Introduction
The Upper Palaeozoic carbonates in the subsurface Barents Sea have significant reservoir potential (Stemmerik et al. 1999). It has therefore been an increased interest for this part of the succession and several semi-regional industry 3-D seismic surveys have been designed to cover the Upper Carboniferous – Lower Permian section in the Barents Sea. We focus here on analysis of Upper Palaeozoic carbonates using established 3-D seismic interpretation techniques combined with automated 3-D seismic facies mapping. The close line spacing of the three-dimensional seismic data have, combined with application of all data-points throughout the interpretation process, increased the understanding of the palaeoenvironment in different geologic settings. The high lateral seismic resolution (~40 m) is preserved through the process to the final maps, giving less room for subjective interpretations.

Geological setting
In the Barents Sea, Carboniferous and Permian rifting led to the development of fault-controlled basins and more stable platform areas (Beauchamp and Desrochers, 1997). The study area is located on the Finnmark Platform, a stable platform where marine, locally evaporitic, warm-water dolomite-dominant carbonates of the Gipsdalen Group prevailed in the Upper Carboniferous and Lower Permian time (Larssen et al. 2002). During Permian time the Barents shelf drifted towards more northern latitudes (Beauchamp and Desrochers, 1997) and in the mid Permian time a change to cooler climate, in combination with increasing water depth, took place in the study area (Bugge et al., 1995). In the Lower to Upper Permian limestones dominate, while cherty limestone, shale and siltstone are represented in the uppermost Permian. *Palaeoaplysina*-phylloid algal build-ups were formed during Gzelian-Asselian (Bugge et al., 1995) and bryozoan build-ups during the Sakmarian-Artinskian (Blendinger et al., 1997). The carbonate build-ups have a mounded seismic reflection pattern when viewed in 2-D cross sections, comparable to modern day pinnacle reefs, but in 3-D map view they appear as large, elongated ridges forming a network of ridges that amalgamate and bifurcate laterally (Elvebakk et al. 2002).

Carbonate buildups
From reliable well ties we interpret the studied ridge features on 3-D seismic time-structure maps from the Finnmark Platform to represent an Upper Palaeozoic carbonate build-up complex (reef-structures), which resulted in a significant topographic high on the sea floor during deposition. The carbonate build-ups are assumed to have formed down-flank of the Permian shelf edge, and appear to be partly controlled by mid Carboniferous and Late Gzelian faults (Fig. 1A and B).
The build-ups occur as oblong, semi-parallel, partly sinuous ridges that are 350-2500 m wide, 21-27 km long and have a relief of several hundred meters (Fig. 1). Some carbonate build-ups seem to be stacked on top of each other. Circular ridges also occur, ranging from 1300-3800 m in width, 1900-4300 m length and 70-160 m in relief, resembling the polygonal network build-ups described by Elvebakk et al. (2002). The circular ridges have an atoll-like shape, enclosing a semi-circular depression that may represent a protected environment, possibly a lagoon. Amplitude anomalies beneath these mapped carbonate build-ups reveal significant contrasts in acoustic impedance, possibly indicating a dramatic change in lithology.

**Figure 1.** Seismic profiles from (A) the seismic amplitude cube and (B) the correlation cube. The faults related to the carbonate build-ups are more readily detectable in the correlation cube. Additionally, details about the internal configuration of the carbonate build-ups, not visible in the seismic amplitude cube, are revealed in the correlation cube. (C) Illuminated time-structure map of horizon Base Tatar, displaying sinuous and straight ridges of carbonate build-ups. The ridges to the far left and right are located on the edge of a topographical high. These continuous ridges are tentatively interpreted to be fault controlled and/or controlled by topography. The vertical exaggeration on the figure is 8x.
Automated 3-D seismic facies mapping

Automated 3-D seismic facies mapping is more efficient and quantitative than manual 2-D seismic facies mapping, and enhances possible lateral facies changes in the carbonate build-ups that may easily be ignored by manual line by line inspection of the data (Fig. 2). By analysis of multiple attribute cubes (Randen et al., 2003), automated 3-D seismic facies mapping permits to detect patterns that might not be mappable from manual analysis. A procedure for automated seismic facies analysis is, as a part of the EU project TriTex (IST-1999-20500), tested here on the Upper Palaeozoic section of a 3-D seismic survey from the Norwegian Barents Sea.

From the original seismic cube a number of attribute cubes that each enhances specific parameters is used in combination with carefully user-selected training points to map the seismic facies. During the automated classification process each point in the 3-D seismic cube is assigned to user-defined classes, providing the user with a detailed 3-D seismic facies map. The automated facies classification and mapping provide a significant contribution to the identification and interpretation of carbonate build-ups and evapoites in the study area (Fig. 2). The method has also proven useful on karst in carbonates from the Loppa High (Hunt et al., 2003).

Figure 2. An example of an original seismic line (above) and the result of an automated 3-D seismic facies mapping (below). The high amplitudes, interpreted to be carbonate build-ups and salt (above), are classified as light grey (below). Note the possible lateral facies changes in the carbonate build-ups that are best visible on the automated seismic facies map (below).
Conclusions

3-D seismic data from the Finnmark Platform reveal the occurrence of long elongated carbonate build-ups of Upper Palaeozoic age. The data also indicate an early phase of salt movement in basins surrounding the carbonate build-ups. Automated seismic facies mapping provide an efficient way of mapping the carbonate build-ups in three dimensions, providing an image of the volume of the build-ups.

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References


