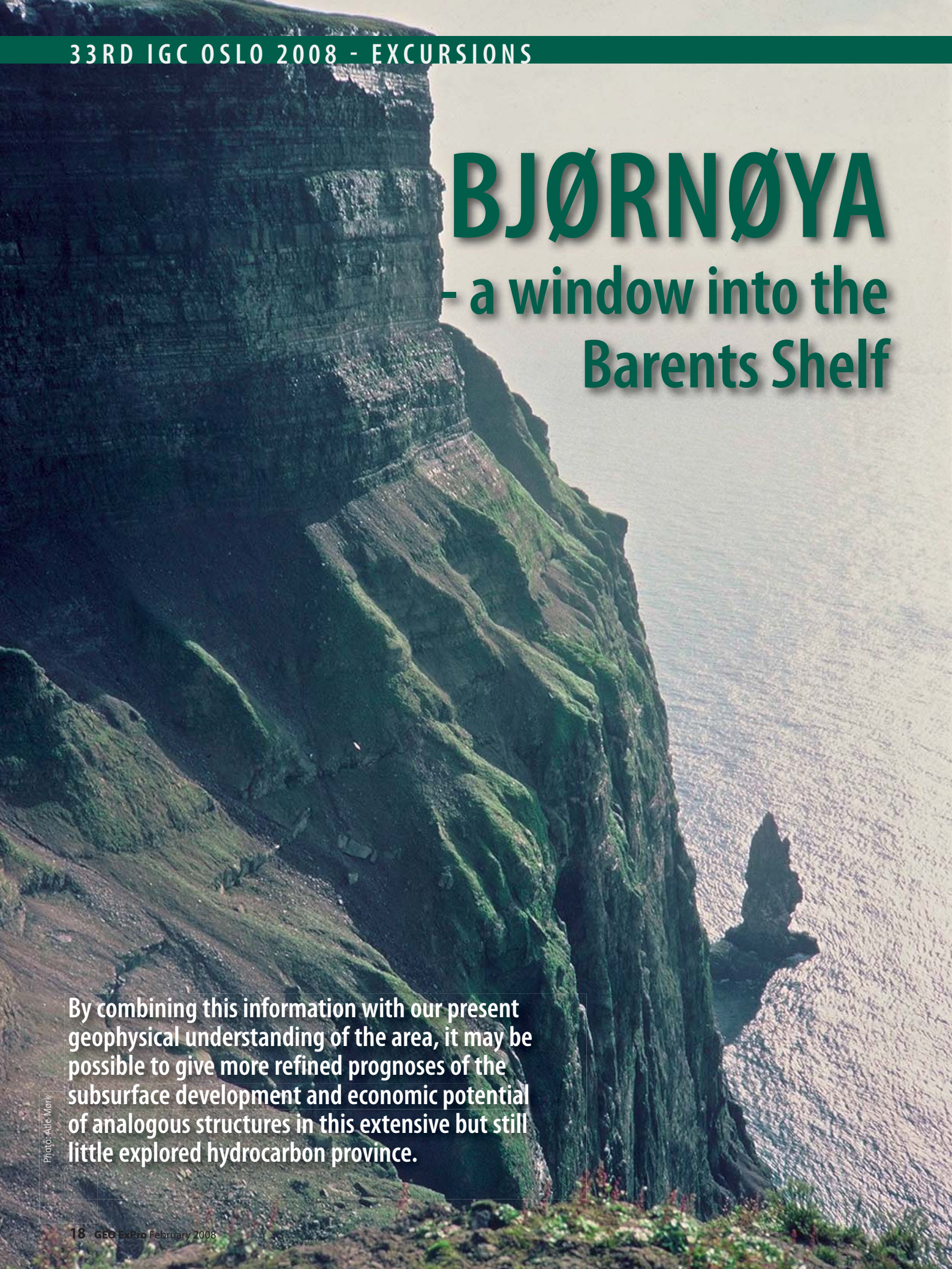
BJØRNØYA
- a window into the Barents Shelf



By combining this information with our present geophysical understanding of the area, it may be possible to give more refined prognoses of the subsurface development and economic potential of analogous structures in this extensive but still little explored hydrocarbon province.

Photo: Atle Mork

Photomosaic of SW part of Bjørnøya showing the relationships between various Carboniferous to Permian units and the Hecla Hoek basement

David Worsley, Consultant, and Atle Mørk, Institutt for geologi og bergteknikk, NTNU

The small island of Bjørnøya ("Bear Island", only 178 km^2 in area), situated near the Barents Sea's western margin almost midway between northern Norway and Spitsbergen, shows a Precambrian to Triassic succession in a continuous series of spectacular cliff exposures. These exposures provide a key not only to the evolution of the Stappen High (on which Bjørnøya rests) but also to the development of the major lineaments that subsequently contributed to the formation of both the Norwegian-Greenland Sea and the Arctic Ocean.

Triassic and Older

The Stappen High was a positive Late Paleozoic feature; it then subsided in the Mesozoic and was again uplifted in the Cenozoic. The sedimentary succession exposed on the island itself ranges from the Upper Precambrian to the Upper Triassic; with a composite thickness approaching 3 km. Significant unconformities define the boundaries between three main depositional complexes: the Pre-Devonian economic basement, the Late Paleozoic basin and the Permo-Triassic platform.

The extensive northern plain of Bjørnøya generally undulates between 20 and 50 m above sea level, with a labyrinth of rock fields, marshes and small lakes and the underlying Upper Paleozoic succession is best studied in low coastal cliffs with spectacular exposures. The southern and southeastern part of the island is a rugged mountainous terrain dominated by basement exposures, and more than 400 m high cliffs rise precipitously from the sea. Mountaintops in this area show almost flat-lying exposures of the Permo-Triassic platform sequence unconformably overlying all older units; however Late Paleozoic half-grabens are locally developed, cutting into the basement but predating the platform units. Triassic strata - the youngest pre-Quaternary deposits preserved on the island - are exposed in three conical peaks on the Miseryfjellet massif, with youngest Carnian (Late Triassic) deposits preserved at 536 m above sea level.

Major Events

The complex development shown by the Upper Palaeozoic succession of Bjørnøya is noteworthy in view of the immense amount of information that can be derived from this small area. The structural development of the Stappen High is not unique, but the spectacular exposures offer an impressive documentation of the ongoing tectonism that characterised the present-day western margins of the Barents Shelf during the Late Palaeozoic.

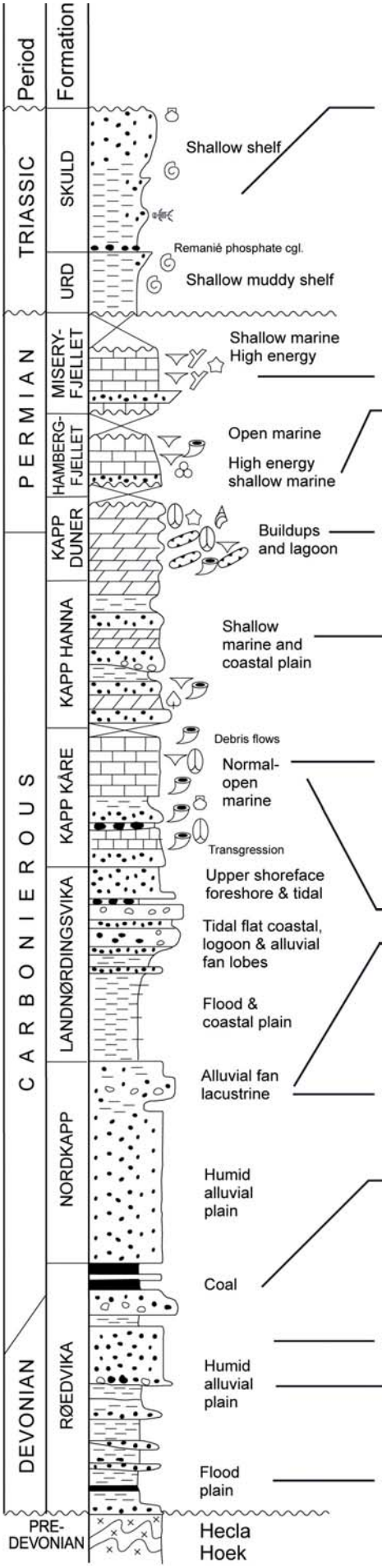
Bjørnøya is especially interesting in that the Late Palaeozoic tectonism can be differentiated from the Tertiary overprint, which usually obscures similar movements both in southern and western Spitsbergen and in parts of the Wandel Sea (NE Greenland) and Sverdrup (Arctic Canada) basins.

Some major geological features to be demonstrated:

- Bjørnøya's Late Precambrian to Ordovician succession was subjected to major overthrusting during the Caledonian orogeny, a feature contrasting with some reviews suggesting no Caledonian deformation.
- The Stappen High was the site of fluvial sedimentation in a NNW trending half-graben from the late Devonian to early Carboniferous,
- Mid-Carboniferous uplift was accompanied by a climatic shift to arid conditions and followed by renewed rifting along a master fault to the west of present exposures on the island,
- Bashkirian and Moscovian sea-level rise led to carbonate deposition over the entire area, in common with the rest of the Barents Shelf,

Preparation of the three metre long labyrinthodont amphibian excavated in 1985 (photo B.T. Simonsen)

Yellow dolomitic limestone form the top Permian locality Osten (Cheese) with overlying grey Triassic shales (photo H.A. Nakrem)



Bjørnøya viewed from NE showing the plateau formed by the Miseryfjellet Fm overlain by Triasssic shales (Urd Fm) and sandstones (Skuld Fm) forming the peaks

The cliff-forming Miseryfjellet Fm limestones

A wedge of the Hambergfjellet Fm overlain by the Miseryfjellet Fm

Palaeoaplysinid reefs in the Kapp Dunér Fm

Yellow sandstone fills channels in the Kapp Hanna Fm

Grey limestones of the Kapp Kåre Fm form coastal caves and arches

Grey sandstones of the Nordkapp Fm overlain by the red beds of the Landnørdingsvika Fm, grading upwards into grey limestones of the Kapp Kåre Fm

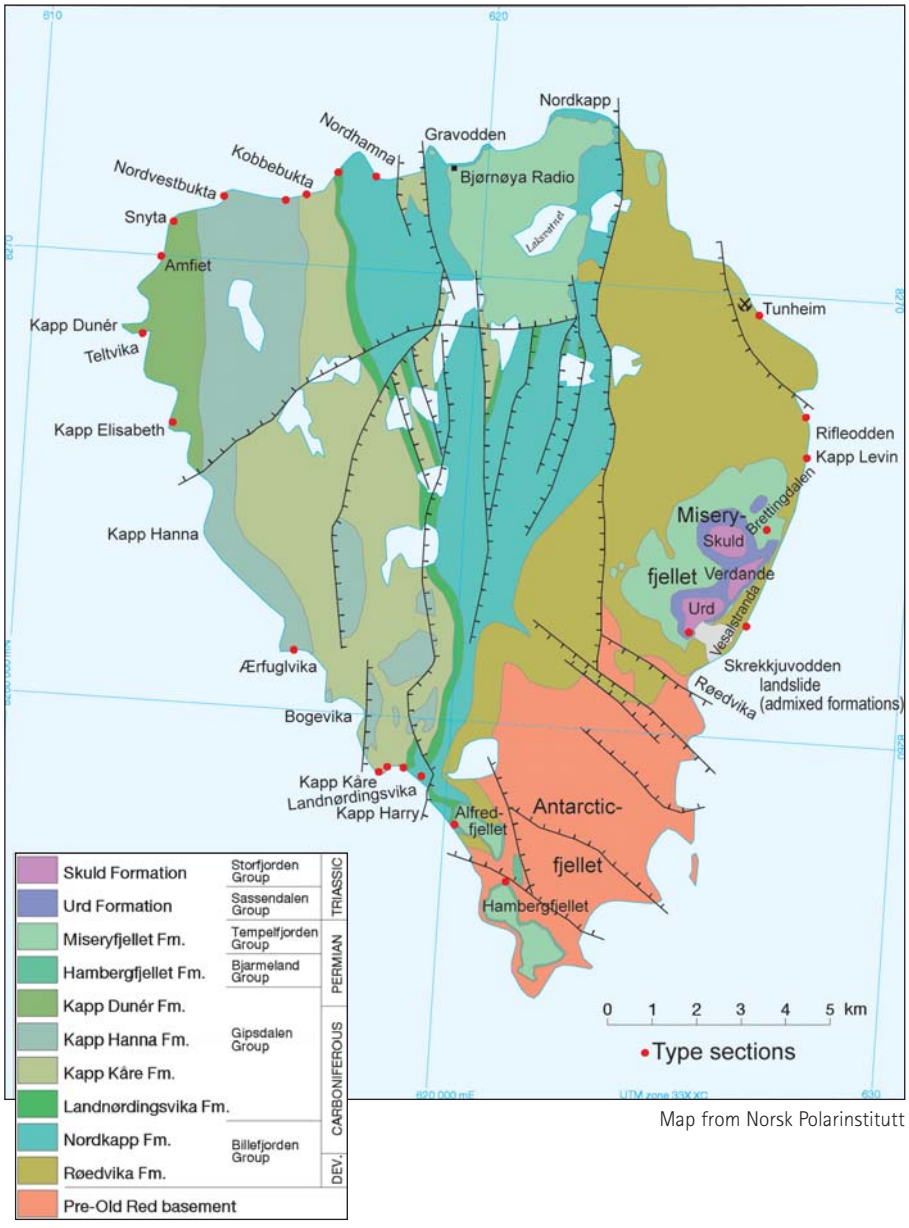
Coarse fluvial conglomerates and sandstones of the Nordkapp Fm

The one metre thick Carboniferous coal seam mined at Tunheim

Carboniferous tree trunk

Fluvial sandstones of the Rødvika Fm

Rødvika Fm sandstones and coals unconformably overlain by the Miseryfjellet Fm limestones with Triassic shales at top



Map from Norsk Polarinstitutt

Cross-bedded sandstones of the Røedvika Fm overlain by silicified limestones of the Upper Permian Miseryfjellet Fm - the boundary marking a 40 Ma hiatus (photo A. Mørk)

A natural harbour is formed by a river in the Nordkapp Formation (Photo H.A. Nakrem)

Stappen, the southernmost point of Bjørnøya has given name to The Stappen High where Bjørnøya is the exposed part (photo A. Mørk)

- Renewed tectonism in the late Carboniferous produced the highly faulted configuration seen today,
- The early Permian was characterised by onlap and then uplift of the newly created high,
- Upper Permian and Triassic sequences progressively onlapped the high before the entire area subsided from the late Triassic to late Mesozoic or Paleogene.

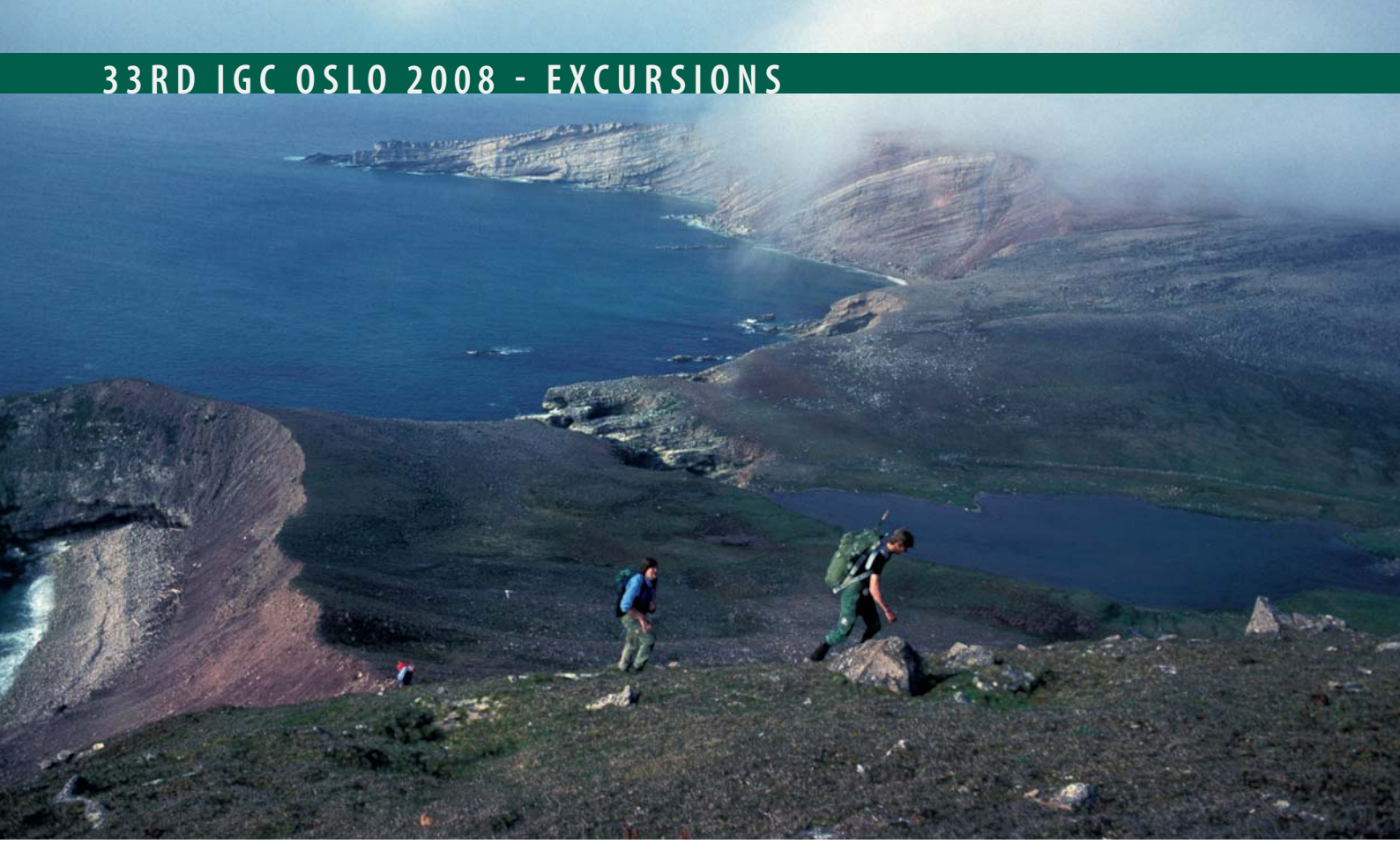
A Multitude of Plays

The island's development also gives striking examples of the type of plays expected to still have great potential for successful hydrocarbon exploration both on the Barents Shelf and in adjacent areas:

- Lower Carboniferous coal-bearing fluvial sequences in local rift basins,
- Upper Carboniferous to Lower Permian platform carbonates and interbedded evaporites, with local structuring related to major lineaments,
- Carbonate buildups and associated facies along major lineaments and basinal margins,
- Combined structural/stratigraphic traps related to Late Paleozic structuring.

Sandstones of the coal-bearing Røedvika and Nordkapp formations may have an interesting trapping potential, especially as they show some of the highest porosities of the entire Upper Palaeozoic succession on Bjørnøya. These sandstones occur in local grabens where they may provide combinations of stratigraphical (pinch-out and truncation) and structural traps, with structuring provided by mid-Carboniferous rifting. Bjørnøya's southwestern cliffs display sections through possible truncation traps related to later Carboniferous and Permian tectonism, with potential seals provided by Permian carbonates; these provide good analogues for geographically restricted but similar structures such as the Loppa High.

These potential sandstone reservoirs would in general be expected to be sourced ▶



A view of Landnørdingsvika. The red exposures in the foreground cliffs and the 120 m high cliff partly covered by claud belong to t the Landnørdingsvika Fm. Lake Ellasjøen, surrounded by exposures of the fluvial Norkapp Fm sandstones, is central in the photo. The farthest point consists of shallow marine limestones of the Kapp Kåre Fm (photo H.A. Nakrem)

by hydrocarbons derived from the adjacent coals and coal shales in the same sequences, but more oil-prone lacustrine units have also been described from comparable fluviatile sequences both in the penecontemporaneous Emma Fjord Formation of the Sverdrup Basin, the Billefjorden Group of Spitsbergen and the Upper Carboniferous of East Greenland.

Bjørnøya

Bjørnøya was discovered and named by Willem Barents in 1596. His expedition killed a polar bear, giving the island its name, although polar bears usually only sporadically visit the island in winter. Walrus hunting and trapping were the main activities there until Swedish expeditions in the latter half of the 19th century made the first general survey of the island. Upper Devonian and Lower Carboniferous coals were then the main objects of geological and economic interest, although other minerals were also investigated. Mining operations started in 1916, but were abandoned as uneconomical in 1925. Since then the island has been the site of a radio and meteorological station, except for a break in activity during the 2nd World War.

Source and Reservoir Potential

The overlying conglomerates, sandstones and limestones in the Carboniferous succession are generally tightly calcite cemented in exposures on Bjørnøya, reflecting the predominantly marine diagenetic regimes in spite of repeated uplift and erosion. In contrast, the bioherms and associated dolomites of the Permocarboniferous Kapp Dunér Formation are much more porous bodies than the surrounding and overlying sequences, porosities resulting from early leaching and/or dolomitisation linked to repeated subaerial exposure. These carbonate buildups are furthermore associated with bituminous limestones with an interesting source potential.

Overlying mid-Permian limestones appear to have been formed in cooler water transgressive regimes and are characterised by pervasive marine calcite cementation leaving no effective reservoir potential. Indeed in analogous subsurface situations, these units could have acted as an effective seal for hydrocarbons trapped in the underlying truncated units. Large-scale carbonate build-ups of this age on the Barents Shelf are also tight, with no effective reservoir potential. Such build-ups are observed along the tilted flanks of the Loppa High where they were eroded and presumably karstified as a result of repeated uplift in the late Permian, probably giving good dissolution porosities; they were subsequently directly overlain and sealed by onlapping Triassic shales with a probable source potential.

Uplift in the latest Permian was apparently accompanied by regional regression and at this time even the silica-cemented Upper Permian sandstones and limestones may have suffered dissolution and karstification over large areas, giving rise to an interesting mouldic secondary porosity development; this play is especially interesting in areas such as the Finnmark Platform or Loppa High where structuring may put these potential reservoirs in direct contact with possible uppermost Permian or lowermost Triassic potential source intervals which have been tentatively identified in several wells.

A synthesis of all recent work will be presented on the excursion following the International Geological Congress in Oslo in August, comparing and contrasting the development of Bjørnøya with the remainder of the Barents Shelf (www.33igc.org).