Architecture of the evaporite accumulation and salt structures dynamics in Tiddlybanken Basin, southeastern Norwegian Barents Sea

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Funding information
Norges Forskningsråd, Grant/Award Number: 228107; Equinor; Vår Energi; AkerBP; Lundin Norway; OMV; Wintershall DEA

Abstract
An extensive, reprocessed two-dimensional (2D) seismic data set was utilized together with available well data to study the Tiddlybanken Basin in the southeastern Norwegian Barents Sea, which is revealed to be an excellent example of base salt rift structures, evaporite accumulations and evolution of salt structures. Late Devonian–early Carboniferous NE-SW regional extensional stress affected the study area and gave rise to three half-grabens that are separated by a NW-SE to NNW-SSE trending horst and an affiliated interference transfer zone. The arcuate nature of the horst is believed to be the effect of pre-existing Timanian basement grain, whereas the interference zone formed due to the combined effect of a Timanian (basement) lineament and the geometrical arrangement of the opposing master faults. The interference transfer zone acted as a physical barrier, controlling the facies distribution and sedimentary thickness of three-layered evaporitic sequences (LES). During the late Triassic, the northwestern part of a salt wall was developed due to passive diapirism and its evolution was influenced by halite lithology between the three-LES. The central and southeastern parts of the salt wall did not progress beyond the pedestal stage due to lack of halite in the deepest evaporitic sequence. During the Triassic–Jurassic transition, far-field stresses from the Novaya Zemlya fold-and-thrust belt reactivated the pre-salt Carboniferous rift structures. The reactivation led to the development of the Signalhorn Dome, rejuvenated the northwestern part of the salt wall and affected the sedimentation rates in the southeastern broad basin. The salt wall together with the Signalhorn Dome and the Carboniferous pre-salt structures were again reactivated during post-Early Cretaceous, in response to regional compressional stresses. During this main tectonic inversion phase, the northwestern and southeastern parts of the salt wall were rejuvenated; however, salt reactivation was minimized towards the interference transfer zone beneath the centre of the salt wall.

KEYWORDS
Barents Sea, evaporite dynamics, halokinetic sequences, layered evaporitic sequences, pre-salt rift geometries, salt structures, tectonic inversion
INTRODUCTION

The Barents Sea includes several stratigraphic units of Upper Carboniferous to Lower Permian Gipsdal Group layered evaporitic sequences (LES) deposited in relatively shallow water depositional environments and arid climate conditions at a palaeo-latitude of ca. 30° N (e.g. Larsen et al., 2002; Stemmerik, 2000). The Gipsdal Group LES consist of halite rich successions, layered anhydrite and warm water carbonates (Larssen et al., 2002). The thickest section of the LES is found within the deeper basins, that is, the Nordkapp, the Tiddlybanken, the Tromsø, the Sørvestsnaget and the Ottar basins, whereas relatively thin LES are located in the more elevated parts of positive structures like the Haapet, the Veslekar, the Signalhorn, the Samson and the Norvag domes (e.g. Breivik, Gudlaugsson, & Faleide, 1995; Gudlaugsson, Faleide, Johansen, & Breivik, 1998; Mattingsdal, Hoy, Simonstad, & Brekke, 2015; Rojo, Cardozo, Escalona, & Koyi, 2019; Rowan & Lindsø, 2017; Hassaan et al., 2020). The Tiddlybanken Basin is located at the southwestern margin of the Fedynsky High towards the Finnmark Platform (Figure 1). It is a NW-SE trending, elongated basin, which contains an isolated salt wall with associated rim synclines in its centre, whereas an elongated ellipse-shaped and low-relief evaporite-cored anticline, named Signalhorn Dome, encompasses the western and southwestern basin margins (Figure 1) (Gernigon et al., 2018; Mattingsdal et al., 2015; Rowan & Lindsø, 2017; Hassaan et al., 2020). The study area is covered by a high-quality, extensive seismic 2D data set, and has attracted recent hydrocarbon exploration interest (Figure 1; Table 1a-b). In 2019, two exploration wells 7132/2-1 and 7132/2-2 have been drilled over the Signalhorn Dome with no hydrocarbon discovery (Figure 1).

Several studies have highlighted both the distribution of the lithostratigraphic units and age relations in the context of basin development (prekinematic, syn-kinematic and post-kinematic) and the relation between the sediment accumulation and salt rise rates (Giles & Rowan, 2012; Jackson & Hudec, 2017; Jackson & Talbot, 1991 and references therein). Similarly, the base salt relief generated by inherited rift geometries are believed to influence the salt tectonics, and deformation of its overburden (Dooley, Hudec, Pichel, & Jackson, 2018; Pichel, Finch, & Gawthorpe, 2019; Pichel, Finch, Huuse, & Redfern, 2017 and references therein). The influence of the pre-salt basin architecture on the primary distribution of LES and the along-strike effects on the evolution of the salt structure are still poorly understood (Ge, Gawthorpe, Rotevatn, & Thomas, 2017 and references therein), especially because the timing of salt movements influences key time-stages both of the petroleum system and of the potential hydrocarbon traps. Through seismic and structural interpretations, the Tiddlybanken Basin is utilized to investigate the control of pre-salt geometries on the facies distribution within the LES and the effect of the LES facies change on the passive diapirism along-strike of the salt wall. Furthermore, the study aims to highlight the link between salt wall rejuvenation and pre-salt structures; and to elucidate the along-strike transition between passive diapirism to the salt wall rejuvenation effects on the presence or absence of composite halokinetic sequences (CHS).

GEOLOGICAL SETTING

A great vicinity of the study area has been influenced by the NW-SE trending Timanian Orogeny structural fabric of late Neoproterozoic age (e.g. Barrère, Ebbing, & Gernigon, 2009; Barrère, Ebbing, & Gernigon, 2011; Faleide et al., 2018; Gabrielsen, 1984), and by the dominantly NE-SW trending Caledonian Orogeny basement grain (Silurian–Devonian) that becomes NNW-SSE northwards (Gernigon & Brönner, 2012; Gernigon et al., 2014). It has been recently shown that during the late Devonian, the southeastern Norwegian Barents Sea comprised of a central structural high (Fedynsky High), and two depressions to the north and south, that could be related to a prerift stage of crustal thinning and directly linked to the
structural grain of the deep-seated NW-SE trending Timanides (Hassaan et al., 2020). The Fedynsky High and the two depressions were influenced by transtension during late Devonian–early Carboniferous NE-SW regional extension (Hassaan et al., 2020). This event created NW-SE striking graben structures at the time when the Billefjorden Group (Soldogg, Tettegras and Blærerot formations; Figure 2) was deposited, and also affected the Pechora Basin, eastern Barents Sea and the Olga-Sørkapp region (Klitzke et al., 2019; Stoupakova et al., 2011). During the late Carboniferous to early Permian, evaporites were deposited into the Carboniferous basins and carbonates were deposited (Gipsdalen Group including the Falk and Ørn formations; Figure 2) on the structural highs in a warm, semi-arid to arid climate in the central and western Barents

| TABLE 1 | (a) Utilized seismic reflection data set, (b) calculated vertical seismic resolution for the reprocessed BSSE14RE survey |
|----------|----------------------------------------------------------------------------------------------------------------|
| **Survey** | **Year** | **Company/Authority** | **Record time (twt, s)** |
| BSSE14-RE | 2014 | NPD/TGS | 9 |
| NBR-12 | 2012 | TGS | 10 |
| BARE-02 | 2002 | NPD/TGS | 6 |
| **Zone** | **Frequency (Hz)** | **Velocity (m/s)** | **Wavelength (m)** | **Vertical resolution (m)** |
| Shallow | Cretaceous to Jurassic | 50 | 2,335 | 47 | 12 |
| Intermediate | Triassic | 30 | 4,000 | 133 | 33 |
| Deep | Permian to Pennsylvanian | 15 | 6,280 | 419 | 105 |
| | Mississippian | 20 | 6,280 | 314 | 79 |
| | | 15 | 4,960 | 331 | 83 |
| | | 20 | 4,960 | 248 | 62 |

**FIGURE 2** Stratigraphic framework and key seismic horizons interpreted throughout the study area based on wells 7229/11-1 and 7130/4-1. Regional stratigraphy and depositional environment scheme is based on Larssen et al. (2005) modified after Gernigon et al. (2018) and Rojo et al. (2019), and geologic timescale after IUGS (2018). GP: (stratigraphic) group. The seismic-stratigraphic framework is also tied with the earlier chrono-stratigraphic schemes for Triassic successions by Glørstad-Clark et al. (2010) and Klausen et al. (2015)
Sea (Gudlaugsson et al., 1998; Larsen et al., 2002). The Carboniferous graben system controls the facies and thickness of the evaporites in the southeastern Norwegian Barents Sea and the evaporite facies consist of mobile (i.e. halite) and non-mobile lithologies (i.e. anhydrite) (Rojo et al., 2019; Rowan & Lindsø, 2017; Hassaan et al., 2020). The depositional environment shifted and allowed the deposition of cool-water carbonate platforms (Bjarmeland Group including the Isbjørn and Palarrev formations; Figure 2) at the primary basin margins due to the northwest drift of the southern Barents Sea at approximately 45°N (Beauchamp, 1994; Stemmerik, 2000). During the middle to late Permian, the sediments (Tempelfjorden Group including the Roye and Ørret formations; Figure 2) were deposited under regional subsidence conditions over the carbonates (Worsley, 2008).

The thick Triassic sediments (Havert, Klappmøs, Kobbe and Snadd formations; Figure 2) derived from the southeast Urals covered the Barents Sea during regional subsidence (Glørstad-Clark, Faleide, Lundschen, & Nysetuen, 2010; Klausen, Ryseth, Helland-Hansen, Gawthorpe, & Lauge, 2016). The Triassic–Jurassic transition, the structural elements in the southeastern Norwegian Barents Sea were probably affected by the westward propagating compressional stress from the evolving Novaya Zemlja fold-and-thrust belt (Indrevær, Gac, Gabrielsen, & Faleide, 2018; Line, Müller, Klausen, Jahren, & Hellevang, 2020; Müller et al., 2019). Minor reactivation during the Middle Jurassic and earliest Cretaceous have also been reported; however, all structural elements were buried beneath the prograding Lower Cretaceous shelf-platform complex (Knurr, Klipfabsk, Kolje, and Kolnabe formations; Figure 2) during a tectonically quiescent period in the southeastern Norwegian Barents Sea (Midtkandal et al., 2020; Hassaan et al., 2020). During the early Cenozoic, the western Barents Sea margin was shaped by the multiphase Eurekan/Spitsbergen orogenic deformation (Leever, Gabrielsen, Faleide, & Braathen, 2011; Piepjohn, Gosen, & Tessensohn, 2016). Similarly, far-field compressional stress from this orogeny affected the southeastern Norwegian Barents Sea and reactivated the deep-seated Carboniferous structures (Hassaan et al., 2020). During the Neogene, the entire Barents Shelf experienced uplift and erosion related to Plio–Pleistocene glaciations (Baig, Faleide, Jahren, & Mondol, 2016; Green & Duddy, 2010; Henriksen et al., 2011; Tsikalas, Faleide, Eldholm, & Blaich, 2012). Preglacial uplift is also considered to have affected the region (Dimakis, Braathen, Faleide, Elverhøi, & Gudlaugsson, 1998; Lasabuda, Laberg, Knutsen, & Safonova, 2018; Zattin, Andreucci, Toffoli, Grigo, & Tsikalas, 2016).

3 | DATA AND METHODS

The seismic database comprises of conventional 2D multichannel seismic (MCS) reflection profiles covering an area of ca. 6,600 km² with total line length of ca. 2,900 km along the entire Tiddlybanken Basin and Signalhorn Dome (Figure 1; Table 1a-b). The seismic reflection profiles are part of the regional surveys BSSE14RE and NBR12 with an average line spacing of 4 km and 6 km, respectively. Two deep exploration wells 7130/4-1 (deepest penetrated strata within the Billefjorden Group of Mississippian age) and 7229/11-1 (deepest penetrated strata within the Gipsalen Group of Pennsylvanian to early Permian age) are located on the eastern Finnmark Platform and have been utilized along with shallow stratigraphic boreholes that penetrate uplifted, originally deep-stratigraphy (Bugge et al., 1995) on the southern part of the east Finnmark Platform (Figures 1 and 2). The well data were used to establish detailed well-to-seismic ties (Figure 2), a seismo-stratigraphic framework for the study area, and time-to-depth conversions. Formation tops from wells 7130/4-1 and 7229/11-1 were used for the subdivision of the Upper Paleozoic to Cretaceous successions. Ten seismic sequences bounded by 11 seismic horizons were identified and mapped (Figure 2). The seismic sections that were used for the detailed analysis of structural and stratigraphic configurations were chosen because they cut across the Tiddlybanken Basin and the Signalhorn Dome, and are part of the reprocessed BSSE14RE seismic survey that exhibits very good seismic resolution as discussed below (Table 1b). The survey was acquired in 2012 and reprocessed in 2014 by TGS utilizing a processing sequence that included among other: bandwidth enhancement, multiple elimination using linear transforms, Tau-p deconvolution, premigration conditioning, Kirchhoff prestack time migration, anisotropy analysis and radon de-multiple. Reprocessing has increased considerably the quality of seismic imaging, especially of the evaporite sequence and the deep pre-salt structural configurations. It is the first time the BSSE14RE data set becomes available to academia. Time-thickness maps were generated to study the lateral and vertical configuration of the stratigraphic units, the tectonostratigraphic evolution, the salt evacuation from different part of the pre-Permian basin over the geological time, and the sedimentary thickness relationships with the pre-salt rift geometries.

The seismic horizons that subdivided the Triassic succession were tied to earlier well-established chrono-stratigraphic schemes for this period (e.g. Glørstad-Clark et al., 2010; Klausen et al., 2015) in order to analyse the impact of the regional Barents Sea sediment routing of the Triassic succession into the study area. The further subdivision of the evaporites and pre-salt rift strata is based on the seismic facies analysis (Table 2). We do not have any direct lithological evidence of these evaporites and the pre-salt sedimentary strata as no deep frontier exploration wells have been drilled. Recently, two exploration wells 7132/2-1 (deepest penetrated succession of late Triassic) and 7132/2-2 (deepest penetrated succession of late Permian) have been drilled over the Signalhorn Dome (Figure 1) but data from these wells are not publicly available.
4 | RESULTS

4.1 | Pre-salt Carboniferous rift architecture

The large-scale base Carboniferous graben system south of the Fedynsky High and beneath the Tiddlybanken Basin and Signalhorn Dome is the key target of the present investigation (Figure 1c). It exhibits a full-graben system bounded by NW–SE-striking, normal master faults that dip towards the centre of the Tiddlybanken Basin (Rowan & Lindsø, 2017; Hassaan et al., 2020) and was mapped regionally, following a relatively flat platform south of the Fedynsky High. However, the architecture of the Carboniferous graben system as seen beneath the thick layer of evaporite covering the Tiddlybanken Basin and Signalhorn Dome is more complex (Figures 3–6). The observed full-graben geometry is due to the effect of several evolution phases, that is, post-rift evaporite deposition, supra-salt sedimentation and complex diapirism stages. The current study maps in detail the structural architecture

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**TABLE 2** Interpreted seismic facies (SF)

| Seismic facies (SF) | Description |
|---------------------|-------------|
| SF1                 | Horizontal to inclined, semi-continuous, subparallel to diverging and medium to high amplitude seismic reflections, characterized as clastic infill of the Billefjorden Group of Mississippian age (Figure 2) in the half-grabens GU1-3 and on the platform or hinged margins. The reflections become chaotic beneath the salt wall and show velocity pull-up effect. |
| SF2                 | Featureless and chaotic seismic reflections delimited at top and base by high amplitude and continuous reflections that laterally converge and pinch out, characterized as mobile halite lithology of the Gipsdalen Group of Pennsylvanian to early Permian age (Figure 2). |
| SF3                 | Semi-continuous, parallel to subparallel and medium amplitude seismic reflections interpreted as inter-bedded, mixed non-halite and non-mobile lithologies, that is, anhydrite, gypsum of the Gipsdalen Group of Pennsylvanian to early Permian age. These seismic facies are mainly found at the hinged margin of the GU3 graben and are difficult to separate into evaporite layers L1 and L2. |
| SF4                 | Semi-continuous to continuous, parallel to subparallel and medium to strong amplitude seismic reflections interpreted as inter-bedded, mixed non-halite and non-mobile lithologies, that is, anhydrite, gypsum of the Gipsdalen Group of Pennsylvanian to early Permian age. |
beneath the Pennsylvanian to Permian evaporites that is further subdivided into three half-graben units (GU) that are described below.

The northwestern part of the Tiddlybanken Basin and the rimmed Signalhorn Dome comprise of two half-graben units at the base Carboniferous level (BCa?), named GU1 and GU2, that are separated by a NW–SE trending horst (H) (Figures 3 and 4). The strike of the horst changes from NW-SE to NNW-SSE around the western margin of the Tiddlybanken Basin and has an arcuate geometry (Figure 4). The master faults M1 and M2 of the two half-grabens GU1 and GU2 that bound the horst are thick-skinned structures, penetrating into presumed prerift rocks and basement. The southwestern boundary of the horst (H) structure is defined by master fault M1. The M1 is the top-southwest extensional fault that defines the half-graben GU1 along the hinged margin towards the southwestern Finnmark Platform (Figures 3 and 4). The magnitude of vertical separation of fault M1 reaches its maximum (ca. 700 ms) near its centre (Figure 3b), decreasing towards its tips at a regular rate. The northeastern boundary of the main horst (H) is defined by master fault M2. The M2 is a top-northeast extensional fault (throw: ca. 950 ms) that bounds the GU2 half-graben with the hinged margin towards the northeastern part of the Finnmark Platform (Figures 3 and 4). Seismic reflections of

**FIGURE 3** (a–e) Interpreted seismic sections, illustrating pre-evaporite geometries, layered evaporitic sequences (LES), along-strike salt wall variations and supra-salt sedimentation patterns in the northwestern part of the Tiddlybanken Basin and southeastern part of the Signalhorn Dome. GU: half-graben, H: horst, M: master fault, CHS: composite halokinetic sequence. Stacked layered evaporitic sequences (LES) are subdivided into layers L1 (deepest), L2 (middle) and L3 (shallowest); colours correspond to interpreted sequences (Figure 2). Open white circles connected by white lines display the thickness variations. Seismic data courtesy of NPD and TGS.
the sedimentary strata dip towards M2, defining a sedimentary wedge (e.g. Morley, Nelson, Patton, & Munn, 1990). The faults defining the northeastern hinged margin of the GU2 half-graben display curved traces, merging with the GU1 half-graben at the northwestern border of the Tiddlybanken Basin (Figure 4). The master fault M3 strikes NW-SE, with a top-southwest extension, and forms the GU3 half-graben with hinged margin towards the southwestern Finnmark Platform (Figures 4–6). The master fault M3 (throw: ca. 1,300 ms) separates the GU3 half-graben from the southern platform on the western part of the Fedynsky High within the southeastern Norwegian Barents Sea. The depression of the GU3 half-graben deepens (ca. 1,550 ms) and widens (ca. 20 km) towards the northeast against the M3 master fault (Figure 6). The southeastern margin of the GU3 half-graben is relatively flat and shows only minor normal faults, which contrasts with the northwestern margin of the GU1 half-graben (Figures 3a,b and 6e).

Internally, the half-grabens GU1-GU3 include numerous intrabasinal synthetic and antithetic normal faults. These strike parallel to the master faults M1-M3 and constrain several intrabasinal fault-blocks tilted towards the faults and with overall wedge-shaped depositional configuration that demonstrates syn-rift deposition (e.g. Morley et al., 1990) (Figures 3–6). However, it is difficult to illustrate the wedge-shaped geometry of syn-rift sedimentary strata beneath the thick salt wall (Figures 3c–e and 6a,b). The observed seismic facies are composed of horizontal to inclined, semi-continuous, subparallel to diverging and medium to high amplitude seismic reflections (Figures 3, 5 and 6; Table 2). Based on the correlation extrapolated from wells on the Finnmark Platform, SF1 is characterized as clastic infill of the Billefjorden Group of Mississippian age in the half-grabens GU1-3, on the platform and hinged margins (Larsen et al., 2002; Hassaan et al., 2020) (Figures 3, 5 and 6; Table 2).
4.2 Evaporite distribution and related features

The accumulated LES within the Carboniferous grabens beneath the Tiddlybanken Basin and the Signalhorn Dome are characterized by a number of seismic facies (Table 2). We subdivided the LES into three distinct evaporite layers, namely the deepest (L1), the middle (L2) and the shallowest (L3). The central salt wall within the Tiddlybanken Basin is stretching across the half-grabens GU2 and GU3, and shows variable along-strike morphology (Figures 3, 5 and 6). The stacked layered evaporitic sequences (LES) are subdivided into layers L1 (deepest), L2 (middle) and L3 (shallowest); colours correspond to interpreted sequences (Figure 2). Open white circles connected by white lines display the thickness variations. Seismic data courtesy of NPD and TGS.

4.2.1 Layered evaporitic sequences

The seismic facies of the L1 show chaotic seismic reflections delimited at top and base by high amplitude and continuous reflections that laterally converge and pinch out (SF2) (Figure 3b; Table 2). The seismic facies are characterized as mobile halite lithology that formed pillow structures beneath the northwestern part of the Tiddlybanken Basin and Signalhorn Dome (Figure 3). This halite-rich and chaotic
part of L1 follows the borders of the GU1 and GU2 half-grabens in the northwestern part of the Tiddlybanken Basin and Signalhorn Dome (Figures 3 and 4). Presently, the L1 shows weld geometry (e.g. Jackson & Hudec, 2017) between pre-salt Carboniferous structures and the L2 below the southwestern rim syncline of the Tiddlybanken Basin (Figure 3). However, part of L1 is supporting the pillow-shaped structure following the southwestern weld in the northwestern part, along the central axis of the Tiddlybanken Basin outside the salt wall (Figure 3b). The L1 also seems to source the main salt wall and is thinning towards the centre of the salt wall (Figures 3c–e and 5). In the central and southeastern parts of the Tiddlybanken Basin, it is difficult to differentiate between the L1 and L2 layers because both layers show similar seismic facies character (SF3) (Figure 5c; Table 2). Nevertheless, the seismic facies of the L1 change into semi-continuous, parallel to subparallel seismic reflections with medium amplitude (SF3), suggesting non-halite lithology (i.e. anhydrite) in the central and southeastern parts of the Tiddlybanken Basin (Figure 6; Table 2).

The seismic facies units of the L2 are composed of semi-continuous to continuous, parallel to subparallel and medium to strong amplitude seismic reflections (SF4), indicating non-halite lithology (i.e. anhydrite) at the basin margins (Figure 3b; Table 2). The seismic facies units develop into a pattern dominated by lens-shapes defined by chaotic seismic reflections (SF2; halite lithology) at the centre of the basin, thus supporting an interpretation as a pillow structure (Figure 3b; Table 2). Importantly, the L2 thickens abruptly at the northeastern edge of the pillow structure sensu Jackson and Hudec (2017), formed by L1 beneath the Signalhorn Dome, and sourced the central salt wall (Figure 3b). The central halite part of L2 connects with the salt wall, but seismic data resolution does not allow the differentiation between L1 and L2 within the salt wall. The L2 thins to the centre of the basin (Figure 5) and thickens towards the southeastern part of Tiddlybanken Basin (Figure 6).

The L3 consists of two lens-shaped seismic packages near the basin margins (SF2), which we interpret as pillow structures sensu Jackson and Hudec (2017), connected to the central salt wall in the entire Tiddlybanken Basin (Figures 3, 5 and 6; Table 2). The seismic facies of L3 are composed of high-amplitude reflections with a chaotic internal pattern (SF2, halite lithology) (Table 2). The L3 is thinner along the basin edges where pillow structures pinch out beneath rim synclines, and is thicker towards the salt wall near the centre of the basin. The largest pillow (length: 58 km, width: 12 km) is located on the southwestern margin of the Tiddlybanken Basin beneath the Signalhorn Dome (Figure 3).

4.2.2 Central salt wall

The Tiddlybanken Basin comprises of an isolated, ca. 39 km-long, central salt wall along its axis with associated pronounced rim synclines (Figure 1c). In the northwestern part of the basin, a central pillow-like structure that connects with the salt wall occurs and illustrates that LES (L1, L2 and L3) amalgamate into the salt wall (Figure 3b,c). The base of the salt wall shows a triangular pedestal geometry sensu Jackson and Hudec (2017), which widens downwards to a width of ca. 15 km and connects with the source of all layered evaporites L1-L3 (Figure 3d). The basal salt pedestal develops into a narrow stem of ca. 3.2 km to the northwest, where it is connected to a ca. 6.6 km wide bulb-shaped overhang (Figure 3d). This hourglass-shaped bulb geometry becomes smoother and slimmer towards the northwest and southeast of the salt wall. The northwestern part of the salt wall subcrops at the seafloor (Figure 3c–e).

In the central part, the salt wall is reduced to ca. 1.8 km of width, subcrops at the seafloor, and tilts towards the southwest at the transition between the central and northwestern part of the salt wall (Figures 3e and 5a). The base of the salt pedestal is ca. 16.5 km in the southeast and the upper part becomes narrowest with a width of ca. 1.2 km (Figure 5b). The top of the salt wall shows ca. 1.6 km wide smoother bulb-shaped geometry that is covered by Upper Triassic strata (Figure 5b). In the central part of the salt wall, the contribution of halite from L1 was minimal and the salt wall was mainly sourced from L2 and L3 (Figure 5). The southeastern part of the salt wall that evolved above the GU3 half-graben obtains the widest base of the salt pedestal ranging ca. 17.6–18.8 km (Figure 6). The salt wall stem and bulb are also the widest ranging ca. 3.5–5.3 km and ca. 4.1–6.4 km respectively (Figure 6a,b). However in the southeast, the salt wall that is mainly composed of halite sourced from L2 and L3 is laterally equivalent to a salt pillow outside the salt wall (Figure 6c). The salt wall base is 2.5 km wider in the southeastern part than the northwestern part of the basin (Figures 3 and 6).

4.2.3 Signalhorn Dome: evaporite cored anticline

The Signalhorn Dome is located along the western and southwestern margins of the Tiddlybanken Basin and is a NW–SE trending, ca. 58 km-long, ellipsoid-shaped and low relief evaporite cored anticline (Figure 1c). The Signalhorn Dome formed above two stacked salt pillows composed of halite lithology from L1 and L3 that are separated by non-mobile evaporites from L2 (Figure 3). The base of the southwestern upper pillow is related to L3 and displays an arch-shaped geometry above the lower pillow structure made up with halite from L1, the GU1 half-graben and horst (H) (Figure 3d). The base of the southwestern upper pillow becomes flat over the hinged margin of the GU3 half-graben (Figures 5 and 6).

The thickness of the mobile halite in sequence L1 decreases within the southwestern lower pillow and transitions into non-mobile mixed sedimentary facies, that is, anhydrite,
FIGURE 7  Time-thickness maps of the seismic sequences displaying major depocentres along the salt wall inside the Tiddlybanken Basin. Note the shift of the thickest depocentres during the evolution signifying the salt evacuation from different parts of the basin.
towards the southeast along the margin of the Tiddlybanken Basin (Figures 3, 5 and 6). However, it is difficult to comprehend that the L2 is thickening towards the southeast or few layered sequences from L1 are also mixed (SF3) (Figure 5c; Table 2). The thickness of L2 abruptly changes towards the salt wall at the northeastern edge of the lower pillow that comprises of L1 (Figure 3b,c). The thickness of the L3 that forms the upper pillow is almost uniform and occasionally depressed by the overburden carbonate platforms of the Bjarmelend Group (Figures 3e and 5a).

4.3 Supra-salt sedimentation and halokinesis

In this section, we describe the growth history of the central salt wall and the Signalhorn Dome with the help of geometric relationships (i.e. thickness, contact, age) between the suprasalt strata and the salt structures, rim synclines variation and CHS. Supra-salt sedimentation was initiated during the transition from warm and arid to temperate conditions due to the northward drift of the Baltic plate in the early Permian (Larsen et al., 2002; Stemmerik, 2000). At that time, coldwater carbonates of the Bjarmelend and Tempelfjorden groups were deposited (Figure 2) (Larsen et al., 2002; Stemmerik, 2000). In places, the L1 was compressed by the developed carbonate platforms of the Bjarmelend and Tempelfjorden groups at the margins of the basin (Figures 3e, 5c and 6a). However, these sedimentary units show concordant contact and prekinematic age relationship (sensu Jackson & Talbot 1991; Jackson & Hudec, 2017) with the LES. Lower Triassic strata (sequences S1 and S2; Induan) display sedimentary thickening near the salt wall (Figures 3e, 5a, 6c and 7a,b). The thick combined sequences S1 and S2 of the Havert Formation are upturned at the basal salt pedestal and slightly thin upward along the wall flanks (Figures 3c–e, 5 and 6a,c). The upturned flanks were eroded (Rowan & Lindstro, 2017), giving rise to an angular unconformity between sequence S2 (upper Havert Formation) and sequence S3 (Snadd Formation) at the flank below the northwestern overhang of the salt wall (Figure 3d). In the central and southeastern parts of the salt wall, sequence S2 (Havert Formation; Induan) subcrops at the seafloor (Figures 5c and 6a).

The overall deposition of Lower Triassic (Olenekian) to Middle Jurassic sedimentary rocks in the basin rim synclines varies along-strike of the salt wall (Figure 7). Sequence S3 (Klappmyss Formation; Olenekian) displays syn-kinematic relation and discordant contact as its strata on lap sequence S2 and thin towards the flanks of the salt wall, exhibiting wedge-shaped geometry (Figures 3b–e, 5 and 6a,b). In the northwestern part of the salt wall, the lateral distance between sequence S3 and the base of the salt wall overhang is ca. 3.3 km at a depth of ca. 1775 ms two-way travel time (twt), and sedimentary strata abruptly pinch out (Figure 3d). In several places, the strata of sequence S3 reach the salt wall, exhibiting variable along-strike geometries (Figure 3e). In particular, in the central and southeastern rim synclines the strata of sequence S3 are more upturned and reach shallow depths of ca. 600–1000 ms twt (Figures 5c and 6a). During the Olenekian, sequence S3 shows maximum thinning at the northwestern edge of the salt wall (Figure 7c). The thickest sequence (defining the depocentre) was formed in the northwestern part of the basin that reached to a thickness of ca. 400 ms twt (Figure 7c). Furthermore, several other depocentres exhibiting thicknesses of ca. 200–300 ms twt were also formed along the central part of the salt wall (Figure 7c). Sequence 5 (Snadd Formation) is unconformably deposited above sequence S3 within the rim synclines along the flanks of the salt wall (Figures 3c–e, 5, 6a,b and 7c).

Sequence 4 (Kobbe Formation; Anisian) displays discordant contact with sequence S3 (Klappmyss Formation; Olenekian), thinning towards the flanks with wedge-shaped geometry and syn-kinematic relation (Figures 3c–e, 5 and 6a,b). The upturned strata separate the pinch-out of sequence S4 and the base of the northwestern overhang. The lateral distance between the sequence S4 pinch out and the northwestern overhang is ca. 3.9 km at a depth of ca. 1900 ms twt (Figure 3d). In the central and southeastern rim synclines, sequence S4 is more upturned and reaches shallow depths of ca. 900–1500 mst wt (Figures 5 and 6a). During the Anisian, main depocentres were developed that exhibit thickness of ca. 570–485 ms twt along the central part of the salt wall in the rim synclines (Figure 7d). The second largest depocentre with thickness of ca. 370 ms twt is located along the northwestern part of the salt wall. However, in the southeastern rim synclines, sequence S4 is relatively thinner than in the rest of the basin, reaching thickness of ca. 230 ms twt (Figure 7d). Finally, sequence S5 (Snadd Formation; middle to late Triassic) unconformably overlies the upturned sequence S4 within the rim synclines on the flanks of the salt wall (Figure 3d).

The base of sequence S5 (Snadd Formation) is unconformably overlaying all of the underlying strata, defining a Middle Triassic unconformity (MTu) (Rowan & Lindstro, 2017). The strata of sequence S5 onlap the northwestern overhang of the salt wall where they display syn-kinematic character (Jackson & Hudec, 2017) and develop CHS (sensu Giles & Rowan, 2012) (Figures 3c–e, 8a,b and 9). In the central and southeastern parts of the Tiddlybanken Basin, the MTu is also present, although sequence S5 thins and subcrops at the seafloor (Figures 5c, 6a, 8c,d and 9). The main depocentres are located along the northwestern and central parts of the salt wall with maximum thickness of ca. 300 ms twt and ca. 270 ms twt, respectively, whereas sequence S5 gradually thins towards the southeast (Figure 7e). A minimum
thickness of ca. 40 ms twt is observed along the southeastern edge of the salt wall (Figure 7e).

The strata of sequence S6 (Upper Triassic-Lower/Middle Jurassic) onlap the northwestern overhang of the salt wall and form thick, tabular CHS (ca. 850 ms) that, in turn, indicate a syn-kinematic episode (e.g. Giles & Lawton, 2002; Giles & Rowan, 2012) (Figures 4c–e, 8a and 9). This sequence is truncated over the southwestern margin of the Tiddlybanken Basin where the Signalhorn Dome is located (Hassaan et al., 2020) (Figures 3c and 7f). Furthermore, the Upper Triassic–Lower/Middle Jurassic strata gradually thin towards southeast and subcrop at seafloor (Figures 5 and 6a–c). In the southeastern

**FIGURE 8** (a–d) Interpreted seismic sections illustrating the presence and absence of the composite halokinetic sequences along the salt wall in different parts of the Tiddlybanken Basin. Location of the seismic sections is given in Figure 9. (e) End-members of halokinetic sequences (HS): hooks and wedges. (f) End-members of composite halokinetic sequences (CHS): tabular and tapered (modified from Giles & Rowan, 2012), where R and A represents relative rates of salt rise and sediment accumulation respectively.
and central rim synclines, the strata are subdivided into two units that are separated by the salt wall. The lower sedimentary unit (U1) is thickening towards the centre of the rim synclines and is thinning towards the salt wall, whereas the upper unit (U2) shows opposite patterns (Figure 5c). The main depocentre, reaching thickness of ca. 700 ms twt, is located along the northwestern overhang of the salt wall and laterally minimizes towards the southeast (Figure 7f).

The Upper Jurassic strata thin towards the salt wall and over the southwestern edge of the basin (Figures 3c and 7g), whereas lowermost Cretaceous strata onlap the underlying Upper Jurassic strata (Hassaan et al., 2020) (Figure 3c). The younger Lower Cretaceous strata are concave upwards along the salt wall flanks and subcrop at seafloor (Figures 3c–e, 5 and 6a,b). On the southwestern margin, Lower Cretaceous strata are eroded over the crest of the Signalhorn Dome (Figure 7h). The thickest depocentre with thickness of ca. 1,000 ms twt is showing a fan-shaped geometry in map view and is located on the northeastern rim syncline along the entire salt wall (Figure 7h).

5 | DISCUSSION

In the context of the first-order controls on the structural development of the pre-salt geometries, we address the impact of the initial rift architecture on the facies variations within the LES in the following sections. The dependency of the passive diapirism on the facies variations within the LES is generally not well constrained. We also discuss the halite feeding system from multiple LES layers during passive diapirism and the connection between the pre-salt geometries reactivation and salt wall rejuvenation. The effect of the transition between the passive diapirism and salt wall rejuvenation along the strike of the wall on the CHS is also discussed.

5.1 | Carboniferous graben architecture

The late Devonian southern and northern depressions around the Fedynsky High were likely directly linked to the NW-SE trending Timanian structural grain in the southeastern Norwegian Barents Sea (Hassaan et al., 2020). The late Devonian to early Carboniferous NE-SW oriented extensional regional stress regime along with pre-existing Timanian structures transformed the initial broad southern depression into two grabens within the area of the later Tiddlybanken Basin, Signalhorn Dome and Finnmark Platform (Hassaan et al., 2020). Our detailed analysis shows that the earlier suggested (Hassaan et al., 2020) simple full-graben geometry beneath the Tiddlybanken Basin and Signalhorn Dome is more complex and can be further
(a) Synrift-1

(b) Synrift-2

(c) Synrift-3

M Master fault
H Horst
GU Graben unit
TZ Transfer zone

Regional stress direction
- Yellow: Sediment in all grabens during synrift-3 stage
- Pink: Sediment in graben unit-1 (GU1) associated to localized subsidence
- Green: Sediment in graben unit-2 (GU2) associated to localized subsidence
- Blue: Sediment in graben unit-3 (GU3) associated to localized subsidence
- Brown: Pre-rift
subdivided into multiple graben units, that is, the half-grabens GU1, GU2 and GU3 (Figures 9 and 10). The NW-SE to NNW-SSE trending horst (H) along the southwestern and western margins of the Tiddlybanken Basin that separates the GU1 and GU2 half-grabens is subtle and exhibits an arcuate geometry. This is believed to be the effect of the pre-existing Timanian structural grain because the horst (H) follows a strike as the Timanian basement lineament and it is bounded by thick-skinned basement-involved faults, although its curved nature signifies the inheritance origin (Figure 4). We have constructed a detailed tectono-stratigraphic evolution model that is subdivided into three distinct syn-rift (1–3, late Devonian–early Carboniferous) stages (Figure 10) and three post-rift (1–3, Pennsylvanian–early Permian) stages (Figure 11) following widely accepted rift evolution models (Gawthorpe & Hurst, 1993; Gawthorpe & Leeder, 2000; Morley et al., 1990; Rosendahl et al., 1986).

During the syn-rift-1 stage, sedimentary deposition was restricted and localized along the isolated sub-basins in the hanging-walls of the dense, small-displacement and basement involved thick-skinned normal fault segments (Gawthorpe & Leeder, 2000) (Figure 10a). In the syn-rift-2 stage, the continuous exertion of the stress regime led to the linkage of the isolated fault segments and influenced the enlargement and coalescence of the early fault depocentres (Fossen & Rotevatn, 2016; Fossen, Schultz, Rundhovde, Rotevatn, & Buckley, 2010; Gawthorpe & Hurst, 1993; Gawthorpe & Leeder, 2000; Morley et al., 1990) (Figure 10b). However, the syn-depositional sedimentation was still restricted to the isolated GU1, GU2 and GU3 half-grabens. The master faults M2 and M3 show stepping geometries and opposite dip directions that caused the faulted and hinged margins to be located side by side (Figures 4 and 10b). Furthermore, the fault tips of master faults M2 and M3 have propagated laterally towards each other and formed the arcuate elevated ridge at the centre of the Tiddlybanken Basin, beneath the salt wall that compartmentalized the GU2 and GU3 half-grabens (Figures 4 and 5). This zone is similar to the ‘conjugate convergent overlapping transfer zone’ (sensu Morley et al., 1990), also called ‘antithetic interference transfer zone’ by Gawthorpe and Hurst (1993) (Figures 4 and 10b).

In contrast to the major tilted fault-blocks that mostly parallel the basin margin master faults, accommodation zones typically formed broad zones of relative high-relief or topography (Burgess et al., 1988; Faulds & Varga, 1998; Gawthorpe & Hurst, 1993; McClay, Dooley, Whitehouse, & Mills, 2002; Morley et al., 1990; Rosendahl et al., 1986; Younes & McClay, 2002). The vertical separation associated with the GU2 and GU3 half-grabens tends to decrease towards the interference transfer zone. The transfer zone separating the GU2 and GU3 half-grabens was bordered by segmented normal faults with minor throws that were dipping towards the centre of the greater Tiddlybanken Basin. These geometries with overlapping/interference transfer zone in salt-free rifts, are common that is, in the northern part of Lake Tanganyika, East African Rift and the Gulf of Evvia (Burgess et al., 1988; Gawthorpe & Hurst, 1993; Morley et al., 1990; Rosendahl et al., 1986; Specht & Rosendahl, 1989; Versfelt & Rosendahl, 1989).

We suggest that this arcuate transfer zone beneath the salt wall in the centre of Tiddlybanken Basin is the combined effect of a pre-existing Timanian lineament and the opposing geometrical arrangement of master faults M2 and M3 (Figure 10c) because extension along the thick-skinned master faults played an important role on the formation of the rift architecture. Furthermore, such zones commonly cross the rift axis and are frequently seen to be associated with high fault density from adjacent half-grabens or rift segments and low fault displacement (Ebinger, Rosendahl, & Reynolds, 1987; Morley et al., 1990; Withjack et al., 2002) (Figure 10b,c). However, the depth-related, decreasing quality of the seismic data makes it difficult to constrain the structural overlap, the propagation of master faults M2 and M3, the directional throw of the deep faults and the connection of normal faults with the GU2 and GU3 half-grabens in the centre of the Tiddlybanken Basin.

During rift climax (syn-rift-3) (Figure 10c), the topographically elevated interference transfer zone served as a barrier to sediment spill over, in contrast to subsided GU2 and GU3 half-grabens. At this stage, sediments belonging to the spill-over facies were more evenly distributed in the GU1, GU2 and GU3 half-grabens but the units deposited on top of the transfer zone were thinner than those in the basins (e.g. Rosendahl et al., 1986) (Figure 10c). During multiple reactivation phases (i.e. Triassic–Jurassic transition and early–middle Eocene), the Carboniferous half-graben configuration separated by a NW-SE to NNW-SSE trending horst (H) and the transfer zone was responding selectively to the propagated far-field stresses. The major reactivation zones were the GU1, GU2 and GU3 half-grabens and the mapped horst (H). However, the effect of stresses generated by regional shorting was minimized towards the transfer zone (Figure 10c).


5.2 | Impact of base-salt rift architecture on evaporite distribution

Deposition of the L1 that belongs to post-rift 1 stage was influenced by existing syn-rift topography associated with the GU2 and GU3 half-grabens and their transfer zone (Figure 11a). The topographic control exerted by the transfer zone on the drainage basins and depositional systems commonly continues into the post-rift stage, but may be subdued by progressive evolution since the remnant rift topography is progressively infilled (Gawthorpe & Hurst, 1993). In the present case, which affected the L1 accumulation, the elevated transfer zone acted as a flow obstacle or barrier that developed two separate depocentres in the northwest and the southeast (Figures 3 and 11a). In the northwestern depocentre, the L1 evaporites consist mainly of halite-rich (mobile) facies that played an essential role to the evolution of the Signalhorn Dome and the northwestern part of the salt wall (Figure 11a). The evaporite layer L1 in the northwest region was highly mobile as it can be observed by the thickness variation in the evaporitic layer L2 (Figure 3b). In the southeastern depocentre, mixed-layer non-mobile evaporites were accumulated (Figure 6) and no deposition took place over the transfer zone because it was a topographic high (Figure 11a). This variability change in evaporitic facies is likely related to the depositional palaeo-environment or the sea-level change where the transfer zone has created the initial compartmentalization.

The L2 was deposited during the post-rift 2 stage, with non-mobile mixed evaporites at the margins and halite-rich mobile evaporites in the centre of the basin (Figure 11b). Layer L2 was the main source of halite for the salt wall (Figure 3c), but the significance of this layer for the growth of the Signalhorn Dome was less due to the non-mobile nature of the evaporites at the basin margins (Figure 3b). Furthermore, layer L2 is thinning at the southwestern margin parallel to the centre of the Tiddlybanken Basin that signifies the latest influence of the transfer zone (Figure 5c). At the end of the post-rift stage (post-rift 3), the correlation between sediments of this facies becomes easier to correlate as the effect of the interference transfer zone on the drainage basins and depocentres would be eliminated and the entire basin system became linked and subsided in harmony. The L3 was accumulated during the post-rift 3 stage when the entire graben system collectively underwent a regional subsidence phase with no effect of compartmentalization created by the transfer zone (Figure 11c). The accumulated evaporites are of mobile nature and mainly consist of halite lithology that are thinning at the margins and thicken towards the centre of the basin (Figures 3, 5 and 6).

The combination of the contrasting facies distribution, the prediapiric stacked configuration of evaporitic layers L1-L3 beneath the different parts of the basin and the Carboniferous half-graben architecture controlled the evolution of the Signalhorn Dome and Tiddlybanken Basin and the along-strike development of passive diapirism. In the northwestern region, layers L1, L2 and L3 have lithologies that are halite-rich and mobile, favouring passive diapirism and creating thick, tabular, CHS of Upper Triassic to Lower Jurassic strata (Figures 3 and 8a). In the central region, the L1 was not deposited above the elevated transfer zone (Figure 11a, causing the absence of passive diapirism in this area and during the rejuvenation phase the central part never reached to the seafloor (Figures 5 and 8c). The northwestern part of the salt wall, however, subcrops at seafloor due to the salt wall rejuvenation (Figure 3). Also in the southeastern part, the salt wall subcrops at the seafloor but no CHS are observed (Figures 6a,b and 8d). The main reason for this is the presence of the non-mobile mixed facies in the L1 that signifies the importance of the halite lithology in the LES at different levels. In the southeastern part, the salt wall reached to the seafloor because of the GU3 half-graben, which supported a wider depocentre development in contrast to the transfer zone region during the deposition of the L3 (Figures 6a,b and 8).

The Signalhorn Dome is developed above the stacked evaporitic layers L1, L2 and L3 (Figure 3b). We suggest that the evolution of this structure is related to the combined effect from the arcuate horst (H), the GU1 half-graben and presence of L1 (Figures 3 and 4). It is noteworthy that the base of the L3 at the southwestern margin beneath the Signalhorn Dome shows an arch-shaped geometry where the halite-rich L1 is present (Figure 3c,d). The base of the L3 becomes flat as the facies of the L1 develop into a sequence of mixed (non-mobile) evaporites (Figure 5a). The development of any salt structure is dependent on the relative lithological combination between mobile to non-mobile evaporites and the thickness of each accumulated layer (Jackson & Hudec, 2017; Rowan & Lindsø, 2017; Hassaan et al., 2020). The stacked evaporitic layers L1, L2 and L3 cannot source the Signalhorn Dome to obtain its present geometry because the halite is limited. These layers are still sufficient to support a pillow-structure, which may have existed in the core of Signalhorn Dome. However, the main formation mechanism of the dome is the reactivation (i.e. Triassic–Jurassic transition, early–middle Eocene) of the arcuate horst and the GU1 half-graben.
5.3 Along-strike salt wall evolution

The observations of the supra-salt sediment patterns, salt–sediment interactions, sediment thickness in the rim synclines, contact, age, CHS (CHS) and regional relations are all used to define and discuss the genetically linked supra-salt development with the stacked LES and pre-evaporite rift architecture. The early differential loading caused by the developed carbonate build-ups initiated inflation of the L3 (Figure 5c). These minor salt evacuations were localized and overall created a prekinematic relation with the LES (Rowan & Lindsø, 2017). The slow salt mobilization was initiated by differential loading caused by the deposition of thick, prograding sequences S1 and S2 (Havert Formation; lower Induan) supported by abrupt thickness change commonly seen near the salt wall (Figures 7a,b and 12a). The pillow structure continued to develop during the deposition of sequence S3 (Klappmyss Formation; Olenekian) when the cumulative load triggered the LES (Figure 12b). The northwestern part of the pillow structure developed faster due to the presence of mobile halite in the L1 in contrast to the central and southeastern regions where there was less halite (Figure 12b). During the Olenekian, the main salt evacuation occurred in the northwestern part of the Tiddlybanken Basin that created the rim syncline (Figure 7c). During this syn-kinematic phase, strata of the sequence S3 onlap sequence S2 and thin towards the pillow structure due to the pillow development (Figure 12b). The extra load caused by the thick sequence S4 (Kobbe Formation; Anisian) around the pillow structure in the rim syncline revealed two prominent evolutionary phases. Initially, the central and southeastern pedestal structure was slightly rejuvenated by regional stresses during the Triassic–Jurassic transition as inferred from the thinning of the upper sedimentary (U1) package towards the salt structure (Figures 12c). The main salt depletions occurred along the centre of the salt structure and is minimized towards the northwestern and southeastern parts (Figure 7d).

The four deposited sequences (S1–S4) are found to be upturned along the flanks of the salt pedestal (Figure 12c) and are truncated at the base of sequence S5 (Snadd Formation) that formed the prominent angular Middle Triassic Unconformity (MTu) (Rowan & Lindsø, 2017) (Figures 3d and 12c,d). The roof of the basal salt pedestal was thinned and eroded to allow the salt to break through and allowed passive diapirism to commence in the northwestern part of the Tiddlybanken Basin (Figure 12d). However, in the central and southeastern regions, the growth of the salt structure was slow and the development was not progressed beyond the pedestal stage due to lack of the halite lithology in the L1 (Figure 12d). In the northwestern part, sequence S5 onlaps the salt wall and formed tabular CHS (Figure 12d). The sedimentary thickness variations of the sequence S5 in the rim synclines suggest that the salt layers were mainly depleted in the northwestern part and that the evacuation gradually diminished towards the southeast (Figure 7e). In the central and southeastern parts, the slow evacuation caused minor growth of the pedestal as it is apparent by the thinning of sequence S5 towards the salt structure (Figure 12e).

During deposition of the thick sequence S6 (Upper Triassic–Lower/Middle Jurassic), maximum evacuation of the salt from the LES has continued in the northwestern part of the salt wall that formed an overhang above the basal salt pedestal (Figure 12e). The growth of the salt wall was accelerated by the reactivation of the GU2 half-graben due to the propagated far-field compressional stresses from the Novaya Zemlya fold-and-thrust belt (Indrevæ et al., 2018; Müller et al., 2019; Hassaan et al., 2020) (Figure 12e). The L1 was deformed and formed the southwestern weld (Figures 3 and 12e). This far-field activity also reactivated the horst and half-graben GU1 that started the development of the Signalhorn Dome as it is evidenced by the eroded and truncated strata over the southwestern margin (Figures 3 and 7f).

However, detailed analysis of sequence S6 strata in the rim synclines of the central and southeastern parts of the basin revealed two prominent evolutionary phases. Initially, the central and southeastern pedestal structure was slightly rejuvenated by regional stresses during the Triassic–Jurassic transition (Figures 12c). The main salt depletions occurred along the centre of the salt structure and is minimized towards the northwestern and southeastern parts (Figure 7d).

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However, detailed analysis of sequence S6 strata in the rim synclines of the central and southeastern parts of the basin revealed two prominent evolutionary phases. Initially, the central and southeastern pedestal structure was slightly rejuvenated by regional stresses during the Triassic–Jurassic transition as inferred from the thinning of the lower sedimentary (U1) package towards the salt structure (Figures 5c and 12e). Subsequently, the complete cessation of the salt mobilization and creation of the broad sag basin over the salt pedestal in the central and southeastern parts of the Tiddlybanken Basin is supported by the thickening of the upper sedimentary package (U2) towards the salt structure (Figures 5c and 12e).

During the late Jurassic and earliest Cretaceous the Tiddlybanken Basin and Signalhorn Dome were slightly reactivated as it is evidenced by the thinning and onlaps at the southwestern margin (Figure 12f) (Hassaan et al., 2020).
However, thinning over the salt wall could not be observed as the strata have been eroded during the later salt wall rejuvenation (Figure 12f). During tectonically quiescent conditions, a thick Lower Cretaceous shelf-platform sedimentary deposition buried the salt and Signalhorn Dome topography (Midtkandal et al., 2020; Hassaan et al., 2020). The salt wall and dome were rejuvenated due to the reactivation during the Palaeogene due to the Eurekan/Spitsbergen Orogeny (Figure 12g). As a consequence, the post-middle Cretaceous strata were eroded from the Signalhorn Dome due to the reactivation of the horst structure and GU1 half-graben (Figure 12g). The northwestern and southeastern parts of the salt wall subcrop at the seafloor due to the salt wall rejuvenation that upturned Upper Jurassic to Lower Cretaceous and Upper Triassic to Lower Cretaceous strata, respectively (Figure 12g). Due to this salt wall rejuvenation, the strata were also upturned along the central and southeastern parts of the salt wall (Figures 8a,b and 9).

6 | CONCLUSIONS

We used reprocessed 2D seismic reflection profiles and well data to analyse the evaporite-dominated Tiddlybanken Basin and the evaporite-cored Signalhorn Dome in the southeastern Norwegian Barents Sea. The late Devonian–early Carboniferous (Mississippian) NE-SW oriented regional stress regime that affected the area that led to the development of three half-grabens separated by a NW-SE to NNW-SSE trending horst and an interference transfer zone beneath the area of the later Tiddlybanken Basin and Signalhorn Dome. The arcuate nature of the horst structure is believed to be the consequence of a pre-existing Timanian lineament. We suggest that the transfer zone formed due to the combined effect of the Timanian lineament and the geometrical configuration of the opposing master faults. The remnant Carboniferous syn-rift topography affected the depositional facies and thickness of the three observed LES during the post-rift development. The influence of the existing transfer zone topography on the depositional system minimized with time, as the remnant rift topography is progressively infilled.

The relatively elevated transfer zone in contrast to the half-grabens acted as a flow obstacle during the accumulation of the L1. The mobile halite-rich lithology was accumulated in the northwestern part of the basin, whereas non-mobile/mixed lithologies were deposited in the southeastern part due to the relic compartmentalization. However, the drastic change in the evaporitic facies could be related to the depositional palaeo-environment or the sea-level change. The L2 was mildly affected by the transfer zone, whereas the L3 accumulated without any influence of the remnant topography during the last phase of the post-rift development. The prediapiric stacked configuration of the LES had a decisive control on the passive diapirism of the salt wall. During the late Triassic to early/middle Jurassic, passive diapirism occurred in the northwestern part of the salt wall due to the presence of the halite-rich/mobile lithologies in the LES. However, the central and southeastern parts of the salt wall have not progressed beyond the pillow stage due to lack of the halite lithologies in the L1. The Signalhorn Dome was mainly supported by the deepest halite layer.

Far-field stresses from the Novaya Zemlya fold-and-thrust belt (Late Triassic–Early Jurassic) reactivated the half-grabens and the horst structure. The activity was responsible for the generation of the Signalhorn Dome, rejuvenation of the NW part of the salt wall and has affected the sedimentation rates in the southeastern broad basin. The salt wall and Signalhorn Dome were mildly reactivated during the Upper Jurassic and earliest Cretaceous. In the early Cretaceous, the prograding shelf-platform strata complex buried the Signalhorn Dome and the salt wall until reactivation of the half-grabens and the horst led to the rejuvenation of these structures and to the erosion of the post-Lower Cretaceous strata over their crest. The main phase of reactivation took place during early–middle Eocene and is probably related to the regional compressional stresses from the transpressional Eurekan/Spitsbergen orogeny that rejuvenated the salt wall and the Signalhorn Dome. Nevertheless, the reactivation was minimized towards the transfer zone beneath the centre of the salt wall.

The Tiddlybanken Basin area was demonstrated to represent an excellent example of base salt rift structures, evaporite accumulations and evolution of salt tectonics. The revealed processes and study outcomes can have similar implications for the evolution of the nearby extensively larger Nordkapp Basin and other evaporite-dominated basins in the Barents Sea, as well as similar basins in a worldwide perspective.

ACKNOWLEDGEMENTS

The study is part of the ARCEx (Research Centre for Arctic Petroleum Exploration) project which is funded by the Research Council of Norway (grant number 228107) together with ten academic and six industry partners (Equinor, Vår Energi, AkerBP, Lundin Norway, OMV and Wintershall DEA). We want to thank all academic institutes, industry and funding partners. Vår Energi is acknowledged for sponsoring the Adjunct Professor position of F. Tsikalas at the University of Oslo. Schlumberger is thanked for providing academic license to the Petrel© software. The Norwegian Petroleum Directorate (NPD) and TGS-NOPEC Geophysical Company ASA are also acknowledged for providing access to the regional seismic data. Reviews by Zoe A. Cumberpatch and Rachelle Kernen, with editorial remarks from Craig Magee helped to improve the manuscript. The technical contents and ideas presented herein are solely the authors’ interpretations.
CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

AUTHORS’ CONTRIBUTIONS
M.H. and J.I.F designed and directed the research. M.H. interpreted the seismic data. M.H., J.I.F., R.H.G. and F.T. analysed the results and contributed to interpretation of the same. M.H. prepared the figures and wrote the manuscript text. All authors reviewed the manuscript.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from NPD and TGS. Restrictions apply to the availability of these data, which were used under license for this study. Uninterpreted seismic sections are available as supplementary material.

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**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section.

**How to cite this article**: Hassaan M, Faleide JI, Gabrielsen RH, Tsikalas F. Architecture of the evaporite accumulation and salt structures dynamics in Tiddlybanken Basin, southeastern Norwegian Barents Sea. *Basin Res.* 2020;00:1–27. https://doi.org/10.1111/bre.12456