Introduction

During the Late Paleozoic, the Barents Sea was at the edge of the Pangea Supercontinent, recording major climatic and oceanographic changes in the large Panthalassa Ocean (Shulgin et al., 2018). These changes preclude major tectonic events in the Urals and further south, in Central Europe (Faleide et al., 1993; Glørstad-Clark et al., 2010). The oldest marine episode in the Barents Sea is marked the development of Upper Carboniferous (Bashkirian) polygonal carbonates over older continental deposits (Lower Carboniferous to Lower Baskirian). Large bryozoan mud mounds were formed later, prior to their gradual drowning and replacement by siliceous (spiculite) mounds at the end of the Permian (Alves, 2015). These spiculite mounds record the onset of cold-water currents in the region and led to the drowning of the early Permian mud mounds. The accepted depositional models consider that carbonates grew on active structural highs of the Barents Sea (Elvebakk et al., 2002; Colpaert et al., 2007).

This paper focuses on a region located ~150 km to the North of Finnmark, in Northern Norway (Fig. 1). It relates, for the first time, how the geometry and distribution of Carboniferous and Permian mounds relates to vertical movements of the Samson Dome, and adjacent platform areas (Fig. 1a). In essence, this work will demonstrated Samson Dome area presented a much different palaeogeography in the Carboniferous and Permian from the present day, hinting at the presence of sheltered (shallow) platform areas away from the salt structures that are imaged, on seismic data, at present (Figs. 1b and 1c). The identification of such sheltered areas suggests that either: a) older salt structures (pillows, ridges) existed away from the Samson Dome and salt was subsequently withdrawn from below them during the Mesozoic, or b) important vertical movements in the Mesozoic led to the subsidence of these older Paleozoic carbonate platforms.

Methods

This work uses three-dimensional (3D) seismic data and regional 2D profiles across 1160 km^2 of the Barents Sea (Figs. 1a and 1b). The interpreted seismic volume was shot over the Samson Dome, a salt anticline of undetermined age (Fig. 1b). The 3D seismic volume has a bin spacing of 12.5 × 25 m, a 4 ms vertical sampling window and was acquired by a 10 × 6000-m array of streamers. Time–depth conversions were undertaken by considering V_p-wave velocities of 5800 m/s for Upper Permian mounds and 6600 m/s for Carboniferous–Lower Permian strata based on wells 7121/1-1 R and 7124/3-1 drilled above and near the Samson Dome. Vertical seismic resolution approaches 60 m at the depth in which the carbonate build-ups occur.In this work, a series of high-resolution maps will be used to address the morphological differences between distinct carbonate build-up types, and any differences between the locations of such build-ups relative to the present day structure.

Geological setting of the Barents Sea

Multiple Late Paleozoic structural highs in the Barents Sea record thick build-up successions, the best example being the Loppa High the western Barents Sea (Fig. 1c). Carboniferous build-ups on the Loppa High were relatively long-lived (~35 Ma), show polygonal shapes, and had depositional reliefs that reach more than 400 m (Elvebakk et al., 2002). An aspect of important to the study area is that build-ups in the Loppa High were relatively static, changing laterally into evaporites and dolomites in adjacent basin depocentres (Ehrenberg et al., 1998). A similar setting is observed in the study area in this work, where evaporites are observed juxtaposed with Carboniferous-early Permian carbonate build-ups (Fig. 2).

In contrast to the older carbonate build-ups, large isolated carbonate mounds of Early Permian (Artinskian) age were detached from shelf areas on the Finnmark Platform (Colpaert et al., 2007). The reason behind this relates to a change from photozoan assemblages below the Artinskian (the unit L-7 of Ehrenberg et al., 1998) to heterozoan biota above (unit L-8 in Ehrenberg et al., 1998), due to a shift from warm-water to cool-water conditions. Significantly, rapid flooding of isolated carbonate build-ups occurred after the Kungurian (end of Lower Permian) throughout the Barents Sea, in contrast to a regression recorded in global sea-level curves.

Upper Permian detrital banks formed by locally derived bryozoan–echinoderm–spicule fragmental debris also been identified on Finnmark and Svalbard (Ehrenberg et al., 1998, 2010). They comprise ?Kungurian to Late Permian mounds and buildups, and comprise the cold-water 'hyalosponge-bryonoderm' assemblages that are part of unit L-9. At a regional scale, this L-9 unit marks the closure of the Uralian seaway, which extended as far south as the tropical regions of the Pre-Caspian basin.

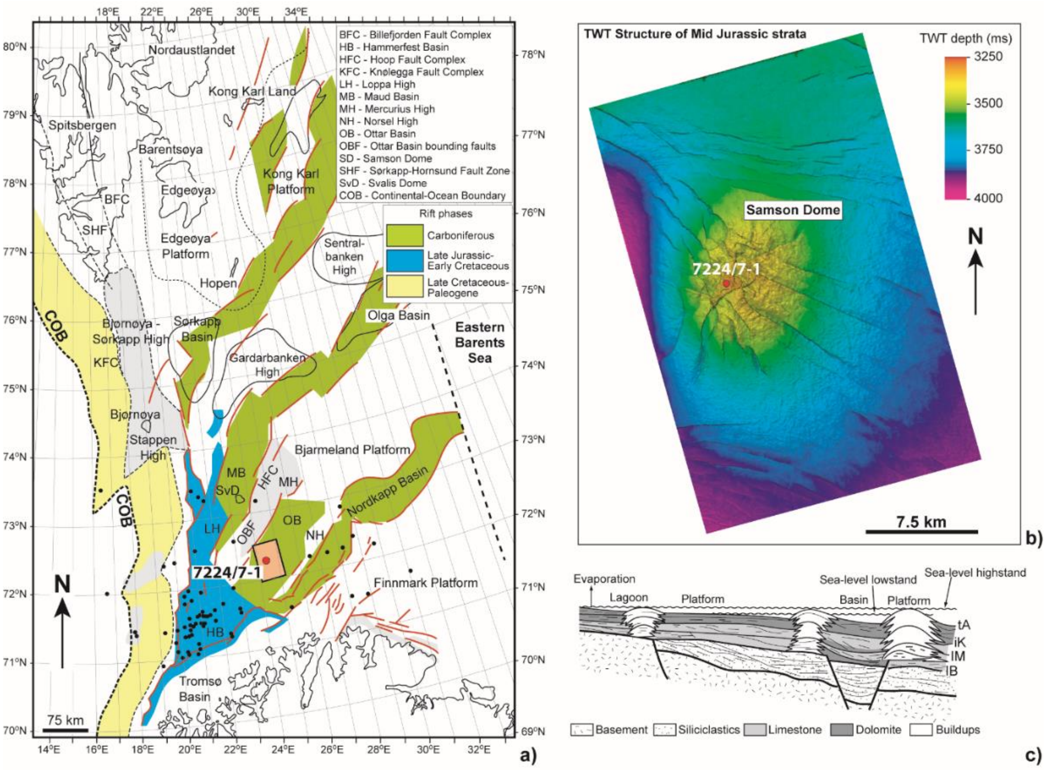

***Figure 1** (a) Tectonic map of the western Barents Sea between Northern Norway and Svalbard. The map highlights the location of the interpreted 3D seismic volume relative to adjacent basins and highs. Well 7224/7-1 is also shown on the map. (b) Two-way time (TWT) structural map of Mid Jurassic sequences above the Samson Dome. Note the complex fault sets that occur at this level over the latter dome. (c) Sketch highlighting the morphology of Late Carboniferous build-ups over the Loppa High (modified from Elvebakk* et al.*, 2002). The map in Fig. 1a has been modified from Gudlaugsson et al. (1998) and Glørstad-Clark et al. (2010).*

Results

This work defends that by mapping in detail the distribution of Late Paleozoic carbonate successions in the Barents Sea, one will be able to reveal geological and depositional settings that are much different from the present day's. In this work, we divide these settings into distinct stages:

Stage 1 - The oldest of the Carboniferous polygonal build-ups have long and short ridges, and show a predominant northwest strike for the longest ridges in what was called Horizon 5 in this work (Fig. 2a). More distal facies are interpreted northwest of the Samson Dome where build-ups are scarce. An important aspect revealed by the structural map in Fig. 2a is that the buildups occur away from the Samson Dome, with the most distal of the buildups accommodating its geometry and growing around it. In fact, buildups are only formed in the NE and SE corners of the interpreted seismic volume, with water depths being suggestively larger to the NW (Fig. Z). We interpret the growth of carbonate build-ups away from the Samson Dome as reflecting local structural highs in the Late Paleozoic to the NE and SE, completely distinct from the present-day dome. A combination of salt halokinesis (older salt pillows?) and local tectonics may have formed these structural highs to the NE and SE.

Stage 2 - A major change in geometry is recorded above Horizon 4 with the appearance of isolated (and cool-water) mounds. In Fig. 2b, a two-way time (TWT) structural map of Horizon 3 demonstrates the wide distribution of isolated build-ups in the study area. A maximum thickness of ~739 m was observed to the southeast of the Samson Dome based on velocity (Vp) data from well 7121/1-1 R (Fig. 2b). Importantly, these buildups seem to occur widespread in the study area, and the Samson Dome is not yet revealed as an important structure across which the carbonate build-ups cease to growth (Fig. 2b).

Stage 3 – Polygonal spiculitic build-ups occur again in Late Permian strata in the study area, close to the Permian-Triassic boundary. Figures 2c and 2d show twt structural maps across the Samson Dome area to reveal the presence of polygonal build-ups to the SE of the Samson Dome, which became a prominent feature in the latest Permian.

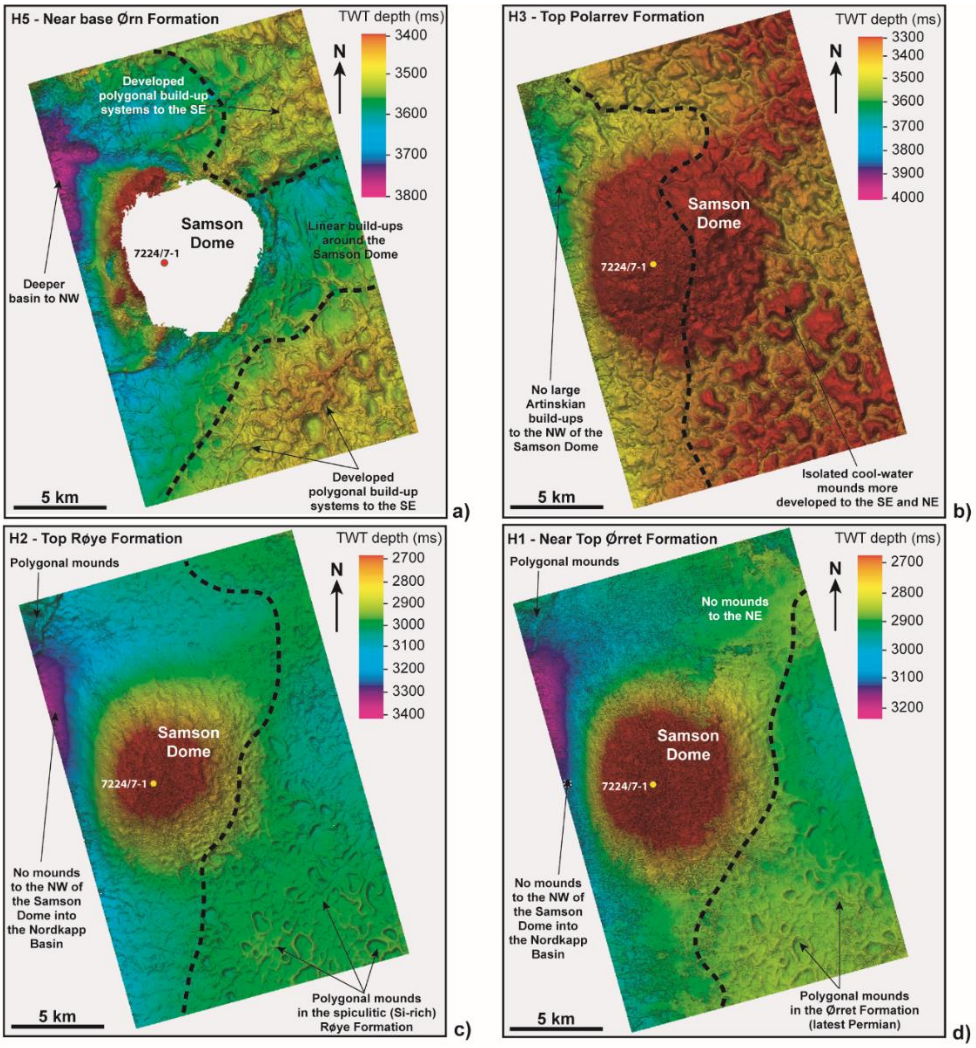

Figure 2 *TWT structural maps showing the geometry of carbonate build-ups and mounds across the Samson Dome area. The outer limits of developed carbonate sequences are highlighted on the maps. (a) Reveals two areas to the NE and SE of the Samson Dome with sets of developed polygonal build-ups at the base of the Ørn Formation, Late Carboniferous. (b) Depicts the broader distribution of isolated (cool-water) mud mounds in the Polarrev Formation (Early Permian). Note the very moderate effect of the Samson Dome on the growth of these cool-water mud mounds. (c) and (d) Polygonal mounds in the Røye and Ørret Formation, showing a predominant Samson Dome.*

Conclusions

The interpreted data favours the comprehensive mapping of carbonate build-ups in the Barents Sea as a method to document paleogeographic and palaeo-depth changes across the Late Paleozoic evolution of this region. We show that the position of carbonate build-ups changed significantly during the Late Paleozoic in the study area, and was likely sustained by important organic productivity into the P–T boundary.

The most plausible explanation to the results shown considers variable halokinesis and late Variscan tectonics, which were both necessary to maintain a relatively shallow sea floor over the Samson Dome. Schlager and Purkis (2015) suggest that the primary cause for the generation of polygonal features on carbonate platforms is a tendency for biotic self-organisation. However, the marked changes in the position and extent of carbonate build-ups and mounds recorded in this work hint at larger scale processes affecting their growth. It is therefore postulated here that changes in the position and morphology of carbonate build-ups and mounds should record 4D changes in the evolution (and growth) of salt domes – and underlying Variscan structures – across the whole of the Barents Sea.

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