Upper Carboniferous-Lower Permian Gipsdalen Group karstified reservoir carbonates of the Loppa High, Barents Sea; reservoir potential and drilling challenges.

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Seismic Area C on the Loppa High, southwestern Barents Sea, is covered by a 1 x 1 km grid of 2D seismic and with a 3D grid of 970 sqkm covering the most prospective areas. In-house pre-stack depth migration of the 3D data has resulted in a high-quality seismic data set that reveals the 3D heterogeneity of the carbonate buildups and karst systems in the Upper Palaeozoic strata with unusual clarity. Such data is essential for the prediction of reservoir properties and in steering well location away from cavernous areas where the risk of mud-loss during drilling is considered to be greatest.

The present exploration efforts have focused on a gigantic structural high referred to as the “Obelix Structure”. The structure is located in the uplifted footwall block of the extensional N-S trending Polhem Fault. The main prospective Upper Palaeozoic carbonate reservoir section is truncated on the eastward-dipping eastern flank of the Obelix Structure, where it is overlain with angular unconformity by Triassic shales. The unconformity between the Upper Palaeozoic reservoir and the mid-Triassic seal spans the Upper Permian-Ansian, approximately 25 million years. Drainage systems, sinkholes (dolinas) and irregular hummocky topography are considered indicative of penetrative karstification of the carbonates.

Figure 1: Palaeogeographic map, near Top Gipsdalen Group (main reservoir). The light grey coloured area is truncated carbonates and Caledonian-deformed basement. The truncated carbonates represent mainly inner ramp/platform carbonates that represent the main reservoir target for the Obelix Structure, Loppa High. The darker grey areas represent middle and outer ramp carbonates with large polygonal network buildups (see also Figure B) and with a significant lower reservoir potential than updip. Notice also the fault control on deposition with abrupt change in buildup size across faults.
Figure 2: Carbonate reservoir model for the Loppa High. Dolomitization was early diagenetic processes and was controlled by depositional environments (sabkha and hypersaline lagoons) of inner ramp/platform settings. These areas also have the strongest impact from subaerial exposure and together they produced the carbonates with the highest reservoir potential. A later diagenetic Dolomitization stage, perhaps from modified marine waters, is locally pervasive and dolomite cements partially fills some pores and are also associated with anhydrite cements.

5. Upper Palaeozoic & Mesozoic Burial: Key Concepts and Controls on Karst Play

Figure 3: Schematic model illustrating the karst development. There are at least three main karstification episodes related to 1) high-frequency subaerial exposures at glacioeustatic sea level cycles, 2) at major 3. and 2. order sequence boundaries (e.g. Top Gipsdalen Gp.), and 3) at an approximately 25 mill. year unconformity between the Palaeozoic and mid-Triassic. Open palaeo caverns existed far into the Late Triassic when they collapsed at approximately 500m of burial.

The first well on the Obelix Structure will target the warm-water carbonates and the basal transgressive sands of the Gipsdalen Group. The Group is characterized by carbonate buildsups...
deposited on a series of fault-controlled eastward tilted ramps, with a tectonic control on accommodation space, thickness and depositional setting. Carbonate buildups are not isolated pinnacle structures, as earlier thought from study from regional 2D data, but instead form a polygonal network enclosing deeper mini-basins or lagoons. The buildups appear to be preferentially located along the downdip footwall margin of the basement fault blocks, and their distribution closely mimics the basement fault trends. The newly recognized buildup patterns are important when considering the lateral connectivity of the most favourable reservoir strata. The connectivity is considered to be much greater now than when interpreted from 2D data as the buildups are linked into mosaics. The overlying Bjarmeland and Tempelfjorden groups (late Early Permian and Late Permian) are dominated by cool-water carbonates and are considered less prospective. They were deposited during a period of renewed tectonic activity along the Polhem Fault that started in mid-Permian and lasted to Anisian time.

**Epikarst: Seismic Evidence 1**

- Incised valleys in basement – clastic fairway
- Drainage channels in carbonates with sinkholes
- Both fault-controlled
- Related to unique surfaces (tG/tP)

*Figure 4: Seismic examples of large-scale karst features including sinkholes (dolinas) and irregular “chaotic” (darker grey) (A), excavated palaeocaverns developed along linear faults (B) and seismic lines illustrating palaeocaverns (C).*

Between the mid Permian and mid Triassic the Obelix Structure was uplifted and tilted eastwards. It is considered to have formed an ocean island with a maximum relief of approximately 500 m during the Early Triassic. During this time period the Gipsdalen, Bjarmeland and Tempelfjorden groups were subaerially exposed, truncated and karstified. Seismic-scale dolinas (sinkholes), palaeocaverns and hummocky irregular topography related to this exposure event are superbly imaged. In the basal part of the overlying Triassic succession localized deformation is considered to be related to the collapse karst palaeocaverns in the underlying Palaeozoic. The preferential development of karst features adjacent to faults indicates that both faults and fracture systems were selectively solution-enlarged by meteoric waters that drained from the land area in the west. The stratigraphic control on the karst is also clear in the north of the Obelix Structure. Here stratiform area of approximately 50 sqkm, characterized by a particular chaotic seismic signature and irregular topography, is interpreted to be related to preferential dissolution of evaporite beds within the Gipsdalen Group and brecciation of the overlying strata.
Figure 5: Seismic line across a sinkhole (A). Karst features are associated with chaotic seismic facies (B), low acoustic impedance (C), and lower velocities (D).

Figure 6: Seismic line (A) and time slice velocity map (B) with karstified low-velocity inner ramp/platform areas. The first well is planned for within the low-velocity area.

Gravimetric data and velocity data extracted velocity tomography analysis focused on the carbonate succession, show that the karstified areas are characterized by low gravimetry and velocity, suggesting the presence of potential porous reservoir carbonates in this area. Geophysical studies of the carbonates show that truncated carbonates have significantly lower acoustic impedance than the non-truncated carbonates. Integrating geological and geophysical knowledge in this area is crucial to meet the challenge of: 1) mapping the prospective buildups, 2) the carbonate and sulphate karst systems and 3) understanding the fill of the palaeocavern systems.