



CIRCUM ARCTIC PROJECT

HYDROCARBON POTENTIAL OF THE ARCTIC

THE PRODUCT

This review, managed by Exploration Geosciences, is the first known attempt to systematically assess the hydrocarbon potential within the area enclosed by the Arctic Circle. A vast database has been accumulated from many sources and has resulted in new interpretations and insights throughout the region including Russia, Norway, Greenland, Canada and the United States (Alaska). Nearly 20 man-years of work have been done over a period of two years by 30 people from Exploration Geosciences Limited, Canadian Discovery Limited, IGI Limited, FE2 Limited and WAA Limited. The product has made extensive use of the Geographic Information System (GIS) technology and is delivered primarily as a digital product on DVD.

The product has already been purchased by seventeen companies including six supermajors.

Support and updates are provided through a website www.ice-cap.net and general or client specific workshops.

The contents of the assessment are digitally linked and may be interrogated by geographic area, geological age, reservoir rock, geological feature or field. The product is available now in both the English Language and the Russian Language.

OVERVIEW

Many believe that world-wide oil production has already peaked or will not rise significantly in the next few years before declining. Proven oil reserves in North America and Europe are already less than 10 years of current consumption, yet consumption continues to rise. The situation for gas is similar. North American energy consumption is 6 times the global average. The booming economies of China and India with their vast populations will result in combined energy demands exceeding those of North America. Forecasts based on unlimited supply show demand potential for oil by 2025 in excess of 5.7 billion tonnes per year whereas today's proven and probable reserves will be able to supply barely 3.6 billion tonnes per year. The situation for gas is directionally the same although slightly less critical.

Against this background, success in the search for new oil and gas reserves has never been more important and frontier areas such as the area within the Arctic Circle are attracting more and more attention. Much of the work already carried out in the subject area was completed 20 to 30 years ago. In the USA and Canada little new work has been done since 1985 until very recently. Greenland has barely scratched the surface. In Norway the recently started Snohvit project is the only significant development inside the Arctic Circle. Only Russia has

had a consistent programme of development in the area over the last 40 years and many technological breakthroughs have their origins in Russia. Certainly, the experience base of working in the Arctic Regions is greater in Russia than in all other countries together.

Ironically, there is a perception that American and Canadian technology is at the forefront in the region but reality shows a different picture. In the USA in Alaska, the Alyeska Pipeline from Prudhoe Bay to Valdez was completed in 1968, as was most of the onshore drilling on the North Slope. In Canada, most of the work carried out in the area was done under a government subsidy programme in the early 1980's and a "money no object" culture prevailed. Many of the experimental developments of the day would be done now on an entirely different and much less costly basis. Costs in North America are very high compared with Russia. For example, in Russia, gas pipelines with diameters around 1420 mm are being laid for a cost of about US \$1.5 million per kilometer. In Canada, a 762 mm gas pipeline through the Mackenzie Valley is estimated to cost US \$ 2.9 million per kilometer even though its carrying capacity is around 40% of the larger Russian lines. In equivalent carrying capacity terms, the North American lines are nearly 5 times more costly than Russian lines.

In our assessment of the hydrocarbon potential of the area within the Arctic Circle, we have drawn upon a wide range of data sources to assemble a data base that would be nearly impossible for any one oil or gas company to replicate. Due to the independent nature of Exploration Geosciences, we have gained access to data that would not be available to oil companies except at very high cost. Our assessment is based on extensive new analysis and interpretation derived from the database and includes engineering

assessments, example development schemes and economics.

The following sections give a more detailed description of the product.

STRUCTURAL ELEMENTS

New Structural Elements mapping based on over 100,000 km of seismic data provided by 5 geophysical contractors and 7 government agencies. Over 9,000 km of interpreted seismic profiles are provided with the study. A new Bathymetric and Topographic map, a new Residual Magnetic Anomaly map and a new Residual Bouguer Gravity map have all been incorporated in the new mapping. Exploration Geosciences has carried out a major reinterpretation of the area structural elements mapping and is already working on a refined version of the base work. The map is linked to detailed text arranged geographically by feature, cross section and seismic profile:

- ✍ Timan Pechora (16 features, 2 cross sections, 2 seismic profiles)
- ✍ West Siberia (8 features, 2 cross section, 12 seismic profiles)
- ✍ Laptev Sea (18 features, 5 seismic profiles)
- ✍ East Siberia Sea (5 features)
- ✍ Chukchi Sea (4 features, 2 cross sections, 3 seismic profiles)
- ✍ Barents Sea (42 features, 3 cross sections, 8 seismic profiles)
- ✍ Norwegian Sea (29 features, 2 cross sections, 1 seismic profile)
- ✍ East Greenland (7 features, 1 cross section, 1 seismic profile)
- ✍ West Greenland (10 features, 2 cross sections)
- ✍ Canadian North West Territories (24 features, 3 cross sections, 2 seismic profiles)
- ✍ Canadian Queen Elizabeth Islands (35 features, 2 cross sections, 7 seismic profiles)
- ✍ USA Alaska (29 features, 3 cross sections, 4 seismic profiles)

PLATE TECTONICS

New reconstructions of the plate tectonics of the region for 11 geological time periods. Maps are supported by fully linked text and analysis:

- ✍ Precambrian and Cambrian
- ✍ Late Cambrian to Mid Silurian
- ✍ Late Silurian and Devonian
- ✍ Carboniferous
- ✍ Permian
- ✍ Triassic
- ✍ Jurassic
- ✍ Cretaceous
- ✍ Paleocene to Eocene
- ✍ Oligocene to Miocene
- ✍ Pliocene to Recent

STRATIGRAPHY

Detailed stratigraphic analysis is presented by geological age and geographic area. Areas are North America (including USA, Canada and West Greenland) and Eurussia (including East Greenland, Norway and Russia). A polar lithostratigraphic section from the USA Chukchi Sea through to the De Long Basin is supported by linked and detailed text and analysis.

North America is subdivided into 8 areas supported by 6 explanatory figures, 7 well correlation sections, 8 key well presentations, 12 paleogeography maps, and 118 well summaries.

Eurussia is subdivided into 18 areas supported by 12 explanatory figures, 3 well correlation sections, 12 paleogeography maps, and 78 well summaries.

RESERVOIRS

Reservoirs are analysed by area and by quality. Reservoirs are presented under four grades (A through D). Grade A

reservoirs are high quality and likely to contain commercial quantities of hydrocarbons. Grade B reservoirs are high quality but for which no obvious source rock exists. Grade C are good quality reservoirs but which are unlikely to contain commercial quantities of hydrocarbons. Grade D are reservoirs for which there is very little in the way of information.

For North America, results are presented under 7 areas; USA Alaska Chukchi Sea (1 grade A, 1 grade B, 1 grade D), USA Alaska North Slope (7 grade A, 4 grade B, 2 grade C, 2 grade D), Canada Mackenzie Delta (2 grade A, 1 grade B, 5 grade C, 3 grade D), Canada Beaufort Sea (1 grade B, 5 grade C, 3 grade D), Canada Queen Elizabeth Islands (14 grade A, 4 grade B, 2 grade C, 8 grade D), Canada North West Territories (4 grade D), and West Greenland (4 grade D).

For Eurussia, results are presented under 6 areas; East Greenland (3 grade A, 1 grade D), Norwegian Sea (1 grade A, 3 grade C, 4 grade D), Barents Sea (3 grade A, 1 grade B, 5 grade C), Timan Pechora (4 grade A, 2 grade C), West Siberia (4 grade A, 1 grade B, 2 grade C, 1 grade D), North East Russia (6 grade D).

Text is further supported by 27 reservoir maps, 22 reservoir plots, and 40 reservoir logs.

PETROLEUM SYSTEMS (SOURCE ROCKS)

Petroleum Systems are organised geographically going east from the Chukchi Sea, and by the stratigraphic sequences determined by plate tectonic development. Systems covered include:

- ✍ USA, Alaska, Chukchi Sea
- ✍ USA, Alaska, North Slope
- ✍ Canada, Beaufort Shelf

- ✍ Canada, Kandik Basin
- ✍ Canada, Eagle Plains Basin
- ✍ Canada, Lower Mackenzie Valley
- ✍ Canada, Mackenzie Delta
- ✍ Canada, Queen Elizabeth Islands
- ✍ USA/Russia, Bering Sea
- ✍ West, North and East Greenland
- ✍ Norway/Russia, Barents Sea
- ✍ Norway, Haltenbanken
- ✍ Russia, Timan Pechora
- ✍ Russia, South Kara Syncline
- ✍ Russia, West Siberia
- ✍ Russia, East Siberia and Chukchi Sea

The analysis draws upon a geochemical database of some 45,000 samples. Each source rock within a system is analysed as to TOC, Kerogen Type, Maturity, Yield and Productivity. Geochemical models have been derived and calibrated for each source rock.

ENVIRONMENT

The environmental section of the assessment is intended as an overview which points the reader to more detailed sources for each matter raised. It is arranged in 3 sections, General, Physical Environment and Ecological Environment.

The General section provides an introduction and deals with:

- ✍ Principal Agencies and Sources
- ✍ Regulatory Framework
- ✍ Environmental Impact
- ✍ Operation Recommendations
- ✍ Oil Spill Contingency

The Physical Environment section deals with:

- ✍ Themes and Sources
- ✍ Permafrost
- ✍ Ice
- ✍ Climate and Oceanography
- ✍ Transport Corridors
- ✍ Radioactivity

The Ecological Environment section deals with:

- ✍ Sources
- ✍ Land Ecosystems
- ✍ Protected Areas
- ✍ High Impact Species
- ✍ Indigenous Populations

The text analysis is backed up by detailed maps covering both the ecological and physical environment.

ENGINEERING DEVELOPMENT AND ECONOMICS

This part of the assessment is organised in 4 sections; technology review, export infrastructure, economics and case studies.

The Technology Review Section provides an analysis of design issues, reviews drilling approaches and production systems (including artificial islands and solid wall tension leg platforms), discusses transport systems for oil, and presents a detailed review of transport systems for gas including pipeline, liquefied natural gas (LNG), gas to liquids (GTL), conversion to methanol, gas hydrates for transportation, and conversion to electric power (gas by wire). Text is illustrated by 24 linked figures.

The Export Infrastructure section provides a review of existing and planned infrastructure on a country by country basis. The text is illustrated by 3 linked figures.

The Economics section provides an analysis of supply/demand issues for both oil and gas and reviews fiscal systems both in general terms and as specifically applied by each country with Arctic territory.

The Case Study section provides 17 case studies covering the Arctic region. For each field, the location is given, the field and physical setting described, ice conditions are reviewed and a

development concept discussed. Capital and operating costs are determined on a consistent basis case to case and economics derived. Due to the wide range of permutations of government take (taxation) and desired rates of return on a company by company basis, the economics are presented graphically showing oil or gas price versus government take for four different rates of return.

OTHER OUTPUT

43 field analogues are provided which help in the assessment of new fields by comparison.

16 petroleum system montages are provided which bring together the study results. The montages will be provided in hard copy as part of the product. Each montage provides a graphical illustration of:

- ✍ Source rocks (supported by geochemical modeling)
- ✍ Lithostratigraphy (supported by seismic sections, key well summaries and well logs)
- ✍ Reservoirs and field analogues
- ✍ Environmental data
- ✍ Development and Economics

Quality control of the data used was of importance to the participants in the assessment and a section is included recording key data sources and the use made thereof.

Nearly 1,300 references are cited in the text and a detailed list of all of these is provided. References are automatically linked through the base text in each section.

PARTICIPATING COMPANIES



Exploration Geosciences provided overall project management as well as geological and geophysical interpretations including structural elements, plate tectonics and reservoirs. They also secured access to over 100,000 km of seismic data through special relationships with geophysical contractors and others.



Canadian Discovery provided access to a huge Canadian database.



Integrated Geochemical Interpretations (IGI) provided the geochemical database on all modeling and interpretations thereof.



William Arnold Associates Limited (WAAL) provided the engineering, economics and case studies input.



Flat Earth Two Limited (FE2) provided the environmental review and all of the GIS, website, digital linking, and product digitizing.

FURTHER INFORMATION AND CONTACT

To arrange for a detailed presentation and demonstration of the product, please contact Exploration Geosciences at the following address:

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