spatially restricted and apparently geologically short-lived environmental changes are compatible with the effect of a shock wave from the impact of an extra-terrestrial body into the central Arctic Ocean.

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