

ICAM III

Third International Conference on Arctic Margins

A Preface

By Franz Tessensohn and Norbert W. Roland

The Arctic region with its deep oceanic basins, its system of narrow ridges and wide and extensive continental margins, is one of the most exciting areas for geological investigations.

The oceanic basins are 3000-4000 m deep areas underlain by oceanic crust. The Eurasian Basin as the northernmost part of the Atlantic spreading system and the Amerasian Basin as a rather enigmatic rounded deep hole are surrounded by continents without clearly detectable mid-oceanic ridge and without clear connection to any other major spreading system.

The Nansen/Gakkel Ridge is a very slow spreading ridge, the slowest section on the entire Atlantic mid-oceanic ridge. The Lomonosov Ridge forms a narrow band of continental crust, obviously split off by spreading processes from the Eurasian shelf between Spitsbergen and the Laptev Sea. The ill-defined enigmatic Alpha Ridge finally may be a major volcanic feature in parts of its total extension.

The continental margins around the Arctic ocean generally comprise comparatively wide shelf areas and contain most of the sedimentary record of the development of the entire region.

Major tectonic structures dissect parts of the shelves and, from an Arctic viewpoint, form connections to the outside world. These structural breaks in the shelf system are the Fram Strait between Barents shelf and Greenland and the Nares Strait between Greenland and Canada. While there is no marine passage at the Laptev Sea, where the present Atlantic mid-oceanic ridge system enters the Eurasian continental shelf in the form of a complicated mosaic of horsts and grabens, there is an overflow rather than a deep structural break at the Bering Strait passage to the Pacific. Several Mesozoic and Palaeozoic mountain belts, the Caledonides, and Uralides and the Ellesmerian and Verkhoyansk belts cross the Arctic shelves to end abruptly at the shelf breaks with no obvious continuations. The shelves contain large and deep sedimentary basins with a high potential for hydro-carbon development. Together they may well be regarded as a „giant“ petroleum province, although the actual production is still comparatively low.

The whole area is bearing the imprint of the last glacial period in the form of extensive permafrost, partly in submarine form, and related features such as gashydrates, interesting both as possible energy source as well as a possible climate-influencing factor.

The ICAM conferences, initiated soon after the major political changes in Russia, try to provide a forum for the scientific discussion of all these features. The first conference was organized by a spontaneous move of a government institution and a university in Alaska and the conferences are still borne by scientists rather than being attached to a major international organization.

ICAM I was hosted by the U.S. Minerals Management Service in Anchorage, Alaska in 1992 and ICAM II followed in 1994, organized by the Russian Academy of Science in Magadan, Siberia.

The Third International Conference on Arctic Margins was held in the medieval town of Celle in northern Germany from October 12-15, 1998. It was jointly run by the Alfred Wegener Institute for Polar and Marine Research (AWI), the Federal Institute for Geosciences and Natural Resources (BGR) and the German Polar Society. The emphasis of this conference was on the geodynamic evolution of the Arctic region and, in particular, on the geology and geophysics of the margins of the Eurasian Basin.

SCIENTIFIC PROGRAM

The contributions to the conference were grouped under the following 15 themes and included talks and posters. Each theme was coordinated by a group of international experts.

- 1 Magmatic provinces around the Eurasian Basin: interplay with tectonism.
- 2 Aerogeophysics on the Eurasian shelves: signatures and interpretations.
- 3 Plate boundary problems in the Laptev Sea area.
- 4 The Lomonosov Ridge: history, boundaries, function.
- 5 The Barents shelf and the East Greenland margin: a comparison
- 6 Eurekan tectonics in Canada, North Greenland, Spitsbergen: fold belts adjacent to extensional ocean basins.
- 7 Problems of the Caledonian/Ellesmerian junction.
- 8 Polar Urals, Novaya Zemlya and Taimyr: The northern connection of the Uralides.
- 9 Hydrocarbon potential of the Eurasian margins: geological and tectonic factors.
- 10 Metallogenic provinces in the circum-Arctic region.

- 11 Cenozoic sedimentary archives of the Eurasian marginal seas: sampling, coring and drilling programmes.
- 12 Gashydrates and permafrost, onshore and offshore.
- 13 The Amerasian Basin and margins: new developments and results.
- 14 Circum-Arctic margins: The search for fits and matches.
- 15 Geodynamics of the Arctic region.

SESSION SUMMARIES

A summary of the various sessions is given by the convenors or, in a few cases, by the editors.

THEME 1

VOLCANIC PROVINCES AROUND THE EURASIAN BASIN: INTERPLAY WITH TECTONISM

Convenors; Olav Eldholm, Wolfram Richter and Alexander Tebenkov

The theme encompassed six oral and seven poster presentations. Several contributions under themes 5, 6, 13 and 15 were also relevant for Theme 1. The Arctic realm contains several post-Jurassic volcanic provinces some of which may be classified as transient.

Large Igneous Provinces (LIPs), are short-lived, voluminous emplacements of predominantly mafic extrusive and intrusive rocks formed by processes not directly linked to crustal production by steady-state sea floor spreading. Compared to transient LIPs elsewhere, however, the Arctic provinces are still poorly mapped and dated.

The pre-Cretaceous tectono-magmatic setting of the Barents Sea to northern Kara Sea region was presented by KORAGO & TEBENKOV. This region includes the plateau basalts in Franz Josephs Land and central and southeast Svalbard. New datings of the Franz Josephs Land basalts show ages of 128 and 132 Ma for the upper tholeiitic basalts and the lower basaltic andesites, respectively. Furthermore, the rocks have a geochemical plume signature without traces of crustal contamination (NTAFLOS & RICHTER). Less well constrained Barremian to Albian ages were presented for basaltic intrusives and plateau basalts in Svalbard, and analysis of potential field data between Franz Josephs Land and Svalbard suggests an offshore continuation of the onshore exposures (GROGAN et al.). In addition, a crustal profile east of Svalbard shows a 37 km thick crust including a 14-15 km thick, 7.6 km/s velocity layer of lower crust interpreted as an underplated body (HOGDEN et al.). In summary, these observations may indicate a continuous Early Cretaceous North Barents Sea LIP.

TARDUNO addressed the intrusives and flood basalts in the high Canadian Arctic which he related to the distal parts of a much greater LIP, possibly comprising the enigmatic Alpha Ridge for which little data exists. He also reported new $^{40}\text{Ar}/^{39}\text{Ar}$ ages averaging 95 ± 1.6 Ma in Axel Heiberg Land, and about 92 Ma in Ellesmere Island. The Kap Washington Group basaltic lavas, dikes and sills in northernmost Greenland are derived from the

same source and geochemical data suggests a plume-like signature with evidence of lower crustal contamination as the source evolved. Dating indicates that magmatism began at 103 Ma, continuing for about 40 m.y. (MANBY et al., ESTRADA et al.).

Other presentations dealt with new $^{40}\text{Ar}/^{39}\text{Ar}$ ages from the mid- to Late Cretaceous Okhotsk-Chukotsk magmatic arc in north-east Russia (LANE et al.), and with the origin of Cretaceous metamorphic core complexes in the Bering Strait region (NATALIN et al.). New data from the Vestbakken Volcanic Province on the Barents Sea continental margin show that it constitutes the northernmost part of the North Atlantic LIP formed close to the Paleocene-Eocene transition (JEBSEN & FALEIDE). Finally, melt-mantle interaction in plagioclase-bearing peridotites along the present Molloy Ridge plate boundary was discussed by HELLEBRAND et al.

Although many contributions presented important new information, the discussion revealed that the understanding of the Arctic volcanic provinces is still in its infancy. In addition to the provinces mentioned above, we also need to consider the potential early Tertiary Yermak Plateau – Morris Jesup Rise events, and the Neogene volcanism in northwest Svalbard (Themes 5 and 6). Several presentations associated the volcanic provinces with mantle plumes and hotspot activity; however, there appears to be less understanding of how many plumes are required, how the lithosphere has moved over the plume, and how long the plumes were active.

Another key question is whether the Alpha Ridge and the Canadian Arctic province represent coeval events constituting a LIP. Although most Arctic volcanic provinces appear in, or near, rift settings, their tectono-magmatic relations are not well understood. However, it is tempting to relate the North Barents Sea LIP to lithospheric thinning associated with the north-eastward continuation of the Mesozoic Barents Sea rift system and/or to rifting and breakup west of the Lomonosov Ridge. Nonetheless, as new data become available, one or more of the Arctic volcanic provinces may figure prominently in the global LIP inventory.

THEME 2

AEROGEOPHYSICS OF THE EURASIAN SHELVES: SIGNATURES AND INTERPRETATIONS.

Convenors: Sergei Maschenkov and Ron MacNab

The session comprised five talks and seven posters. While some of the contributions dealt with the Arctic area as a whole in the form of compilations (GLEBOVSKY et al., JACKSON et al.) or reports on new data acquisitions (KOVACS et al.), others presented more local results of close-spaced aerogeophysical surveys on the shelves of Canada (FORSYTH et al., Lincoln Sea), of North Greenland (NOGRAM, STEINHAGE et al.), Fram Strait (MEYER & BOEBEL), Svalbard (TEBENKOV et al.), and Russia (N Eurasian shelf, MASHENKOV et al.; NE Siberia, LAWVER et al.). These detailed surveys are particularly useful for the prolongation of geological onshore features over the shelves and for the interpretation of newly found anomalies. (Editors)

THEME 3

PLATE BOUNDARY PROBLEMS IN THE LAPTEV SEA AREA

Convenors: Sergei Drachev, Karl Hinz and Sergei Sekretov

The main attention of the participants was focused on the unique tectonic intersection of the slowest spreading axis (Gakkel Ridge) with the continental margin which occurs in the Laptev Sea. A significant progress in the study of this region was achieved in the last decade owing to Russian and German offshore multichannel seismic reflection surveys. These studies have delineated an extended rift system which was a result of Cenozoic opening of the Eurasia Basin.

A total of eight talks and two posters were presented by scientists from several Russian institutions (VNIIOkeangeologia, St. Petersburg; Institute of Oceanology, Moscow; Murmansk Arctic Geologic Expedition; Institute of Geosciences, Yakutsk) and the German Federal Institute for Geosciences and Natural Resources (BGR, Hannover). Most of the presentations discussed the results of recent studies of the structure, seismic stratigraphy and evolution of the Laptev rift system. The results of the BGR 1997 seismic survey have attracted the greatest interest. Important overviews of the geology of the Laptev Sea region were given by Russian speakers. The preliminary results of the on-shore structural studies by the joint Russian-German CASE-3 team found also great attention.

The main discussion which followed the presentations dwelled upon the problems of seismic stratigraphy and the age of the sedimentary sequences of the Laptev rift system. Most of the participants agreed that a Cenozoic age for the rift sedimentary infill is probable. However, the deficiency of geological and geophysical data still exists and this, in turn, resulted in many open questions during the discussion.

THEME 4

THE LOMONOSOV RIDGE: HISTORY, BOUNDARIES, FUNCTION

Convenors: Wilfried Jokat, Yngve Kristoffersen and Mikhail Sorokin

The six papers and three posters presented on this theme were based on geophysical and geological data acquired on platforms which span three generations of logistic approaches in the history of Arctic ocean exploration; the drifting ice stations, modern icebreaking research vessels and nuclear submarines on unclassified science missions.

Data acquired over the past decade present a new level of opportunities to test our working hypothesis for the first order geologic features in the Arctic Ocean basin such as the more than 1500 km long and 50-100 km wide Lomonosov Ridge. The asymmetric architecture of the Lomonosov Ridge seen in the seismic reflection data presented by KRISTOFFERSEN & JOKAT, KIM et al., and JOKAT presents a strong case in support of the origin of the ridge as a fragment of a former continental margin. The

principal evidence is found in the central part of the ridge where below a regional unconformity, alternating prograding and onlapping strata dip towards the Amerasia Basin. In contrast, the Eurasia Basin side has the character of a steep terraced slope of narrow fault blocks as shown in posters by POSELEV et al., and SOROKIN et al.. The new gravity and bathymetric data collected by the SCICEX-program presented by COAKLEY & COCHRAN demonstrate the persistence of parallel horsts and grabens within the ridge structure between the Canadian Arctic islands and the North Pole, and the change into a series of *en echelon* horsts and grabens oblique to the main ridge trend towards the Siberian margin. Geological samples which can give further clues to the history of the ridge are urgently needed. The first evidence was presented by GRANTZ et al. who found Devonian to Early Mississippian sediments in a piston core from Lomonosov Ridge near the North Pole.

In summary we can say that the last decade represents renewed research activity and optimism in Arctic ocean exploration with utilization of the latest of modern technology including access to submarines.

THEME 5

THE BARENTS SHELF AND THE EASTERN GREENLAND MARGIN: A COMPARISON.

Convenors: Annik Myhre and Lars Stemmerik

This session with ten talks and six posters clearly reflected the present state of knowledge as there were more contributions on the Barents than on the East Greenland shelf.

Both sides of the present North Atlantic were treated by two papers (SKOGSEID, SCOTT). Comparisons of various features between Svalbard and North Greenland were presented by a number of authors, e.g. on post-Caledonian stratigraphy (THIEDIG), on paleomagnetism (BUGGISCH), on Mesozoic tectonic events (TURTON & SCOTT) and on circum-Arctic sequences (MØRK & SMELROR).

The Barents Sea and Svalbard were the subject of papers dealing with the continental margin (FALEIDE et al.), the Scandinavia-Barents shelf relationship (SAKULINA et al.), the basin formation (BREIVIK et al.), the Lower Cretaceous (SMELROR et al.), the Yermak Plateau (SOLLESNES-ANDREASEN), the Svalbard lithostratigraphic lexicon (DALLMANN & MØRK), and the Mjølner impact structure (DYPVIK). The NE Greenland margin was the subject of a paper by ANDRESEN & HARTZ, the N Greenland margin of a paper by JOKAT. (Editors)

THEME 6

EUREKAN TECTONISM IN CANADA, NORTH GREENLAND, WEST SPITSBERGEN: FOLD BELTS ADJACENT TO EXTENSIONAL OCEAN BASINS.

Convenors: Ulrich Mayr and Franz Tessensohn

14 talks and six posters indicate that there was much interest in this subject. The contributions showed rather clearly that

there are differing interpretations on the style of deformation (compressional versus foreland foldbelt or transpressional versus flower structure), on the time of deformation and on the relationship to the plate tectonic frame work. A few papers treated the Eureka foldbelt as an entity (LEPVRIER, PAECH, TESSENSOHN & PIEPJOHN, TESSENSOHN et al.), other contributions discussed various aspects of the different segments, e.g. Svalbard (BERGH et al., KLEINSPEHN, PIEPJOHN & VON GOSEN, SAALMANN & THIEDIG), North Greenland (ESTRADA, VON GOSEN & PIEPJOHN, LYBERIS & MANBY, PIEPJOHN & VON GOSEN, SCHACK PEDERSEN & HAKANSSON), and the Canadian Arctic Islands (HARRISON et al., OAKEY et al., OKULICH et al., PIEPJOHN et al., TARDUNO).

Tarduno's interpretation of the magnetostratigraphy of the Sverdrup Basin was challenged by Stephenson, who argues for thermal subsidence instead of a blind thrust, crustal loading and compression between Greenland and North America. Some papers tried to set up time frames of events. These frames from different sources and areas have to be compared and correlated, if we want to understand the whole. The onset of deformation seems to vary considerably.

THEME 7

PROBLEMS OF THE CALEDONIAN / ELLESMERIAN JUNCTION

Convenors: David G. Gee, Niels Henriksen and Andrew Okulitch

This topic provided a lively forum of presentations and discussions of the latest research on the relationships between the Palaeozoic orogens of Ellesmere Island / North Greenland, East Greenland and Svalbard.

Greenland

Eight lectures dealt with aspects of the Lower Paleozoic fold belts and their Proterozoic foreland in Greenland. The N-S trending Caledonian fold belt of Northeast Greenland includes deep-seated crystalline basement complexes with Paleoproterozoic protoliths, and thin-skinned thrust complexes with Proterozoic-Silurian sediments. The fold belt was formed as a result of the collision of Baltica and Laurentia in the mid- to late Silurian. In North Greenland, deposition in the Franklinian Basin of a Cambrian to lowermost Devonian succession of carbonate shelf deposits and siliciclastic deep sea trough sediments was brought to a close by the Ellesmerian orogeny between Early Devonian and late Carboniferous time.

The E-W trending Ellesmerian fold belt has a border to the south against the Laurentian shield (in Arctic Canada and in Greenland), while the northern border regions may be represented by parts of western Svalbard, the Pearya Terrane of northern Ellesmere Island in Canada, and an unknown continent.

The Caledonian fold belt in Northeast Greenland and the Ellesmerian fold belt in North Greenland trend almost perpendicular to each other and show different styles of deposition and

deformation. The North Greenland fold belt reflects a continental closure which may be up to 100 Ma years later than the final phases of the North-East Greenland Caledonides. It may therefore be concluded that the two Lower Paleozoic fold belts are essentially two separate geotectonic systems. The junction between the two fold belts occurs in the offshore area east of North Greenland. Aeromagnetic data, however, primarily reflect the geological processes which formed the Carboniferous to Tertiary Wandel Sea Basin superimposed on the critical junction area between the two Lower Paleozoic fold belts.

Canada

Two papers described the evolution of Neoproterozoic to mid-Paleozoic strata and intrusions on Ellesmere Island, and their possible relationships with similar rocks in Greenland, Svalbard and Scandinavia. Pearya Terrane, a complex, composite allochthonous assemblage, consists of five successions ranging from late Mesoproterozoic (Grenvillian) crystalline basement through Neoproterozoic to Ordovician platformal and volcanic successions to Late Silurian deep water sediments. Pearya Terrane and the southerly adjacent Clements Markham, Hazen and Central Ellesmere fold belts record numerous tectonomagmatic events beginning with the Grenville-age orogeny in the crystalline basement of Pearya. The Early to Middle Ordovician McClintock orogeny was accompanied by pre-, syn- and post-tectonic intrusions, which were in turn followed by episodes of rifting and volcanism during the Late Ordovician. Pearya approached or was accreted to North American successions during the latest Ordovician to Early Silurian, and underwent further convergence or accretion during the Late Silurian. Middle Devonian granitic intrusions were followed by the Late Devonian to Early Carboniferous compressive Ellesmerian orogeny. The Pearya Terrane and the Caledonian Orogen are related by the Grenville age of their crystalline basements and by Ordovician tectonomagmatism. Svalbard and Ellesmere Island have some similarities in their pre-Devonian geological evolution.

Svalbard

Eight contributions concerned the Svalbard Caledonides and one referred to other areas of the Barents Sea. Research during the 1990s has amplified the evidence that eastern and western Svalbard are composed of independent terranes. In the east, recent structural and stratigraphical studies along with new isotope-age/provenance data have demonstrated that Nordaustlandet (westernmost Barentsia) is dominated by a Grenville-age basement, overlain by the classical Neoproterozoic and Cambro-Ordovician Hecla Hoek successions so similar to the Eleonore Bay and overlying Vendian to Early Palaeozoic strata of central East Greenland. This Nordaustlandet Terrane is separated from the Ny Friesland orogen by an enigmatic ca. 5 km thick packet of semipelitic micaschists (Planettfjella Group) of Neoproterozoic or Early Palaeozoic age. The Ny Friesland transpressive orogen is dominated by a high amphibolite facies, W-vergent, antiformal thrust stack involving Paleoproterozoic basement and Mesoproterozoic or younger cover. The style of deformation is comparable with that reported from northeast Greenland.

Northwestern Spitsbergen is dominated by migmatites, influencing a thick succession of schists and marbles, the migmatization appears to be of Grenvillian age. However, a subordinate complex in the northwest of Biskayerhalvoya, contains eclogites of probable Caledonian age, with some features in common with those described from northeast Greenland. Thus, there is a substantial database from northern Svalbard favouring correlation of Svalbard's Caledonian terranes with those of central east and northeastern Greenland, in marked contrast to the evidence along Spitsbergen's west coast, where correlation with Pearya is favoured.

THEME 8

POLAR URALS, NOVAYA ZEMLYA AND TAIMYR: THE NORTHERN CONNECTION OF THE URALIDES

Convenors: Helmut Echter and Valery Vernikovskiy

Reports of this session are dedicated to improving our understanding of Neoproterozoic, Paleozoic and even Phanerozoic evolution of the Russian Arctic including the Urals, Novaya Zemlya and Taimyr regions. The most important problems in the discussion were:

Taimyr and the tectonic evolution of the Eurasian Arctic. The first question is connected with the nature of the magnetic anomaly over the Uralides which extends far into the high Arctic via Pay Khoy and Novaya Zemlya from where it curves back southeastwards into Arctic Siberia and the Taimyr fold and thrust belt. From there it continues northeastwards to be lost beneath the Laptev Sea. Taimyr is a key element in the interpretation of these events. Close international collaboration of geoscientists in the 1998 Taimyr expedition led by D. Gee forms a basis for solutions of these questions. This region is a 1000 km long segment of a Paleozoic-Mesozoic orogen that is composed of three „blocks“ (VERNIKOVSKY 1996).

The Paleozoic and earliest Mesozoic strata of the southern Taimyr Belt can be correlated with certain Arctic regions as well as with the northern part of the Siberian platform. In this zone, Upper Paleozoic and Triassic sediments are concordantly folded together with Jurassic sediments. To the south, in the Yenisey-Khatanga depression they are deeply buried by Jurassic-Cretaceous sediments. EGOROV supposes that the Taimyr fold area has been formed rather at the end of the Early Cretaceous than in Hercynian times. VERNIKOVSKY refers to this belt as passive margin of the Siberian continent. According to data of SCOTT, the succession of Paleozoic strata shows, at least partly, affinities to Baltica.

KORAGO et al. are considering the fold system of Novaya Zemlya as an intracratonic continuation of the Urals suture. LOPATIN et al. have discussed the problems of tectonic structure of Novaya Zemlya, too. They define three different blocks separated by major sutures.

GEE et al. have presented new Pb/Pb evaporation ages for Vendian granites in the Neoproterozoic basement beneath the Pechora Basin.

THEME 9

HYDROCARBON POTENTIAL OF THE EURASIAN MARGINS: GEOLOGICAL AND TECTONIC FACTORS.

Convenors: Mikhail Kos'ko and Tony Dore

Six talks and one poster were presented at the session. Two oral presentations dealt with the Eurasian Margin as a whole, four talks and the poster dealt with regional geological constraints for the hydrocarbon potential of individual seas.

Eurasian margin

The paper on oil and gas potential of the Eurasian continental margin by GRAMBERG et al. was presented by SUPRUNENKO. The Eurasian continental margin is regarded as a constituent part of a unique planetary scale Arctic hydrocarbon superbasin. The margin comprises a series of sedimentary basins varying in structural position within the Arctic superbasin and in consequence of that in the geologic history and in the age and composition of the sedimentary fill and in the characters of the relevant hydrocarbon systems. The estimate of the hydrocarbon potential of the Eurasian continental margin is up to 100 billion tons.

A paper by BURLIN et al. dealt with the asymmetry of the Arctic sedimentary megabasin and its reflection in oil and gas distribution on its borderlands. The Arctic sedimentary megabasin is divided into two asymmetric segments: the eastern segment related to the Eurasian Basin and the western segment related to the Amerasian Basin. The major sedimentation took place on the eastern borderland in the Permian and in the Triassic as a result of a large scale regional subsidence. On the western borderland the maximum of the accumulation of sediments was in the Triassic, Jurassic and Cretaceous, although large scale accumulation of sediments commenced here in the Devonian. The dominating feature of the tectonic environment in the course of the evolution of the western segment was deep reconstruction of the continental crust. Despite the diversity of individual hydrocarbon systems within elementary basins of both segments it is concluded that the upper Paleozoic and the Triassic have high oil and gas potential and younger sequences have high gas potential in the Arctic megabasin as a whole.

Tectonic factors of basin development and hydrocarbon potential of the western Arctic margins were presented by STOUPEKOVÁ & KIRYUKHINA. A series of sedimentary basins has been identified on the western Arctic continental margin. The tectonic and hydrocarbon potential evolution of each basin followed similar scenarios comprising three stages: aulakogen, syncline and inversion. The age of the basins and of the respective stages varies starting from the Baikalian tectonic epoch. Despite principal similarity in the development of the different age basins, the major hydrocarbon potential of the area is related to the syncline and inversion stages in the pre-Urals, Novaya Zemlya and South Barents Sea areas.

The influence of Mesozoic and Cenozoic igneous activity on the hydrocarbon potential of the Barents Sea shelf was the subject

of EVDOKIMOVA et al.. Regional geology of the Barents Sea area, detailed sampling and advanced lab technology provided a base to correlate the evolution of the organic material in the sediments with igneous episodes from the early Paleozoic to the early Cenozoic. It was concluded that a platform type magmatic activity of a moderate scale increased the potential for hydrocarbon generation of the sedimentary sequence.

A talk on the potential of Laptev Sea basins for petroleum content and a poster on the northwestern margin of the East Siberian Sea were presented by SEKRETOV. The tectonic zonation and hydrocarbon systems were discussed in both presentations based on the interpretation of regional seismic 2-D-surveys carried out by Marine Arctic Geological Expedition during the last 10 years.

CRAMER reported on light hydrocarbons in sea water and near surface sediments of the Laptev Sea. 151 water and near surface sediment samples from 10 localities have been collected in the Laptev Sea in the course of the BGR 1997 Arctic cruise. The distribution and the properties of the gaseous hydrocarbons in the sediments indicate an origin of the gas from a marine source rock at a maturity between 0.9 and 1.3 % vitrinite reflectance. Only one location of thermogenic gas seepage into the water has been discovered from sampling the sea water.

It is remarkable, that most presentations except one under Theme 9 were made by Russians. It indicates that neither the international geoscientific community nor the international industry consider Arctic hydrocarbons among their present day priorities, while for Russia the Eurasian continental margin is the last oil and gas strategic reserve on a national scale.

THEME 10 METALLOGENIC PROVINCES IN THE CIRCUM-ARCTIC REGION

Convenors: Kirill Simakov and Volker Steinbach

The session was the smallest of all with three talks and eight posters. However, it covered the typical types of mineral deposits on the Arctic margins, lead-zinc in sedimentary rocks, placers on the shelf, mercury and gold-bearing quartz veins.

A lead-zinc mineralization in East GREENLAND (PEDERSEN & BOYCE) differs from the North Greenland and Canadian deposits in that it occurs in Permian shales and that it may be related to a Tertiary event of vein formation. Several significant placer deposits of the Russian Arctic shelves (IVANOVA et al.) comprise gold and tin enrichments. A very important factor in circum-Arctic mineralizations are gold-bearing quartz veins which were described from Alaska (RIEHLE & SINGER) and from the Siberian parts of Russia (FRIDOVSKY et al.). A new compilation map of mineral deposits of Russia (EGOROV et al.) includes also occurrences in the Arctic. (Editors)

THEME 11 CENOZOIC SEDIMENTARY ARCHIVES OF THE EURASIAN MARGINAL SEAS: SAMPLING, CORING AND DRILLING PROGRAMMES.

Convenors: Heidi Kassens, Rüdiger Stein and Jörn Thiede

This session (six talks, seven posters) reflects the recent cooperative research activities in the area of the Laptev Sea (nine contributions). Different aspects of the whole Cenozoic sedimentation system in the area are covered: Lithology (ANDREEVA et al.), sedimentary processes (MÜLLER et al.), volumes of terrigenous input (KOSHELEVA et al.), freshwater input (SPIELHAGEN et al.), organic carbon (BOUCSEIN et al.), sea level changes (BAUCH et al.), diagenesis (SCHOSTER & STEIN), foraminifera (BUDE), and palynomorphs as tracers (MATTHIESEN et al.).

Apart from the Laptev Sea, results were presented on the Barents shelf (GATAULIN et al. on sea floor topography; BUTT et al. on glacial evolution). The East Siberian shelves provided a platform to study the interaction with the Pacific using molluscs (TALDENKOVA) and diatoms (POLYAKOVA). (Editors)

THEME 12 GASHYDRATES AND PERMAFROST, ONSHORE AND OFFSHORE

Convenors: Georg Delisle, Hans Hubberten and Nicolai Romanovsky

The session with its two related subthemes on permafrost and gashydrates comprised 13 talks and one poster. A major topic in the papers on permafrost was the submarine (fossil) permafrost on the Arctic shelves and the Laptev shelf in particular (HUBBERTEN & ROMANOVSKY, ARE & REIMNITZ, REIMNITZ, HINZ et al., ROMANOVSKY et al., NEBEN et al.). Another major topic, related to both subthemes was modelling the temporal evolution of the permafrost (TIPENKO et al., KHOLODOV et al., DELISLE).

Gashydrates were treated under two aspects, as a climate factor (ROMANOVSKY & OSTERKAMP) as well as a potential energy source (GINSBURGH et al., CHUVILIN et al., SOLOVIEV et al.). A mud volcano on the Barents shelf (SUNDEVOR et al.) may also be related to earlier gashydrate formation. (Editors)

THEME 13 THE AMERASIAN BASIN AND MARGINS: NEW DEVELOPMENTS AND RESULTS

Convenors: Ashton Embry and Dennis Thurston

This theme focused on new results from the Amerasian Basin and its margins. The origin and evolution of this portion of the Arctic ocean is still hotly debated and this session not unexpectedly included a variety of interpretations regarding the tectonic evolution of the area.

GRANTZ initiated the session with a spectacular display of newly obtained seismic data from the ocean basin southeast of Chukchi Borderland. He postulated that spreading was likely mainly Jurassic in age and that an evaporite unit formed the initial deposit in the basin. BOGDANOV followed with an overview of the current tectonic setting of the basin and his interpretation of the plate movements resulting in its formation, drawing comparisons with the Philippine Sea. BROZENA presented recently collected aeromagnetic and aerogravity data from the southern Canada Basin and used the data to support an elegant rotation model for the opening of the basin.

MASHENKOV used the regional gravity data to interpret the crustal thickness variations over the entire basin. Notably these modeled results compared well with established thicknesses from scattered seismic refraction experiments. LANE then turned the audience's attention to the major latest Cretaceous-Tertiary crustal shortening in northern Yukon and adjacent Alaska. He emphasized the existence of substantial eastward relative motion of Arctic Alaska towards North America and the need to correct for such motion in any tectonic model for the Amerasian Basin. EMBRY followed with a review of the evidence for and against the hypothesis of counterclockwise rotation of Arctic Alaska. He concluded that current arguments against the hypothesis are poorly supported and that it represents the best model for the opening of the basin. STEPHENSON gave the next talks, which dealt with finite element models of stress regimes and their Tertiary to Recent tectonic consequences for the Beaufort Sea margin. DUMOULIN wrapped up the session with a detailed sedimentological and paleontological description of a carbonate succession in the Brooks Range of Alaska and its fossil affinities to Siberia and North America.

The posters for this session by ZAYONCHEK & MASCHENKOV and CHILDERS et al. presented a spectacular tectonic interpretation of the Arctic based on a new compilation of gravity data from Russian and US sources, bathymetry data, as well as some public domain gravity data.

Overall the session provided a variety of new geological and geophysical data which further constrain models for the opening of the Amerasian Basin. The debate continues with the rotation hypothesis still being the model of choice.

THEME 14 CIRCUM-ARCTIC MARGINS: THE SEARCH FOR FITS AND MATCHES

Convenors: Michael Cecile, David Stone and Larry Lawver

This session was a good example of how a lively (heated?) discussion of a particular topic can be very educational for those not deeply involved in the specifics. In this case the topic was the origin of the Canada Basin side of the Arctic ocean, or more specifically, did the Chukotka-Arctic Alaska block rotate away from the Canadian Arctic margin about an axis in the Mackenzie river area, or did it evolve through a quite different set of motions. Though the debate was very educational for the rest,

particularly with regard to the factual and the moot points of the relevant geology, it was not clear that any of the protagonists were in a mood to change their ideas! From comments overheard after the session, the result was very Zen-like, with equal numbers wishing to rotate and not wishing to rotate but all went away with much new food for thought.

As an aside to this part of the whole ICAM meeting, the new potential field data for the Canada Basin give very clear magnetic stripes and a gravity anomaly that is certainly most easily interpreted in terms of an extinct sea-floor spreading center.

Perhaps some of the differences of opinion related to the Cretaceous opening of the Arctic will be resolved when we better understand the nature of the suture or sutures that mark the boundaries between the blocks from the Arctic and those from the Pacific side.

New paleomagnetic and structural data on the paleogeography of the major terranes of Northeast Russia are now indicating a scenario involving many far-traveled terranes, but also showing major terranes such as Omolon and Omulevka that may never have strayed very far from their parent cratons. In addition to the arguments about the origins of today's Canada basin and associated parts of the Arctic ocean, there were many interesting papers related to Proterozoic and early Paleozoic paleogeographies of the whole Arctic region. The paleontologic (dominantly conodont) evidence mixed affinities of Arctic Alaskan collections, part being Siberian, part North American for early Paleozoic time. These data, combined with other geologic arguments raises the possibility or perhaps probability, of an ancestral Arctic ocean followed by collisional or closing events preceding the opening of the modern ocean basins. On the Russian side of the Arctic, several presentations (including posters) showed that considerable progress has been made in understanding the structural framework and the composition and distribution of the deep crust, which will help in testing various tectonic models. These included:

- A proposed division of the Eurasian Arctic Shelf basement into tectonic complexes of different ages using geological and geophysical data.
- A detailed analysis of the South Anyui suture, the ancestral South Anyui Basin and its possible Pacific and European connections through the Taimyr region.
- Detailed tectonic analysis showing the evolution of hydrocarbon rich basins of the Barents and Kara seas shelves, the Timan-Pechora Basin, as well as several other large peri-Arctic continental basins.

There were also posters on the tectonic character and development of the Verkhoyansk-Chersky orogenic belt and Paleozoic to Mesozoic suture zones in northern Eurasia.

THEME 15 GEODYNAMICS OF THE ARCTIC REGION

Convenors: Arthur Grantz and Larry Lane

The talks and posters on the Geodynamics of the Arctic Region

brought a variety of scientific approaches and viewpoints to bear on the geologic framework and tectonic development of the Arctic ocean and its environs, and provided an opportunity for fruitful discussion of diverse points of view. The global interdependence of Arctic geodynamics was reinforced through presentations on the Eurasian, Makarov, and Canada basins as well as the north Atlantic and Pacific basins. New regional surveys of the gravity and magnetic anomaly fields from satellites, aircraft, ships, and submarines are providing significant new insights into the tectonic development of the Arctic region. A new interpretation of magnetic data from Baffin Bay shows, for example, that North Atlantic spreading entered the Arctic via Nares Strait, as well as Fram Strait, and in the process created as much as 85 km of left slip between Greenland and Ellesmere Island between anomalies 34 (84 Ma) and 25 (56 Ma). New gravity data show that a large negative gravity anomaly typical of sea-floor spreading axes overlies the axis of the mid-ocean ridge of the Eurasia Basin, and that large lateral variations in crustal thickness correlate with the extremely low spreading rate there. A new integrated survey of detailed gravity and bathymetry across large right-deflections in Lomonosov and Gakkel ridges support inferences that the two deflections are related, and are possibly features inherited from the initiation of Eurasian Basin formation.

New seismic reflection and refraction data, and the release of older Soviet data are beginning to delineate the crustal structure of several areas of the Arctic Basin. Reflection data show that spreading in the Eurasia Basin was asymmetrical and nonuniform in time, and that it ended abruptly at the continental margin of the Laptev shelf. Sea-floor spreading in the basin was replaced by a system of grabens of similar trend on the shelf itself, which in turn were transformed into late Cenozoic lateral faults that carry the displacement to the continental interior.

Seismic data also show that oceanic crust lies 9-16 km below sea level beneath the Canada Basin, and that the linear negative regional gravity anomaly that extends across the basin from north to south coincides with a fault-bounded trough, which supports previous interpretations that the gravity anomaly and associated symmetric magnetic anomalies mark a sea-floor spreading axis. Refraction data indicate that oceanic crust in the Eurasia Basin near Morris Jesup Rise is less extensive than is suggested by magnetic data and support juxtaposition of the rise with Yermak Plateau at the time of initial opening of the basin. An abnormally thick oceanic layer 3 beneath the Makarov Basin supports the speculation that this thickened lower crust is a lateral effect of the former presence of a hot spot beneath the adjacent Alpha-Mendeleyev Ridge.

Geologic and paleontologic syntheses show a complex history of tectonic migration, assembly and breakup of continents and continental fragments in the Arctic since the Late Proterozoic. This migration was marked, in the Mesozoic and Cenozoic, by net northerly motion of continental fragments across the paleo-Pacific basin, and intermittent, but decreasing interconnection of the Arctic with the World ocean. The ongoing acquisition of uniform regional gravity and magnetic data coverage of the

Arctic is bringing the geologic framework of the Arctic ocean region into focus. Although the geologic framework and tectonic development of the Arctic as a whole has become much clearer in the past few years, the geodynamics of Canada Basin continues to be a difficult problem. An adequate understanding of Canada Basin tectonics will require further integration of offshore geophysical data with onshore geology, as well as the acquisition of additional seismic data and cores, from which a more specific and detailed understanding of the age, distribution and character of its principal geologic features can be obtained.

REVIEW PROCESS

About 200 participants from 14 countries attended the conference. 220 Abstracts were received. Plenary lectures were given by I.S. GRAMBERG, G. GRIKUROV, V. IVANOV, EU. KORAGO, M. KOS'KO, A. PISKAREV, YU. POGREBITSKY & O. SUPRUNENKO on „The Eurasian Arctic Margin: Earth Science Problems and Research Challenges“ and by Y. KRISTOFFERSEN on „The Eurasian Basin.“

As a result of the conference, close to 70 papers are now published in two volumes of „*Polarforschung*“, the international journal of the German Polar Society. Because of several factors, delay in the submission of papers, delay of reviews, technical problems with figures, language corrections etc. it is not possible to publish the papers in the proper order of their thematic contents. The first volume contains all the papers that were ready first, which, regrettably is, in many cases not the order in which the papers were submitted. To help to bring each paper into the proper thematic context, we have added in each paper a line with the theme, under which it was grouped during the conference.

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