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The Jurassic–Cretaceous lithostratigraphy of Kilen, Kronprins Christian Land, eastern North Greenland

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Kilen, Kronprins Christian Land, contains the thickest and stratigraphically most complete Jurassic and Cretaceous sediment succession in North Greenland. This study revises and formalises the lithostratigraphic framework of these deposits. The work is based on recent extensive stratigraphic field work supplemented by photogeological mapping and biostratigraphic studies, and builds on the earlier stratigraphic work conducted mainly in the 1980s and 1990s. According to the new stratigraphic scheme, the more than 500 m thick Jurassic succession is divided into four formations. The poorly dated Gletscherport Formation comprises lagoonal heterolithic sandstones. The Mågensfjeld and Birkelund Fjeld Formations consist of shallow marine fine-grained sandstones of Bajocian–Bathonian and Kimmeridgian age, respectively. The Kuglelejet Formation comprises mainly shallow marine sandy mudstone and sandstone of Volgian age and includes the mudstone-dominated Splitbæk Member. The Lower Cretaceous interval is estimated to be more than 1500 m thick and is divided into three formations. The Dromledome Formation comprises deep shelf to offshore transition, black mudstones of late Ryazanian to Hauterivian age. It is erosively overlain by unfossiliferous, fluvial and estuarine sandstones of the Lichenryg Formation. The overlying, late Aptian to middle Cenomanian Galadriel Fjeld Formation comprises six members, of which the Tågekyst and Kangoq Ryg Members occur in the Gåseslette area, whereas the Pil, Valmue, Stenbræk and Hondal Members occur in the Kilen Fjelde area. The Galadriel Fjeld Formation is characterised by interbedded mudstones and sandstones from offshore–shoreface environments. The 650 m thick Upper Cretaceous succession is assigned to the Sølverbæk Formation, which is undivided in the Gåseslette area and divided into the Skalbæk and Scaphitesnæse Members in the Kilen Fjelde area. The Sølverbæk Formation is dominated by marine mudstones and sandstone-mudstone heteroliths of late Cenomanian to Santonian age. The new lithostratigraphic framework and significant biostratigraphic advances allow a closer correlation of the Mesozoic units between North Greenland and other Arctic basins.

Keywords: Lithostratigraphy, Mesozoic, Jurassic, Cretaceous, Kilen, North Greenland, Wandel Sea Basin.

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The Wandel Sea Basin (WSB) is a fault-bounded Carboniferous–Lower Tertiary sedimentary basin in North Greenland (Dawes & Soper 1973; Håkansson & Stemmerik 1989; Stemmerik *et al*. 1998; Fig. 1), which forms a key area for the understanding of the Mesozoic stratigraphy of the Arctic. The basin contains a more than 3.1 km thick Mesozoic sedimentary succession (Svennevig *et al*. 2016), which records sedimentation on the western margin of the Svalbard–Western Barents Sea Basins and on the north-western flank of the Danmarkshavn Basin. Therefore, the area links the stratigraphy of North-East Greenland to the Svalbard and Sverdrup Basins and forms one of the closest onshore stratigraphic analogues for the offshore Danmarkshavn Basin and the north-western Barents Sea basin.

The WSB covers a number of geographical areas, from south-east to north-west: Holm Land, Kronprins Christian Land (including Amdrup Land, Kilen and Prinsesse Ingeborg Halvø), and eastern Peary Land (Fig. 1). The WSB contains a nearly continuous Middle Jurassic to Upper Cretaceous succession (Håkansson & Stemmerik 1984) that forms one of the most complete upper Mesozoic onshore sedimentary records in the Arctic region. In particular, the presence of onshore Upper Cretaceous deposits is exceptional, considering that such deposits do not crop out elsewhere north of Hold with Hope in North-East Greenland (Kelly *et al.* 1998) and are absent on Svalbard (Dallman *et al*. 1999). However, due to the remote location and arctic conditions, the area has remained one of the least studied Mesozoic onshore sedimentary basins in the Arctic.

Pioneering stratigraphic works on the Mesozoic deposits in the WSB were conducted by E. Håkans-

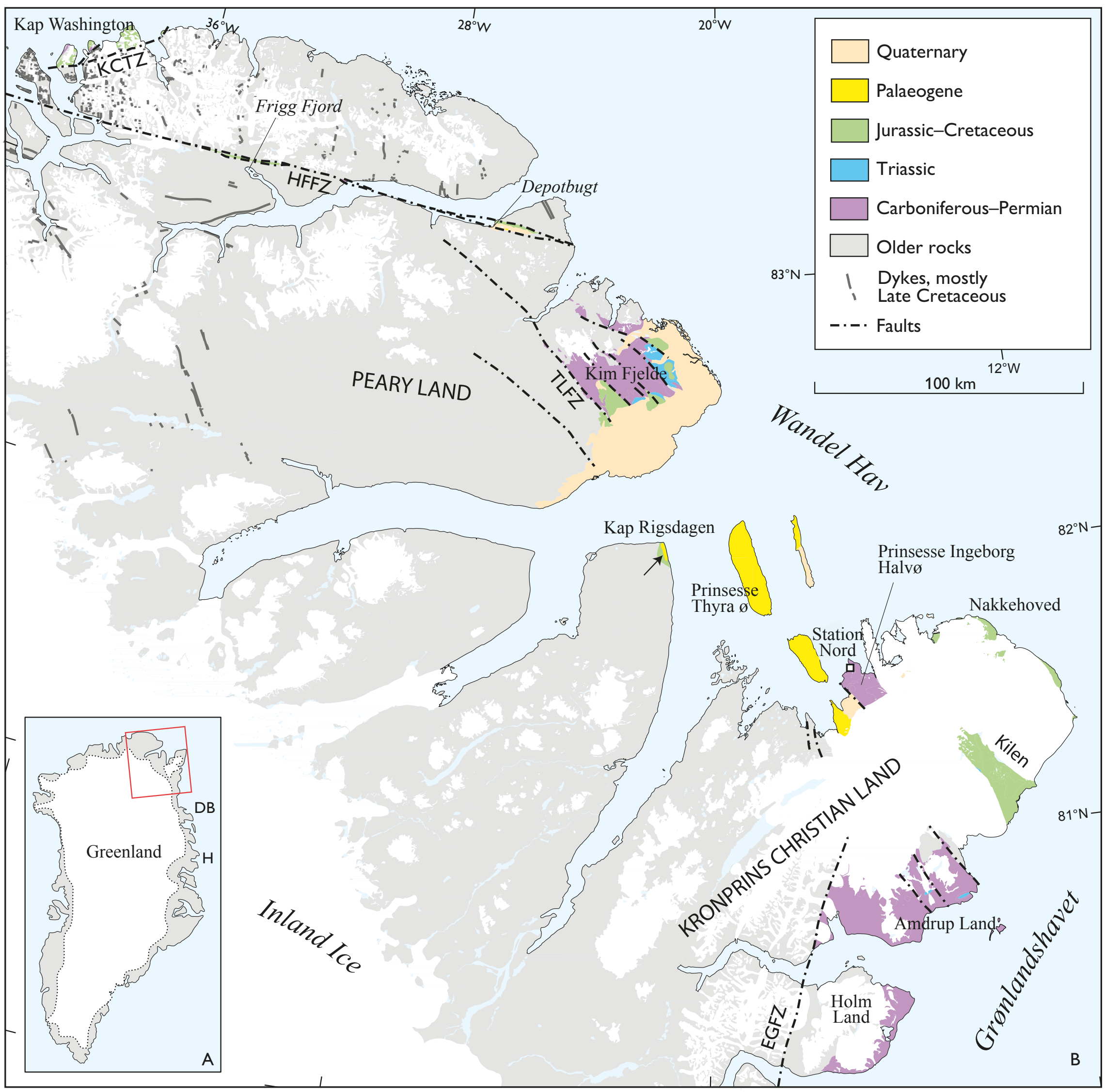


Fig. 1. **A**: Map of Greenland showing the position of the Wandel Sea Basin (framed area), the Danmarkshavn Basin (DB) and Hold with Hope (H). **B:** Map of the Wandel Sea Basin showing the main Mesozoic outcrop areas. The faults of the Wandel Sea Basin are oriented NW–SE. Kilen is located in Kronprins Christian Land and is bounded by an ice cap and the Greenland Sea (Grønlandshavet). The Carboniferous–Permian deposits in Amdrup Land are bounded eastwards by the East Greenland Fault Zone (EGFZ). TLFZ: Trolle Land Fault Zone. North of Peary Land: HFFZ: Harder Fjord Fault Zone. KCTZ: Kap Cannon Thrust-fault Zone. Map based on Håkansson & Pedersen (1982), Bengaard & Henriksen (1986) and Henriksen (2003).

son and his co-workers (Håkansson 1979; Håkansson *et al*. 1981b, 1991, 1993, 1994; Pedersen 1991; Heinberg & Håkansson 1994; Dypvik *et al*. 2002). These studies mapped the main Jurassic–Cretaceous exposures and erected preliminary biostratigraphic and lithostratigraphic divisions for these rocks. The main outcrop areas were identified at Kilen (Kronprins Christian Land) and in eastern Peary Land. In addition, several

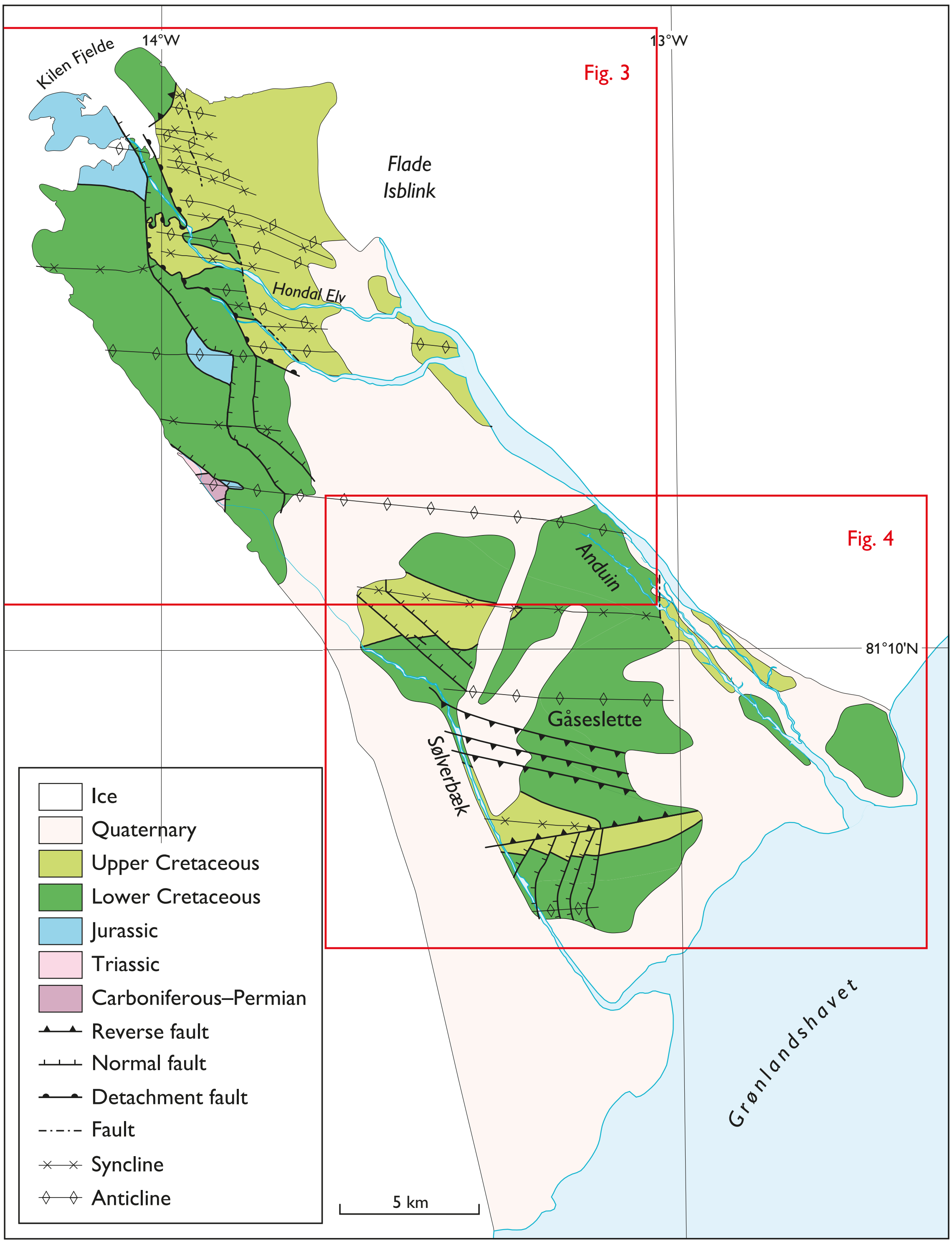


Fig. 2. Simplified geological map of Kilen showing the main faults. Kilen Fjelde is the hilly area to the north-west (Fig. 3) and Gåseslette is the plain to the south-east (Fig. 4). Locations of the detailed maps (Figs 3, 4) are indicated. Modified from Svennevig *et al*. (2016).

Cretaceous outliers with variable degrees of exposure were reported from Kap Rigsdagen, Frigg Fjord, Depotbugt and Nakkehoved (Fig. 1; see also Nielsen 1941; Soper *et al*. 1980; Rolle 1981; Piepjohn & von Gosen 2001, Piasecki *et al*. 2018, Svennevig 2018b).

The most complete and thickest Jurassic–Cretaceous sedimentary succession in the WSB is present at Kilen. Recent extensive field work and significant biostratigraphic advances have provided new insights into the stratigraphy of these deposits, which allow revision and formalisation of the previously erected, informal lithostratigraphic scheme. The revision has reduced the number of formations, especially in the Upper Cretaceous succession. The previous lithostratigraphic names have been retained where possible. The former and new lithostratigraphic subdivisions are shown in Fig. 5.

The Kilen Area

Kilen ('the wedge' in Danish) is a semi-nunatak within the ice cap Flade Isblink (Figs 1–2). Kilen extends for *c*. 10 km NE–SW and *c*. 40 km NW–SE and may be divided into the Kilen Fjelde area, with hills up to 500

Fig. 3. Detailed geological map of the Kilen Fjelde area showing the positions of the studied sections referred to in the text. See Fig. 4 for legend and abbreviations of lithostratigraphic units. Modified from Svennevig (2018a) and Svennevig *et al*. (2018).

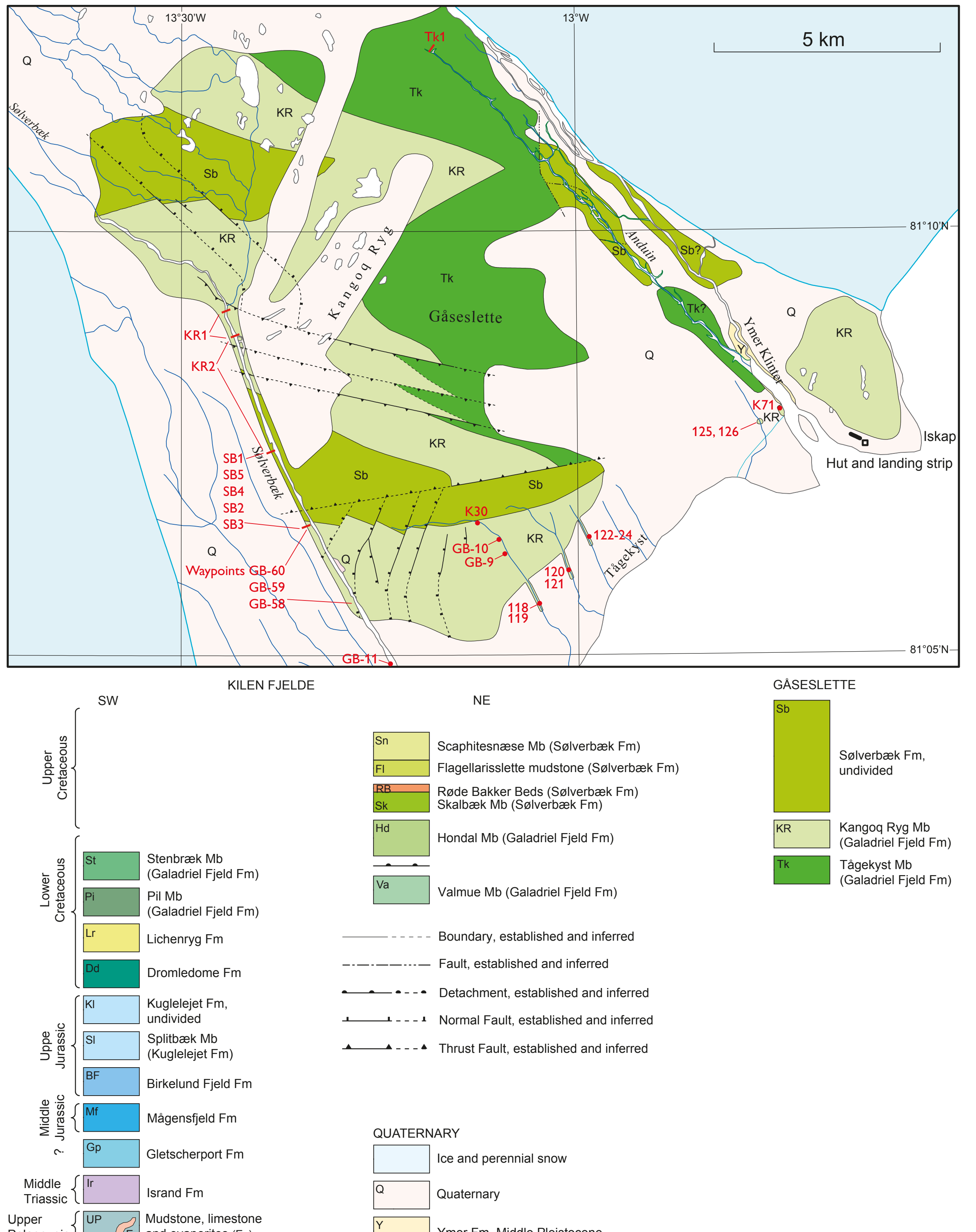
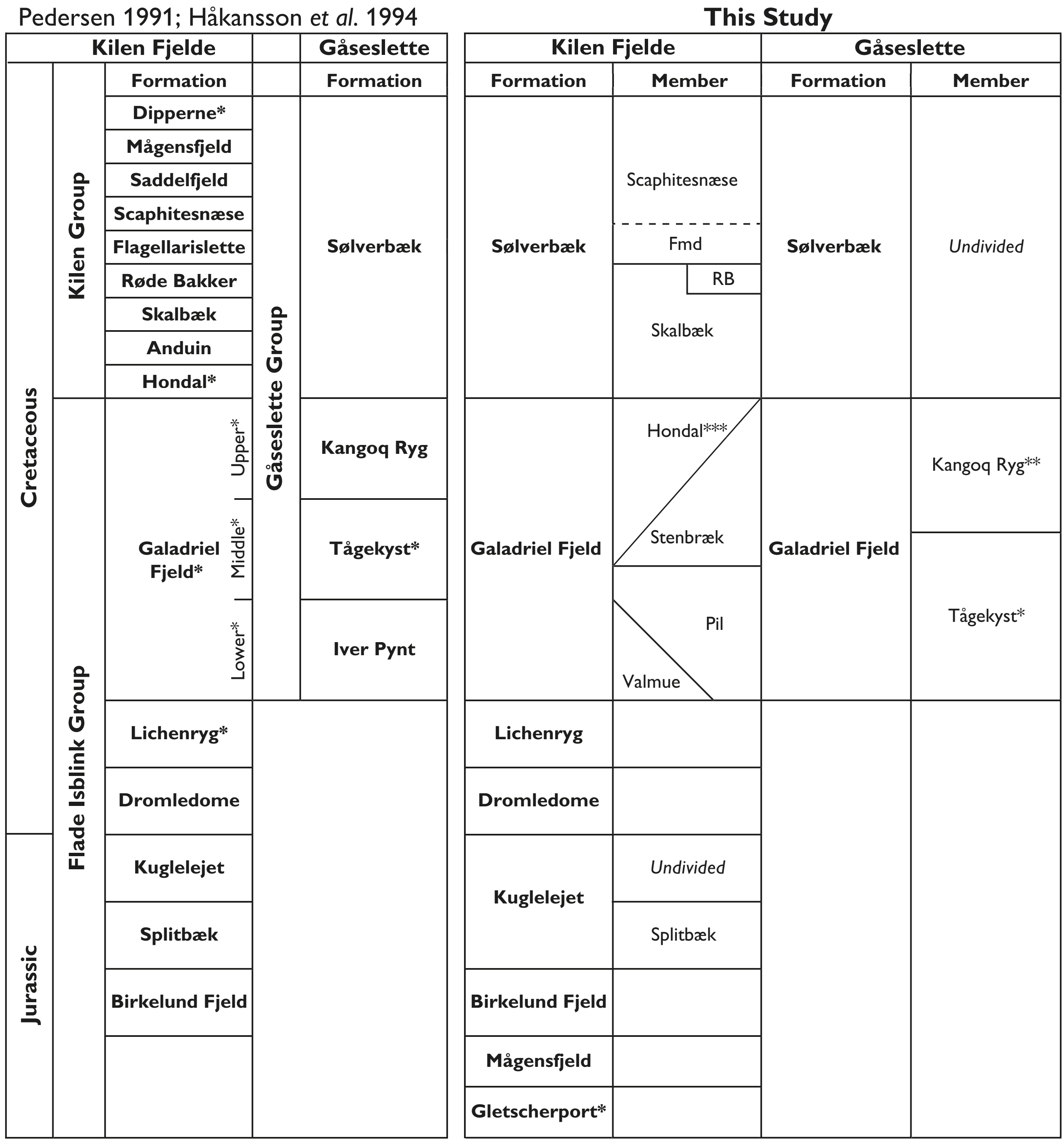


Fig. 4. Legend and detailed geological map of the Gåseslette area showing the positions of the studied sections referred to in the text. Place names in Figs 2–4 are field names. Modified from Svennevig (2018a).

m a.s.l. in the north-west, and the Gåseslette area, the lowlands bordering the sea in the south-east (Figs 3–4).

Kilen is dominated by Jurassic and Cretaceous sediments, although Triassic strata have recently been recognised locally and are referred to the Isrand Formation (Alsen *et al*. 2017). The Jurassic and Cretaceous deposits have been subjected to intense tectonic deformation (Pedersen 1991; Pedersen & Håkansson



* undated; ** includes strata formerly referred to the Iver Pynt Formation; *** includes strata formerly referred to the Dipperne Formation. RB: Røde Bakker Beds. Fmd: Flagellarisslette mudstone.

Fig. 5. Comparison between the lithostratigraphic subdivisions of the Jurassic and Cretaceous successions at Kilen by Pedersen (1991) and Håkansson *et al.* (1994) and the revised and formalised framework presented in this paper. The revised lithostratigraphy includes no groups and fewer formations. Tectonic boundaries separate the four members of the Galadriel Fjeld Formation in most of the Kilen Fjelde area (Figs 3, 6). Depositional boundaries between the Pil and Stenbræk Members, and between the Hondal and Skalbæk Members, are indicated in Figs 18, 23. See text for further discussion.

2001; Håkansson & Pedersen 2015; Svennevig *et al*. 2015, 2016, 2017; Svennevig 2018a). The sedimentary succession at Kilen has been variably exposed to thermal alteration that has commonly destroyed the dinocyst content, e.g. in Kilen Fjelde (Pedersen & Håkansson 2001; Svennevig *et al*. 2017, Pedersen *et al*. 2018). The absence of dinocysts complicates the correlations within different parts of Kilen, and to other sedimentary basins.

The Kilen area was affected by post-Cretaceous N–S compression, which folded the strata and divided the deposits into two thrust sheets (Svennevig *et al*. 2016). As a result, many of the lithostratigraphic units at Kilen are fault-bounded and intensively faulted. Some formations comprise coeval members that belong to different allochthonous thrust sheets (Svennevig *et al*. 2016; but see e.g. Håkansson & Pedersen (2015) for an alternative interpretation).

Previous work

The pioneering stratigraphic work in Kilen produced a geological map that shows the distribution of 19 formations in three groups of Jurassic and Cretaceous age (Fig. 5; Pedersen 1991). The map was accompanied by brief descriptions of lithology, thickness and age of the formations (Håkansson *et al*. 1993, 1994; Heinberg & Håkansson 1994), whereas type sections and boundaries of the formations were not described. The biostratigraphic framework based on the early collections of inoceramids and ammonites indicated that the formations range from the Kimmeridgian to the early Coniacian. Nine of the 19 formations were found to represent the middle Turonian to lower Coniacian (Håkansson 1994; Håkansson *et al*. 1994).

This study

This work is based on extensive field work by the Geological Survey of Denmark and Greenland (GEUS) on Kilen in 2012 and 2013, with supplementary data collection in 2016. A total of 30 sedimentological sections, 17 to 430 m thick, were studied in variable detail. The thicknesses indicated on the sedimentological logs are true thicknesses, with the exception of Fig. 31. The geographical coordinates of the type sections are based on WGS84. The geological ages of the formations are based on biostratigraphic work on ammonites, inoceramids and other bivalves, palynomorphs (dinoflagellate cysts) and foraminifera (Fig. 6). The photogeological mapping supported the identification of the tectonic boundaries between the formations, and the structural model provided estimates of formation thicknesses in areas without sedimentological logs (Svennevig *et al*. 2015, 2016, 2018).

Many of the lithostratigraphic units at Kilen are fault-bounded and intensively faulted, and the age determination for some units is dependent on limited macrofauna. Moreover, some formations comprise coeval members that belong to different allochthonous thrust sheets, which may have brought strata representing different depositional environments closer together than they were at the time of deposition. The members of the Galadriel Fjeld Formation exemplify such relationships (Svennevig *et al*. 2016, 2017, 2018). Due to these complicating factors, the nature of the formation boundaries, the thickness of the stratigraphic units and their correlation cannot always be stated.

In the revised lithostratigraphy, the deposits are assigned to eight formations of which one has six members, one has two members and one has a single member (Figs 5–6). The previous lithostratigraphic names have been retained where possible, but the use of four previous lithostratigraphic unit names, namely Iver Pynt, Anduin, Dipperne and Saddelfjeld, is discontinued. Definition of groups is not undertaken here. This awaits an improved understanding of the genetic stratigraphy of the entire succession, as well as correlations to the successions in other parts of the Wandel Sea Basin.

The terminology of open coast wave- and storm-influenced environments follows Pemberton *et al*. (2012). According to their scheme, the environment located below storm wave base is termed the shelf. The depositional environment located between storm and fair-weather wave-base is termed the offshore. The shoreface environment is located above fair-weather wave base.

Finally, detailed documentation of depositional environments is beyond the scope of this paper, and only brief generalised summaries of depositional settings are presented here. Therefore, features such as facies and facies association divisions, detailed ichnological descriptions and palaeocurrent data will be addressed elsewhere.

Gletscherport Formation

New formation

Name and history. The formation is named after a nearby mouth of a glacier.

Distribution. The unit has a single exposure on the east side of the hill Mågensfjeld in Kilen Fjelde (Fig. 3).

Type section. The east side of Mågensfjeld constitutes

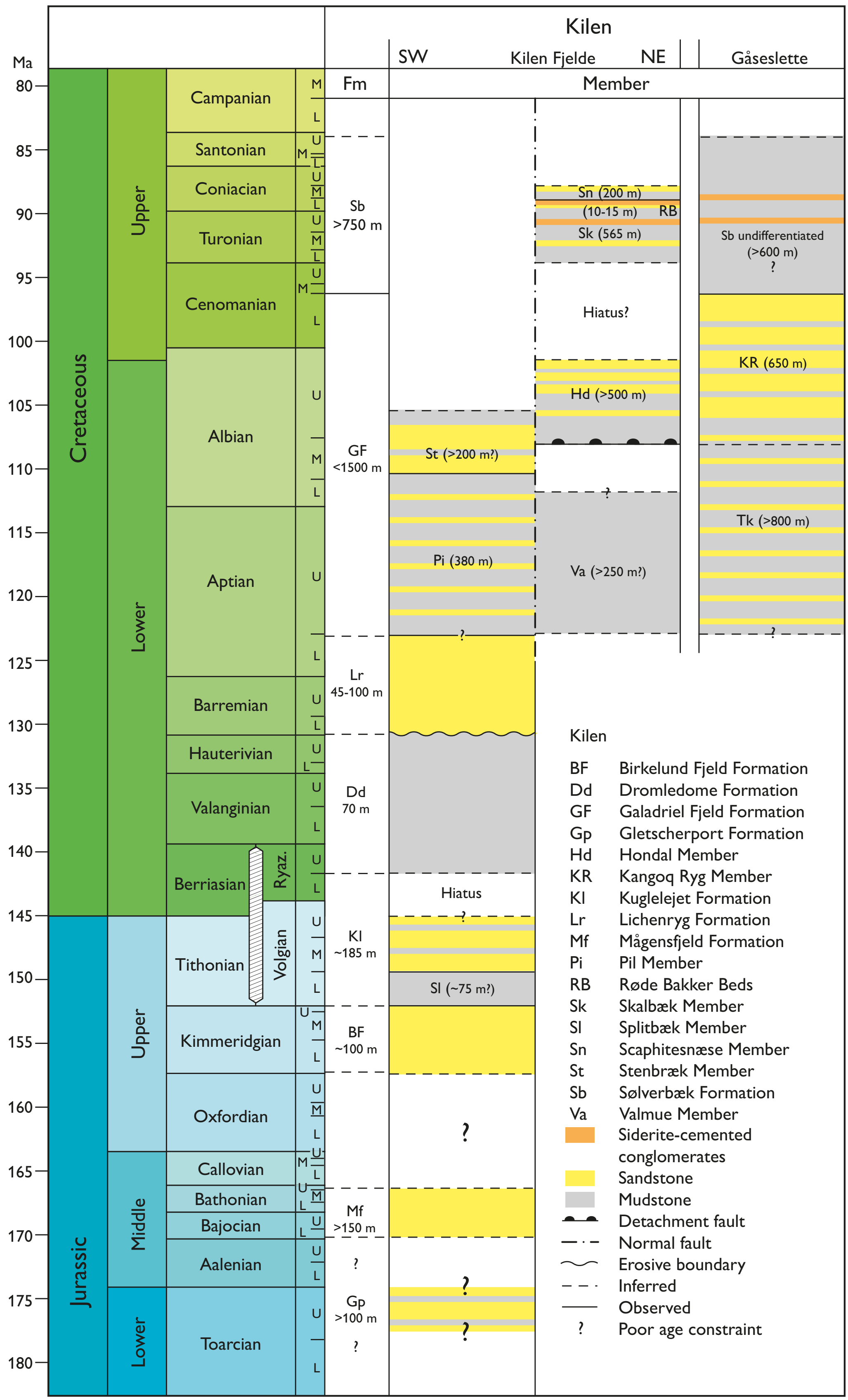


Fig. 6. A: Chronostratigraphic chart of the Jurassic and Cretaceous deposits in Kilen. Note that the Gletscherport Formation is undated. Numerical ages to the left follow the International Chronostratigraphic Chart 2017 (Cohen *et al*. 2013, updated 2017).

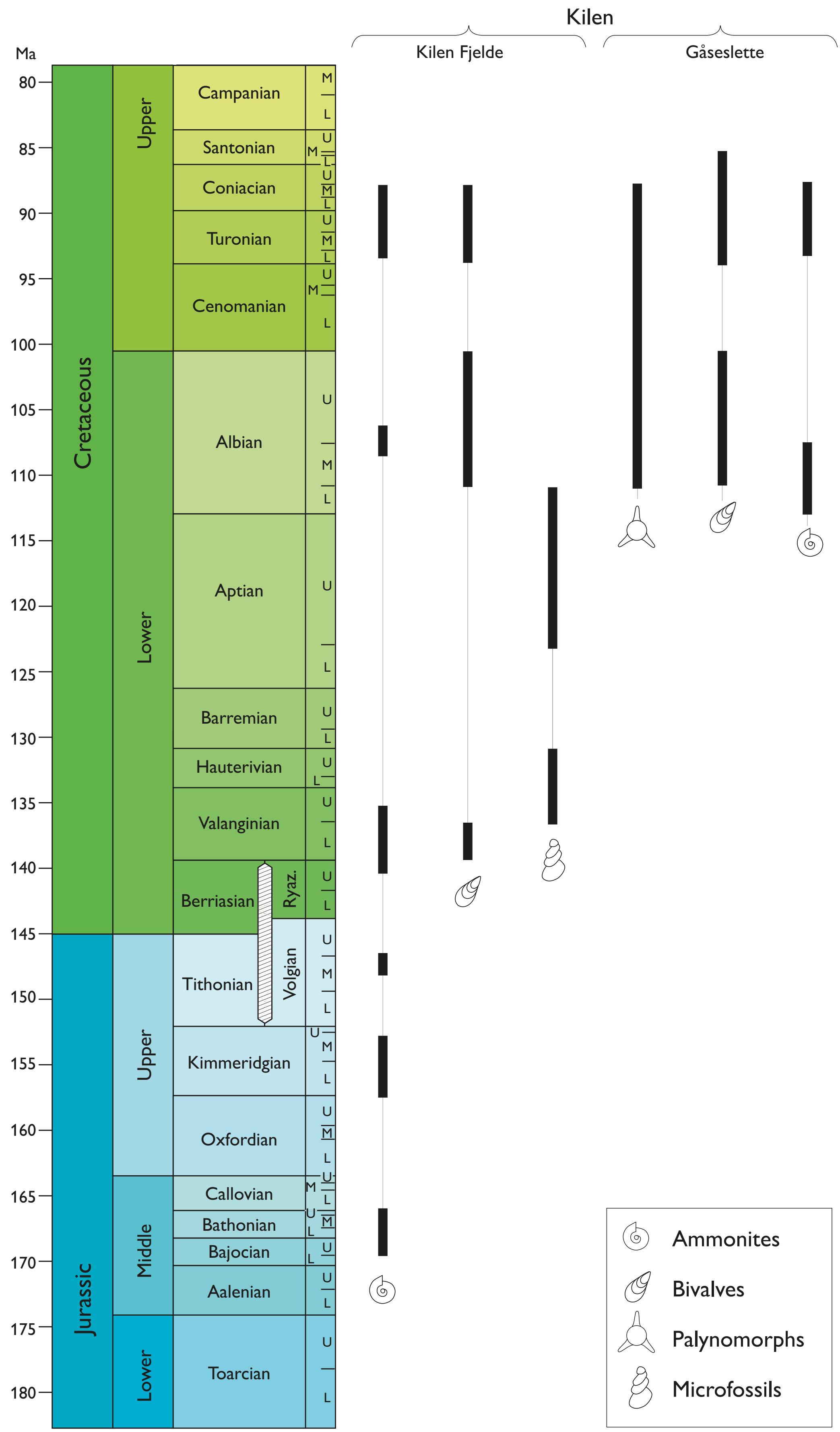


Fig. 6. B: Stratigraphic distribution of the main fossil groups used for biostratigraphic dating. See text for the main age-diagnostic taxa. The occurrence of additional fossils is included in the descriptions of the relevant lithostratigraphic units.

the type section (Fig. 7). The exposed part of the type section is covered by the log Gp1 (Fig. 8A). The base of the exposure is located at 81°18′51.2″N, 014°03′26.3″W.

Thickness. The thickness of the formation is unknown. Photogeological mapping suggests that the formation continues below the scree and is >100 m thick (Svennevig *et al*. 2016; Fig. 6A). The outcrop exposure is ~70 m thick.

Boundaries. The boundaries are not observable.

Fossils and age. Plant fragments, but no marine fossils have been found. A pre-Late Bajocian age is tentatively suggested based on the stratigraphic relationship with the overlying Mågensfjeld Formation.

Lithological description. The formation outcrops as a poorly exposed tectonic sliver at the east-side foot of Mågensfjeld. The deposits consist of heterolithic sandstone showing variously developed wave-ripple cross-stratification, combined-flow ripple cross-lamination, mudstone drapes and interbeds. Terrestrial organic matter, such as leaf and coal fragments, is very common. Synaresis cracks occur locally. The deposits are unbioturbated or variably bioturbated with a low-diversity trace fossil assemblage. Typical trace fossils include *Lockeia* isp., *Planolites* isp. and *Palaeophycus* isp.. Escape and equilibrium structures are also found.

Depositional environment. Sediment structures suggest common wave influence with superimposed non-oscillatory currents. Herringbone cross-lamination coupled with common heterolithicity suggest the presence of tidally modulated currents. The lack of bioturbation in many relatively low-energy facies indicates the presence of environmental stresses that commonly limited infaunal colonisation. The repeated occurrence of low-diversity trace fossil suites, which mainly comprise morphologically simple burrows such as *Planolites,* suggests that the main stress is related to low and/or fluctuating salinity. The inferred depositional environment is a wave- and tide-influenced, low-salinity to freshwater environment in a restricted setting such as a lagoon or bay.

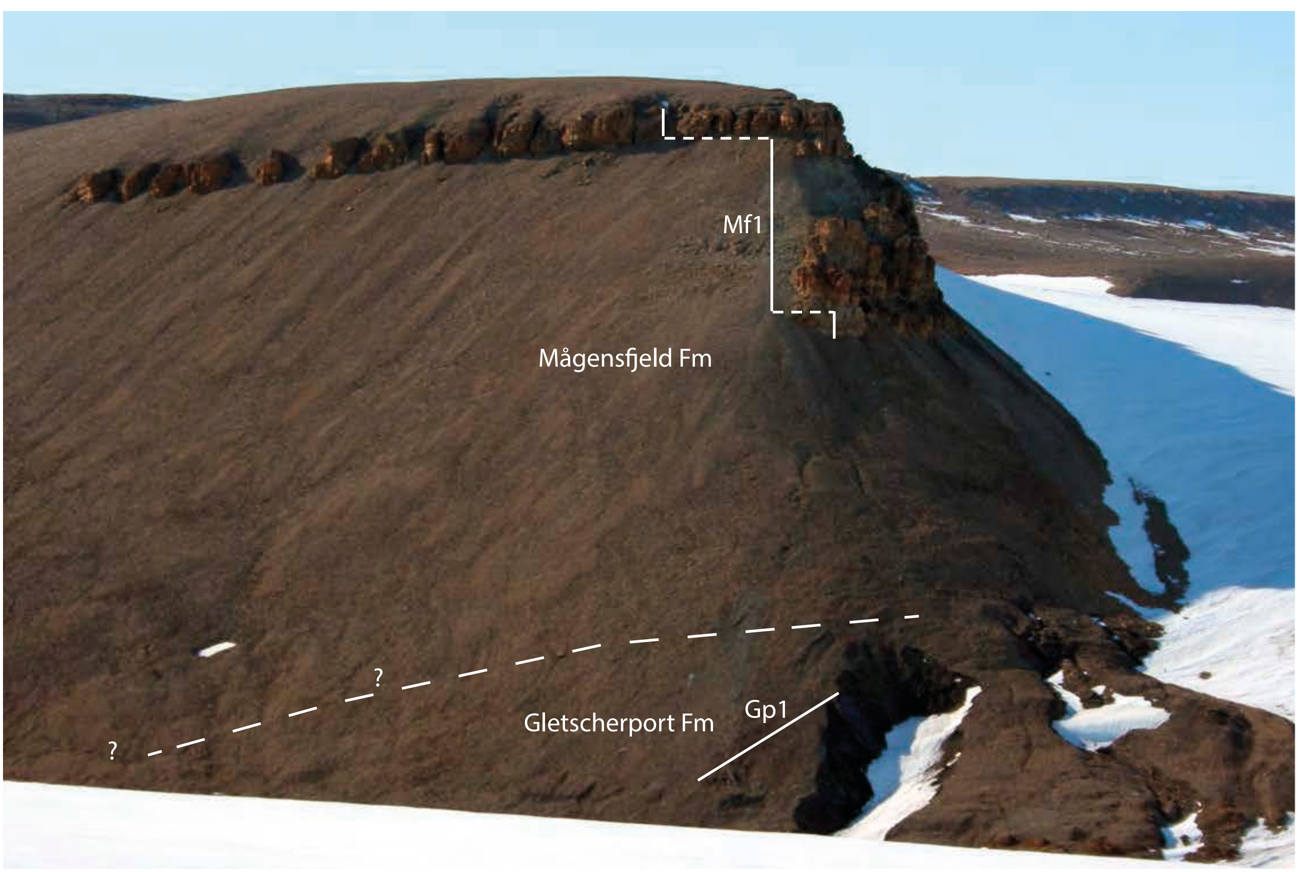


Fig. 7. Type sections of the Gletscherport and Mågensfjeld formations. The Gletscherport Formation is a tectonic sliver exposed at the foot of the Mågensfjeld hill, Kilen Fjelde. Approximate locations of the logs Gp1 and Mf1 are indicated. The exposed cliff of the Mågensfjeld Formation is ~100 m high. View towards the west.

Mågensfjeld Formation

Name and history. The unit was mapped by Pedersen (1991) and described by Håkansson *et al*. (1994) as an Upper Cretaceous formation. The name is derived from a prominent hill formed by this rock unit in Kilen Fjelde. The unit is here formalised and dated to the Middle Jurassic.

Distribution. The formation has a single exposure at Mågensfjeld, Kilen Fjelde (Fig. 3).

Type section. Mågensfjeld constitutes the type section (Figs 7, 9). The exposed part of the type section is shown in the sedimentological log Mf1 (Fig. 8B). The base of the exposure is located at 81°18′47.5″N, 014°04′07.9″W.

Boundaries. The boundaries of the formation are not exposed.

Thickness. The thickness of the formation is unknown, but estimated to be more than 150 m based on the photogeological interpretation (Svennevig *et al*. 2016; Fig. 6). The outcrop exposure is *c*. 100 m thick.

Fossils and age. The fossils include ammonites, belemnites, bivalves, plant fragments and coalified tree trunks. The formation is Middle Jurassic (upper Bajocian – Bathonian) based on ammonites, which include late Bajocian *Cranocephalites* cf. *pompeckji* and *C. furcatus* and Bathonian *Arctocephalites* sp. cf. *delicatus* or *arcticus, Arcticoceras crassiplicatum, Cadoceras calyx, C. apertum* and *Kepplerites* sp. cf. *traillensis* or *tenuicostatus*. Numerous large belemnites are commonly dissolved, leaving cavities sometimes filled with secondary calcite. Such belemnites were probably mistakenly interpreted as Late Cretaceous baculitids by Håkansson *et al*. (1993, their 'Unit 7'). Bivalves include the inoceramid *Retroceramus* sp., that was probably likewise mistaken for a Late Cretaceous (early Coniacian) inoceramid (Håkansson *et al*. 1993).

Lithological description. A uniform sandstone succession comprising thinly bedded, fine-grained sandstone. Parallel lamination, ripple cross-lamination and cross-bedding are locally observed. The rock surface is typically weathered, which prevents observation of sediment structures. The sandstones are variably bioturbated with a low to moderately diverse trace fossil assemblage. Typical trace fossils include *Diplocraterion* isp., *Phoebichnus* isp. and *Thalassinoides* isp. Terrestrial organic matter such as complete leaves occur in places.

Depositional environment. The sedimentological, ichnological and fossil data point to an overall shallow marine environment. The commonly high bioturbation intensity and rarity of preserved wave- or storm-generated structures suggest a confined setting, where oscillation currents were subdued. The interpreted depositional environments include protected lower–middle shoreface environments and deltaic intervals.

Birkelund Fjeld Formation

Name and history. The unit was mapped by Pedersen (1991) and described by Håkansson *et al*. (1994) and Dypvik *et al*. (2002). Birkelund Fjeld is a hill named after the late professor Tove Birkelund, University of Copenhagen. The formation is here formalised.

Distribution. The main outcrop area of the formation is in the Dromledome and Birkelund Fjeld areas, Kilen Fjelde (Fig. 3).

Type section. The Dromledome anticline constitutes the type section. The exposed part of the type section is covered by the log BF1 (Figs 8C and 10). The base of the exposure is located at 81°15′15.5″N, 013°54′46.6″W.

Boundaries. The lower boundary is not exposed. The upper boundary is partially covered by scree but is seen as a sharp change in lithology from sandstone to the mudstones of the Splitbæk Member of the Kuglelejet Formation (Fig. 10).

Thickness. Photogeological mapping indicates that the formation may reach a thickness of ~100 m below a scree slope (Svennevig *et al*. 2016; Fig. 6). The exposed part of the formation is more than 45 m thick.

Fossils and age. The fossils include ammonites, belemnites and plant material. The formation is upper Jurassic (Kimmeridgian), based on ammonites which include the early Kimmeridgian *Rasenia cymodoce* (Håkansson *et al*. 1994) and the late middle Kimmeridgian *Amoeboceras* (*Amoebites*) *elegans* (Fig. 6).

Lithological description. A uniform, dark grey to black, very fine- to fine-grained sandstone. Weathered rock surfaces show a pale coating that locally obscures sedimentary structures. The deposits, where visible, show parallel lamination, faint undulatory lamination, ripple cross-lamination and rare dune-scale cross-bedding. Plant fragments are common, belemnites and ammonites occur locally. The lower part of the formation is characterised by the trace fossil *Thalassinoides* isp., whereas the top part contains common

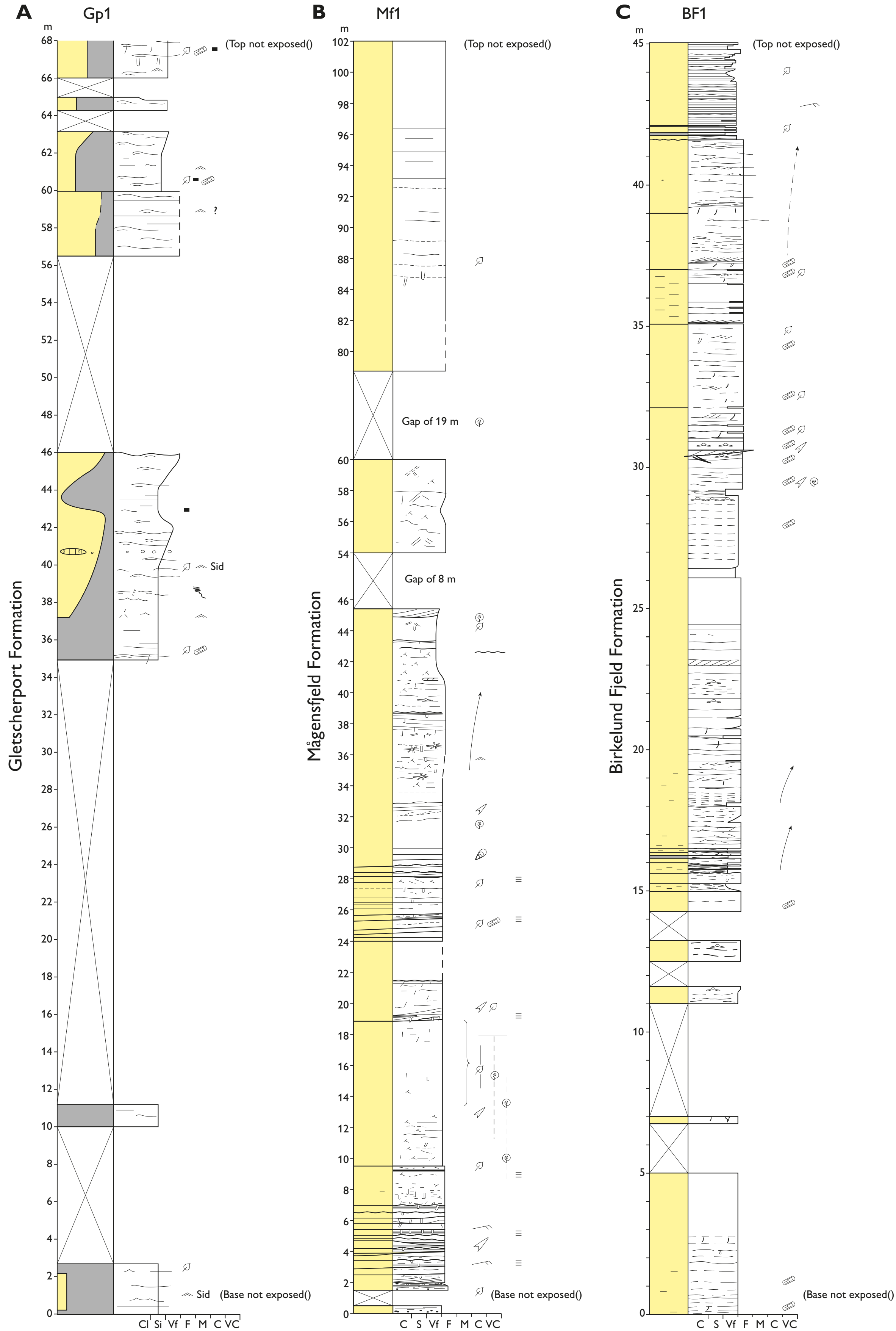


Fig. 8. A: Sedimentological log Gp1 of the type section of the Gletscherport Formation. **B**: Sedimentological log Mf1 covering the exposed part of the type section of the Mågensfjeld Formation. **C**: Sedimentological log BF1 covering the exposed part of the type section of the Birkelund Fjeld Formation. The logs are located in Figs 3, 7, 10.

Rhizocorallium isp. (see also Heinberg & Håkansson 1994; Håkansson *et al*. 1994; Dypvik *et al*. 2002).

Depositional environment. The fossil and trace fossil contents point to an overall shallow marine depositional environment. The deposits lack wave-generated sedimentary structures and comprise unidirectional current-generated structures, which could point to a sheltered setting such as an embayment or a bay. The sporadically bioturbated, stacked parallel laminated beds may point to a gravity flow origin and a proximal prodelta-like environment, particularly in the top part of the formation.

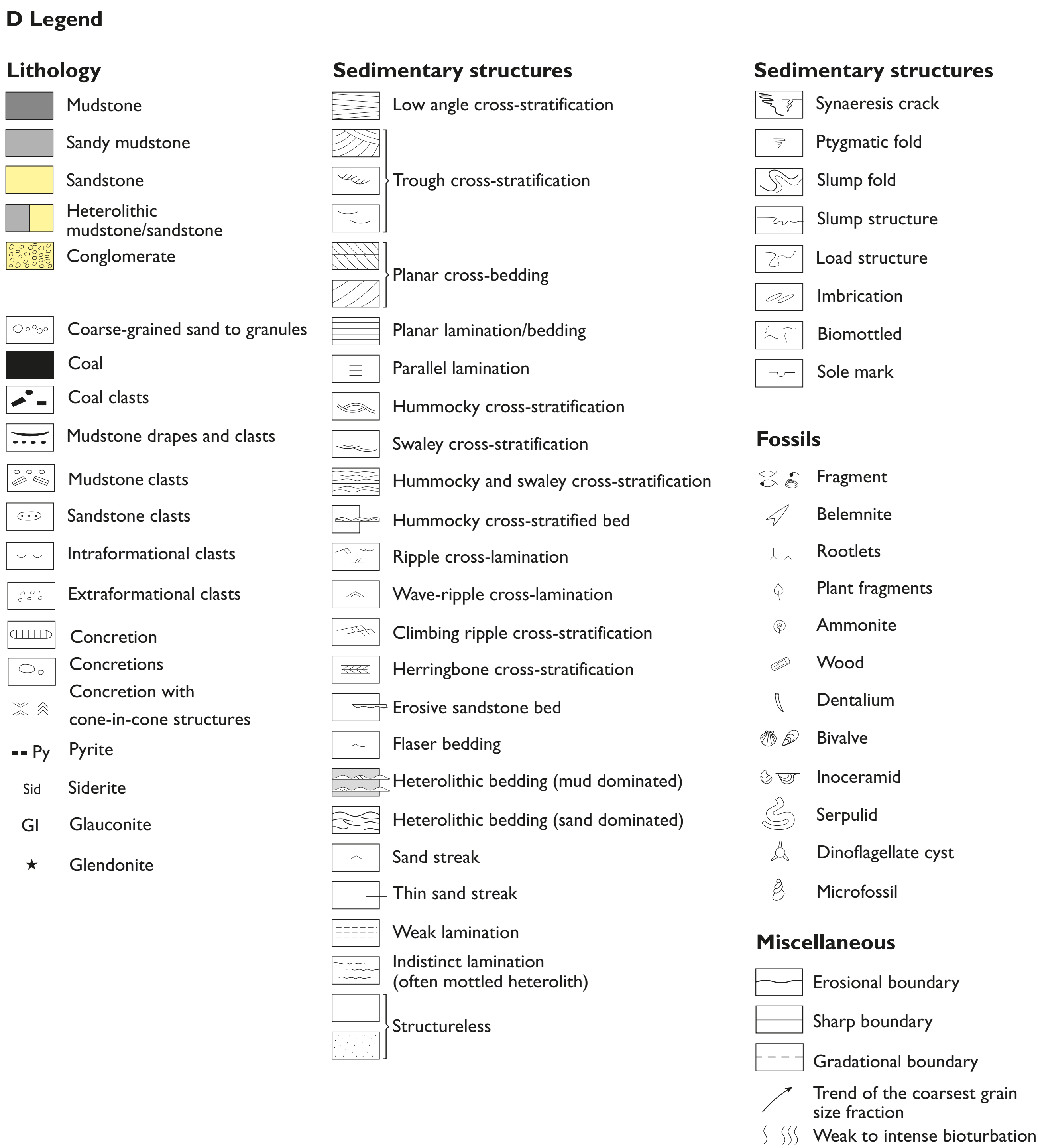


Fig. 8. D: Legend for all sedimentological logs in this paper.

Fig. 9. Type section of the Mågensfjeld Formation, Mågensfjeld hill, Kilen Fjelde. Height of the exposure *c.* 100 m. View towards the south.

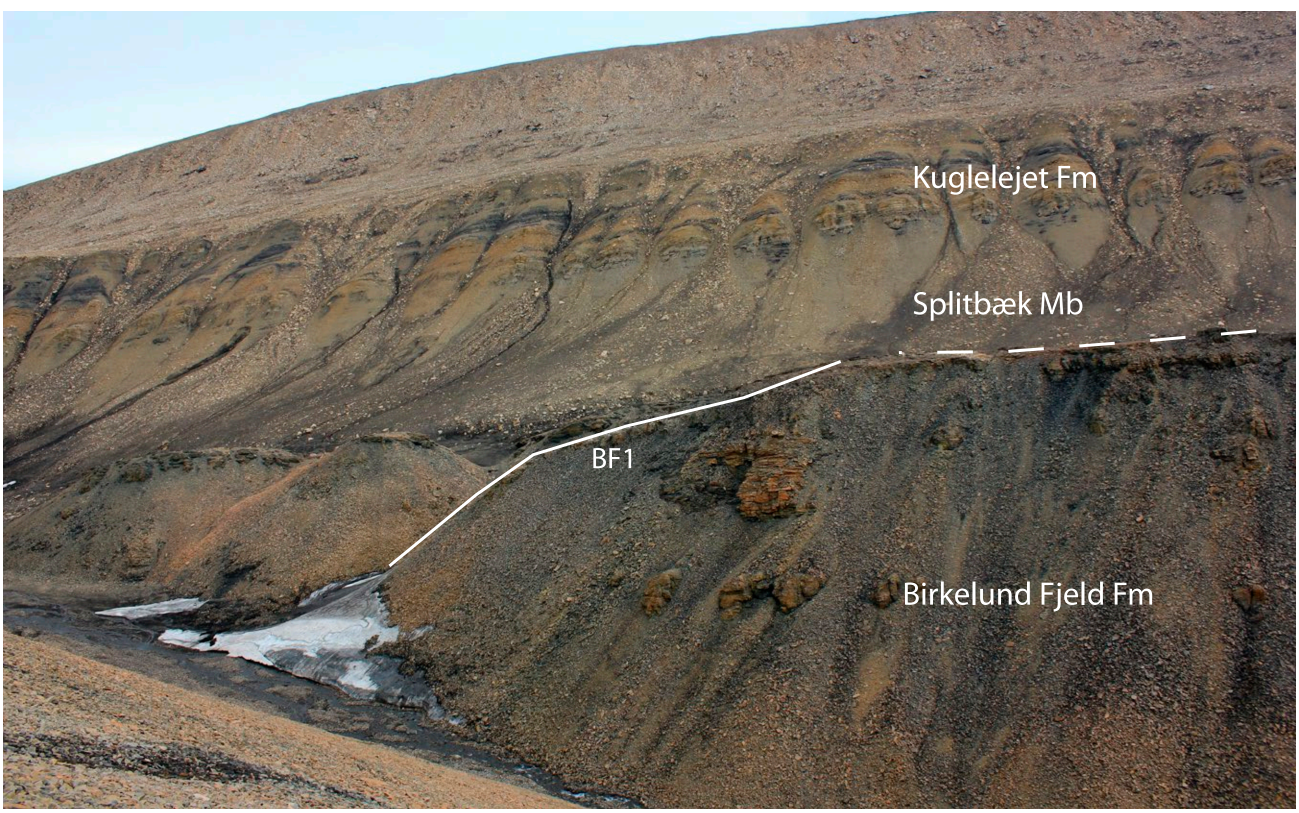


Fig. 10. Type section of the Birkelund Fjeld Formation. Sedimentological log BF1 covers the exposed part of the formation (Fig. 8C); its approximate location is shown. The log trace runs partly behind the ridge. The lower part of the formation is not exposed. The scree slope of the Birkelund Fjeld Formation is *c.* 50 m high. View towards the west-south-west.

Kuglelejet Formation

Name and history. The unit was mapped by Pedersen (1991) and described by Håkansson *et al*. (1994) and Dypvik *et al*. (2002). It is named after a topographic depression with abundant spherical concretions. The unit is redefined and formalised in the present study, and a new member is erected.

Subdivision. The Splitbæk Member forms the lower part of the formation.

Distribution. The unit crops out in the Dromledome, Lichenryg and Kuglelejet areas, Kilen Fjelde (Fig. 3).

Type section. The Dromledome anticline, where the sedimentological logs Kl1 and Kl2 cover the exposed part of the type section (Figs 11–12). The base of the exposure is located at 81°15′05.2″N, 013°55′24.6″W.

Boundaries. The lower boundary is mainly covered by scree, but is placed at the first appearance of black mudstone above bioturbated sandstone of the Birkelund Fjeld Formation (Fig. 10). The upper boundary is partially covered by scree and is placed at the first appearance of black shale (Dromledome Formation; Fig. 14) above bioturbated sandstone.

Thickness. Photogeological mapping suggests that the formation may reach a thickness of ~185 m (Svennevig *et al*. 2016). The exposure is ~80 m thick (Fig. 6).

Fossils and age. The middle Volgian *D. gracilis* Zone was recorded by Håkansson *et al*. (1994), probably derived from material in C. Heinberg's 1980-collection, which contains specimens identified as *D.* cf./aff. *gracilis* by J.H. Callomon. New ammonite data include upper lower Volgian *Pectinatites groenlandicus*, lower middle Volgian *Pavlovia corona*, middle Volgian *Laugeites cf. greenlandicus* and upper middle Volgian *Epilaugeites vogulicus*. Other fossils include plesiosaurus remains (Håkansson *et al*. 1994; Dypvik *et al*. 2002). The Splitbæk Member interval lacks age diagnostic fossils.

Lithological description. The lower half of the formation comprises an upwards coarsening succession consisting of black sandy mudstone that grades into bioturbated muddy sandstone and further into cross-bedded fine- to medium-grained sandstone. The upper part of the formation is characterised by bioturbated muddy sandstone and bioturbated sandstone. Typical trace fossils include grazing structures, *Thalassinoides* isp. and *Teichichnus* isp. (see also Heinberg & Håkansson 1994; Håkansson *et al*. 1994); cross-bedded intervals show vertical trace fossils such as *Diplocraterion* isp. and *Siphonichnus* isp.

Depositional environment. The deposits lack typical wave-generated sedimentary structures and comprise structures generated by non-oscillatory flows. This together with the trace fossil content and the high bioturbation intensity point to a sheltered setting such as an embayment or a bay.

Splitbæk Member

Name and history. The unit was mapped by Pedersen (1991) and described by Håkansson *et al*. (1994). It is named after a stream in Kilen Fjelde near the type section. The unit is hereby formalised as a member within the Kuglelejet Formation.

Distribution. The formation has a single occurrence in the Dromledome area, Kilen Fjelde (Fig. 3).

Type section. The type section is located on the eastern slope of the Dromledome anticline, Kilen Fjelde (Figs 12A, 13). The exposed part of the section is covered by the log Sl-Kl1. The base of the exposure is located at 81°15′05.2″N, 013°55′24.6″W.

Boundaries. The lower boundary corresponds to that of the formation. It is partly below scree and placed at the first appearance of black mudstone above bioturbated sandstone of the Birkelund Fjeld Formation (Figs 10, 11). The upper boundary is gradational and placed where bioturbated muddy sandstone becomes the dominant facies (undifferentiated Kuglelejet Formation; Fig. 12A).

Thickness. The exposed interval is >20 m thick, but the formation continues below the scree slope. Photogeological mapping suggests that the member reaches a thickness of *c*. 75 m (Svennevig *et al*. 2016).

Fossils and age. No macrofossils or microfossils have been observed. The late Jurassic age is constrained by the underlying middle Kimmeridgian and the overlying middle Volgian units (Fig. 6B).

Lithological description. An upwards coarsening sandy mudstone succession above the Birkelund Fjeld Formation. The poorly exposed base shows black mudstone rich in framboidal pyrite. The member grades upwards into bioturbated sandstones of the upper part of the Kuglelejet Formation. Common trace fossils include *Phycosiphon* isp. and *Chondrites* isp. at the top of the member.

Depositional environment. The sedimentological characteristics and the trace fossil suite (stressed distal *Cruziana* ichnofacies in the top of the member)

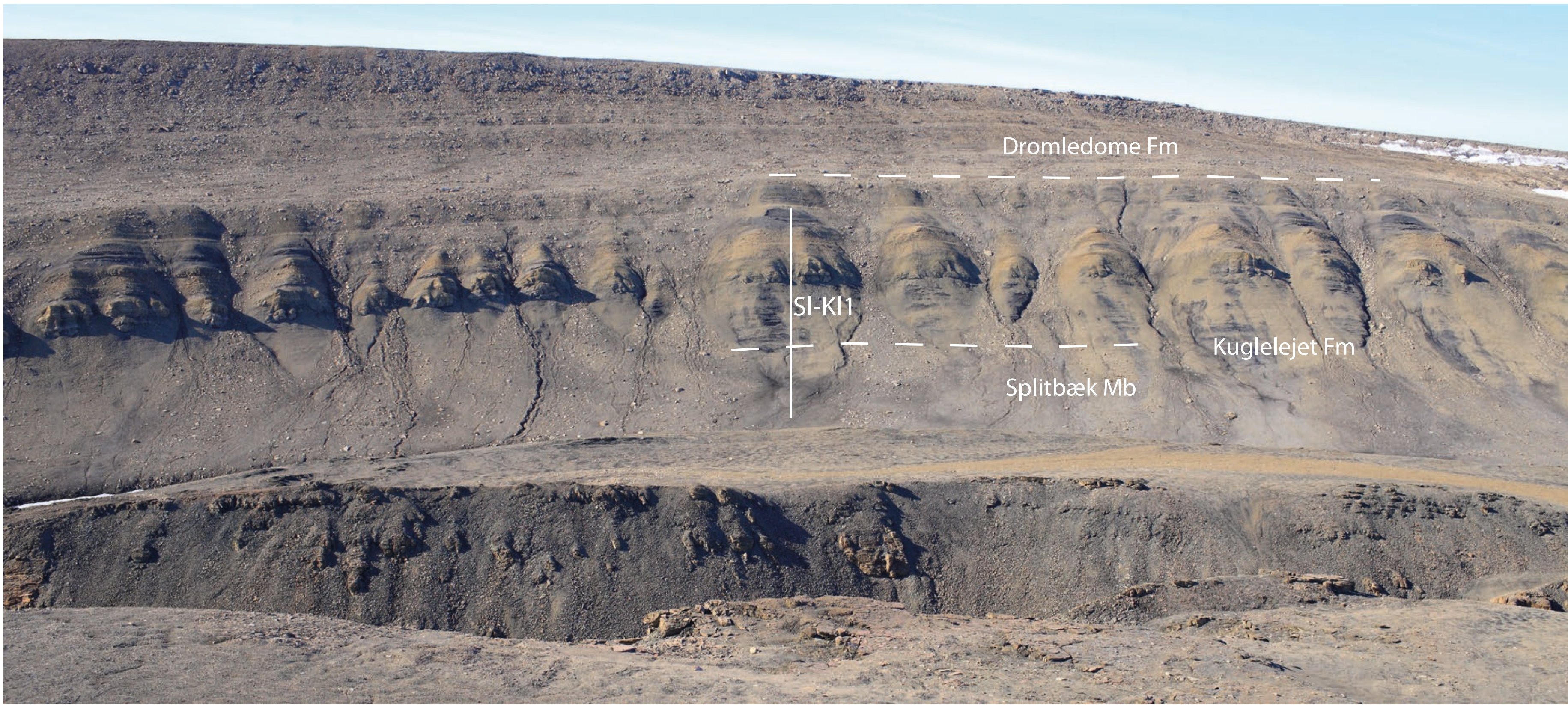


Fig. 11. Type section of the Kuglelejet Formation, Dromledome anticline. Sedimentological log Sl-Kl1 (*c*. 70 m high, approximate location indicated) represents the lower part of the type section (Fig. 12). See Fig. 14 for location of section Kl2. View towards the west.

Fig. 12. A and **B**: Sedimentological log Sl-Kl1 covering the lower half of the type section of the Kuglelejet Formation, including the Splitbæk Member. A dashed line indicates the approximate position of the upper boundary of the Splitbæk Member. **C**: Sedimentological log Kl2 covering the upper part of the type section of the Kuglelejet Formation. For location of the logs see Fig. 3.

Fig. 13. Type section of the Splitbæk Member of the Kuglelejet Formation, Dromledome anticline. Height of the mudstone dominated slope below the cliff is *c.*100 m. View towards the south.

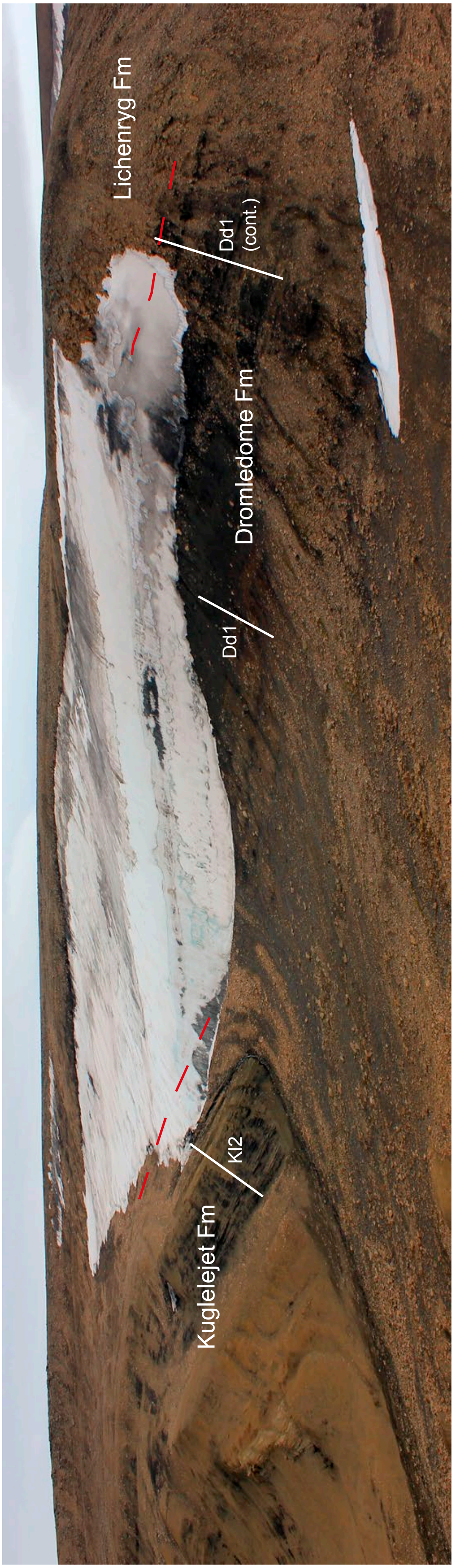


Fig. 14. Type section of the Dromledome Formation, Dromledome anticline. View towards the west. The composite *c.* 70 m thick log Dd1 (approximate location shown) covers the exposed part of the type section. The location of the section Kl2 (Fig. 12C) is also indicated

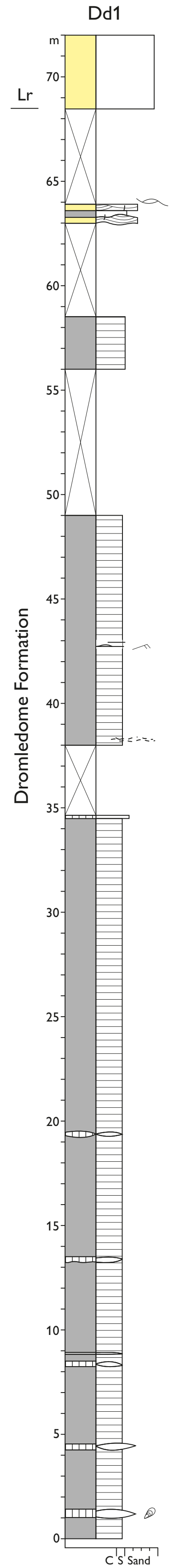


Fig. 15. Sedimentological log Dd1 of the upper part of the type section of the Dromledome Formation and the boundary to the Lichenryg Formation (Lr). For location of the log see Fig. 3.

suggest deposition in an oxygen-restricted offshore environment. The stratigraphic position with a gradational transition to the overlying part of the Kuglelejet Formation (see above) further suggests that the deposition took place in a spatially restricted setting such as an embayment, bay or seaway (see also Heinberg & Håkansson 1994).

Dromledome Formation

Name and history. The unit was mapped by Pedersen (1991) and described by Håkansson *et al*. (1994) and Dypvik *et al*. (2002). It was named after an anticline in the main outcrop area. The unit is formalised here.

Distribution. The formation crops out in the Dromledome and Kuglelejet areas, Kilen Fjelde (Fig. 3).

Type section. The Dromledome area constitutes the type section. The exposed part of the type section is documented in the sedimentological log Dd1 (Figs 14 and 15). The base of the exposure is located at 81°15′39.0″N, 013°57′22.9″W.

Boundaries. The exact lower boundary is covered by scree, but the exposed sediments below and above the scree demonstrate a change in lithology from bioturbated sandstone (Kuglelejet Formation) to black mudstone (Dromledome Formation). The upper boundary is variably exposed but placed at a sharp change in lithology from mudstone with hummocky cross-stratified sandstone layers to conglomerates and coarse-grained sandstone (Lichenryg Formation).

Thickness. The formation is *c*. 70 m thick (Fig. 6).

Fossils and age. The age is late Ryazanian/early Valanginian–Hauterivian based on ammonites, *Buchia* ssp. and foraminifera (Fig. 6B). *Buchia* bivalves were reported by Håkansson *et al*. (1981a), and Valanginian polyptychitid ammonites were reported by Birkelund & Håkansson (1983). New data include a diverse ammonite fauna with *Surites* (*Caseyiceras*) *caseyi*, *S.* (*C.*) *subanalogus, S.* cf. *simplex, Polyptychites* sp., *P.* (*Euryptychites*) spp., *Nikitinoceras* (*Russanovia*) cf. *diptychum* and possible *N. hoplitoides* and *Dichotomites* (*Dichotomites*) *bidichotomus*, indicating an age range of late Ryazanian to late Valanginian. A specimen of *Simbirskites* (*Milanowskia*) aff. *staffi* in the C. Heinberg and E. Håkansson collection extends the age range into the Hauterivian. New collections of *Buchia sublaevis* and *B. keyserlingi* indicate the late early Valanginian, *B. keyserlingi* Zone based on Surlyk & Zakharov (1982). The foraminifer fauna includes common *Falsogaudryina praemoesiana* and has a late Valanginian–early late Barremian age.

Lithological description. A black mudstone succession with recurring concretionary intervals in the lower part of the formation (0–20 m in Fig. 15). The top of the formation shows beds with hummocky cross-stratification. Typical trace fossils include *Zoophycos* isp., *Nereites* isp. and *Chondrites* isp. in the lower part of the formation, whereas *Gyrochorte* isp. and *Paleophycus heberti* occur in hummocky-cross-stratified beds.

Depositional environment. The sedimentological characteristics as well as trace fossil and fossil content indicate a shelf to offshore environment.

Lichenryg Formation

Name and history. The unit was mapped by Pedersen (1991) and described by Håkansson *et al*. (1994) and Dypvik *et al*. (2002); see also Røhr *et al*. (2008). It is named after a prominent ridge formed by the formation in the north-western part of Kilen Fjelde. The unit is formalised in the present study.

Distribution. The Kuglelejet, Dromledome and Lichenryg areas, Kilen Fjelde (Fig. 3).

Type section. The Dromledome anticline. The type section is covered by the log Lr1 (Figs 16, 17). The base of the section is located at 81°15′48.1″N, 013°56′55.9″W.

Reference section. Kuglelejet, where the upper part of the formation and the upper boundary are identified (Figs 18 and 19).

Boundaries. The lower boundary is sharp and erosive. It is placed where conglomerates and coarse-grained sandstones overlie the finer-grained Dromledome Formation (Fig. 17). The upper boundary is sharp and demarcated by an abrupt appearance of mudstone of the Galadriel Fjeld Formation above the sandstone of the Lichenryg Formation (Figs 17–19).

Fossils and age. Only plant fragments and moulds of dissolved bivalves have been discovered. The age is confined by the bounding units to the Hauterivian–late Aptian (see above and below; Fig. 6B).

Thickness. The thickness is variable, from *c*. 45 m to *c*. 100 m (Svennevig *et al*. 2016; Fig. 6).

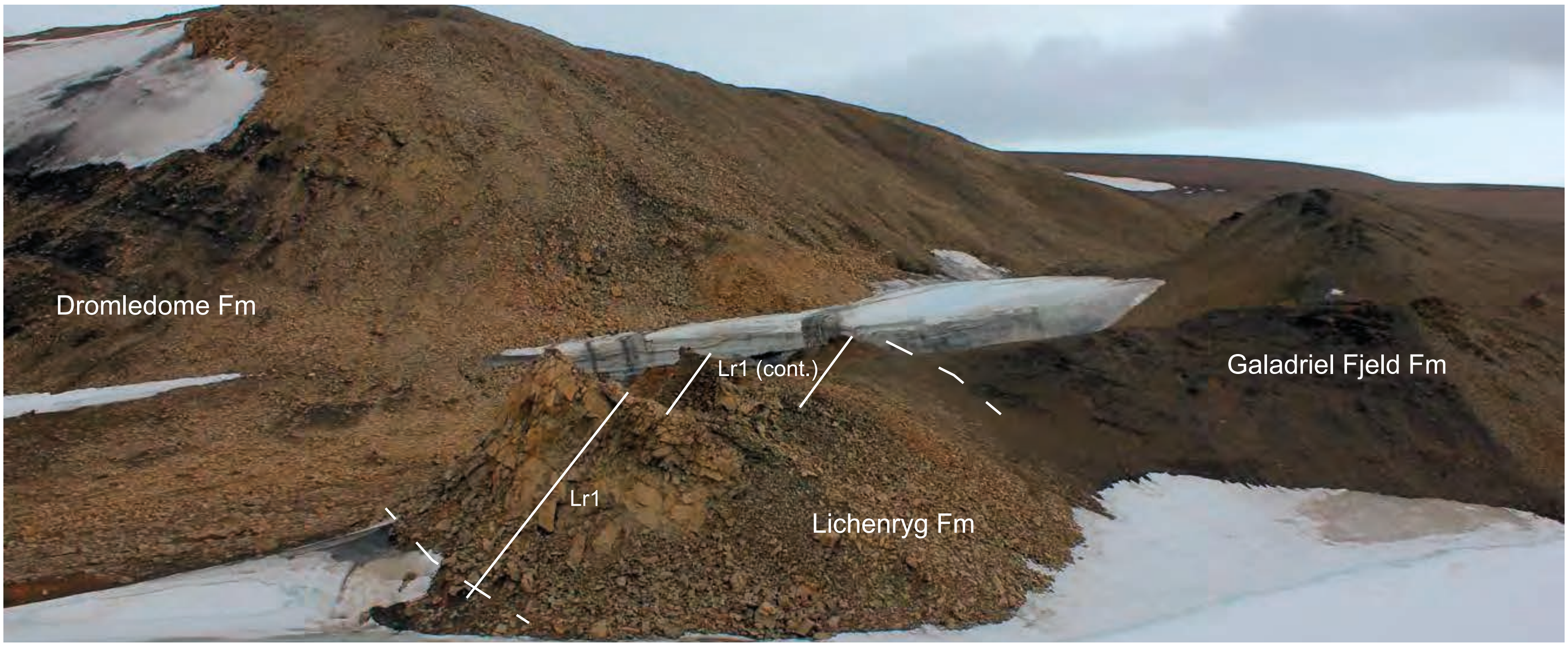


Fig. 16. Type section of the Lichenryg Formation, northern flank of the Dromledome anticline. Approximate location of the log Lr1 is shown. The type section outcrop is *c*. 45–50 m thick. View towards the west-northwest.

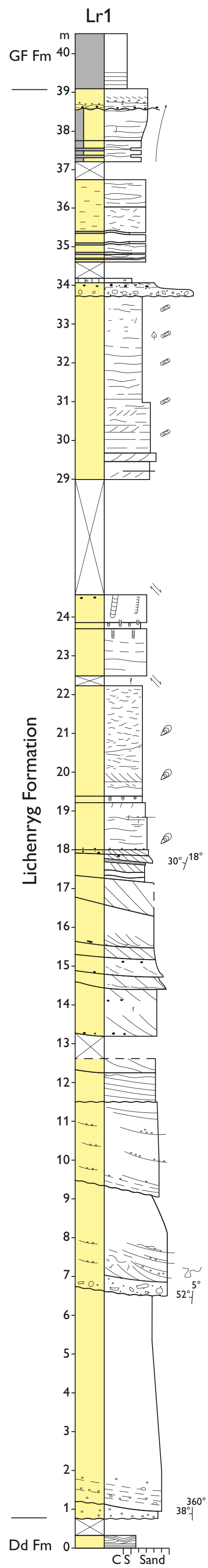


Fig. 17. Sedimentological log Lr1 illustrating the Lichenryg Formation type section. The measured section included a minor repetition which was omitted from this log. Dd Fm: Dromledome Formation. GF Fm: Galadriel Fjeld Formation. For location of the log see Fig. 3.

Lithological description. The lower part of the formation consists of matrix-supported conglomerates and very coarse- to coarse-grained trough and planar cross-bedded sandstones. The upper part of the formation is more heterolithic and shows fine- to medium-grained ripple and dune cross-stratified sandstone, structureless tabular sandstone beds as well as mud-drapes and mudstone interbeds. Erosional surfaces overlain by pebble- or mudclast conglomerates occur locally. Characteristic trace fossils include *Cylindrichnus* isp. and large *Diplocraterion parallelum* in the upper part of the formation (see also Håkansson *et al*. 1994).

Depositional environment. The sedimentological characteristics as well as trace fossil content point to fluvial and estuarine environments.

Galadriel Fjeld Formation

Name and history. The unit was mapped by Pedersen (1991) and described by Håkansson *et al*. (1994) and Dypvik *et al*. (2002). It was named after the hill Galadriel Fjeld in Kilen Fjelde. The formation is here redefined and formalised. Improved biostratigraphic data allow the inclusion of deposits previously referred to five other former formations (Fig. 5). Six new members are erected to cover the lithological variability between the outcrops across Kilen from Iskap and Tågekyst in the south to Saddelfjeld and Dipperne in the north (Figs 3, 4). In addition to the wide geographical distribution, the outcrops represent two thrust sheets that brought originally distant deposits in closer proximity (Svennevig 2017).

Subdivision. The "lower", "middle", and "upper" members of the Galadriel Fjeld Formation of Pedersen (1991) and Håkansson *et al*. (1994) are emended. Most of the deposits of the former "lower" and "middle" members are merged into a single new member, the Pil Member (Figs 5, 18). A part of the former "lower member" is exposed east of the major thrust fault (Fig. 3), and these deposits are described as the new Valmue Member. The former "upper member" is described as the new Stenbræk Member, which overlies the Pil Member in the Galadriel Fjeld area (Fig. 18).

The Galadriel Fjeld Formation now includes the sedimentary successions that formerly were referred to five formations, namely the Iver Pynt, Tågekyst, Kangoq Ryg, Hondal, and Dipperne Formations of Pedersen (1991) and Håkansson *et al*. (1994) (Figs 5, 6). The new Tågekyst Member comprises the deposits of the former Tågekyst Formation in central Gåseslette and along the Anduin river (Figs 4–6). The new Kangoq

Ryg Member includes the deposits of the former Iver Pynt and Kangoq Ryg Formations as well as deposits from the Tågekyst area, which formerly were part of the Tågekyst Formation (Figs 4–6). The new Hondal Member comprises the deposits of the former Hondal and Dipperne Formations. A thrust fault separates the new Hondal Member from the Valmue Member (Figs 3, 23A).

Distribution. The Galadriel Fjeld Formation is present in both the Kilen Fjelde and the Gåseslette areas (Figs 3, 4).

Type section. The Kuglelejet area is the type section of the Galadriel Fjeld Formation and of the Pil, Valmue and Stenbræk Members (sections Pi1, Va1 and St1–2, located in Fig. 3, see also Figs 18–22). The remaining members are exposed in various reference sections. The formation is not fully exposed at any single locality.

Reference sections. Sølverbæk river (exposures of the Kangoq Ryg Member), Anduin river (exposures of the Tågekyst Member), Lille Hondal area (exposures of the Valmue Member and the Hondal Member, separated by a thrust), Dipperne (exposures of the Hondal Member), Dromledome (exposures of the Pil Member), see sections Hd1–Hd3, Hd4–Hd5, Tk1 and KR1–KR2, located in Figs 3 and 4; see also Figs 23–31.

Thickness. The formation is *c.* 600 m thick in Kilen Fjelde. Photogeological mapping suggests that the formation may reach a thickness of 1400 m in the Gåseslette area (Svennevig *et al.* 2016; Fig. 5). Some members are coeval lateral equivalents.

Boundaries. The lower boundary is located at the first occurrence of dark grey shale and storm-deposited heteroliths above the sandstone of the Lichenryg Formation (Kuglelejet and Dromledome sections, Figs 17–19). The lower boundary is not exposed in the Gåseslette area. The upper boundary is variably exposed and is placed at the first appearance of a mudstone succession (Sølverbæk Formation) above sandstones, locally bioturbated, of the Hondal and Kangoq Ryg Members (Figs 23A, 29B, 32, 34).

Fossils and age. The formation is late Aptian – early to middle Cenomanian, based on inoceramids, foraminifera, dinocysts, ammonites and belemnites (Fig. 6B). See the discussion below of the ages of the individual members of the Galadriel Fjeld Formation. Scaphopods occasionally occur in large numbers on bedding planes. Other fossils include pectinid-, nucula- and macoma-type bivalves, ophiuroids, asteroids and wood fragments.

Lithological description. The formation is characterised by upwards coarsening successions comprising interbedded mudstone and sandstone. Storm-related deposits such as sandstone with hummocky cross-stratification and wave ripple cross-lamination are typical. The mudstone facies are strongly bioturbated, with trace fossils characteristic of the *Cruziana* ichnofacies.

Depositional environment. The formation is interpreted to represent storm-dominated offshore – shoreface environments (see below).

Pil Member

New member

Name and history. The member is named after the Arctic willow (*Salix arctica,* Arktisk pil in Danish), which grows in Kilen (Håkansson *et al*. 1993, table 1). The Pil Member comprises most of the former lower and middle members of the Galadriel Fjeld Formation (Pedersen 1991; Håkansson *et al.* 1994).

Distribution. The member is present in the Kuglelejet and Dromledome areas, Kilen Fjelde (Fig. 3).

Type section. The Kuglelejet area constitutes the type section (Figs 18, 19). The section is covered by the log Pi1, except for the upper boundary. The base of the section is located at 81°13′18.0″N, 013°53′11.1″W.

Reference section. The Dromledome area forms the reference section.

Boundaries. The lower boundary corresponds to that of the formation and is located at the first occurrence of dark grey shale and storm-generated heteroliths above the sandstones of the Lichenryg Formation. The upper boundary to the Stenbræk Member in the Kuglelejet area is gradational (Fig. 18) and demarcated by the appearance of metre-thick intervals with amalgamated hummocky cross-stratified sandstones which form the base of the Stenbræk Member.

Thickness. The member is *c.* 380 m thick (Fig. 6).

Fossils and age. The member is late Aptian – middle Albian based on foraminifera and inoceramids. The foraminifer fauna includes *Conorboides umiatensis, Serovaina loetterlei, Quadrimorphina albertensis* and *Saracenaria* sp. cf. *S. projectura,* which indicate a late Aptian to earliest Albian age in the lower part of the unit. Higher in the succession, inoceramids of the two species *I. cadottensis* and *I.* cf. *labiatiformis* occur in low

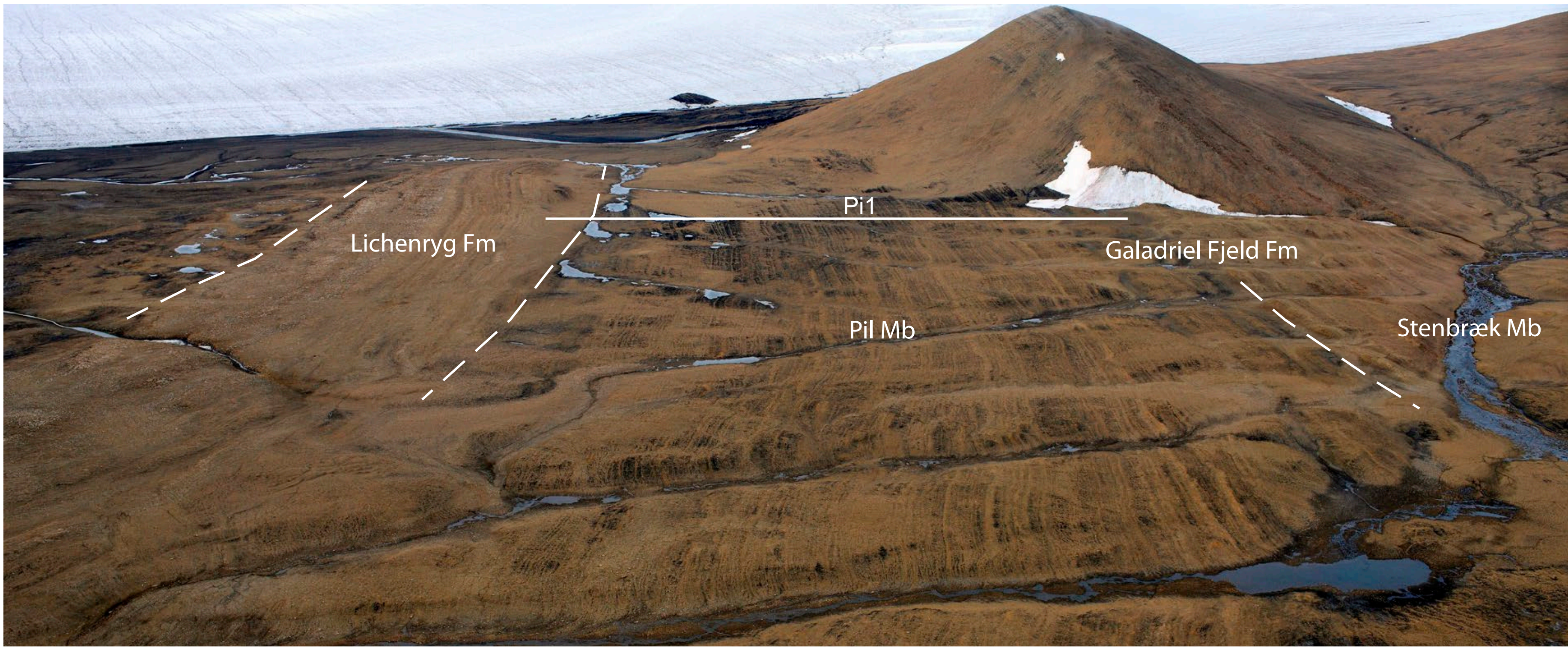


Fig. 18. Type section of the Pil Member (Galadriel Fjeld Formation), Kuglelejet area. View towards the west. The approximate location of the section Pi1 is shown. The strata dip 40°–50° towards the north. The depositional boundary between the Pil and the Stenbræk Members is indicated (dashed line). The hill in the background is Galadriel Fjeld (*c*. 200 m high). The outcrops of the Stenbræk Member are located in the lower slope of the Dromledome anticline (Fig. 3).

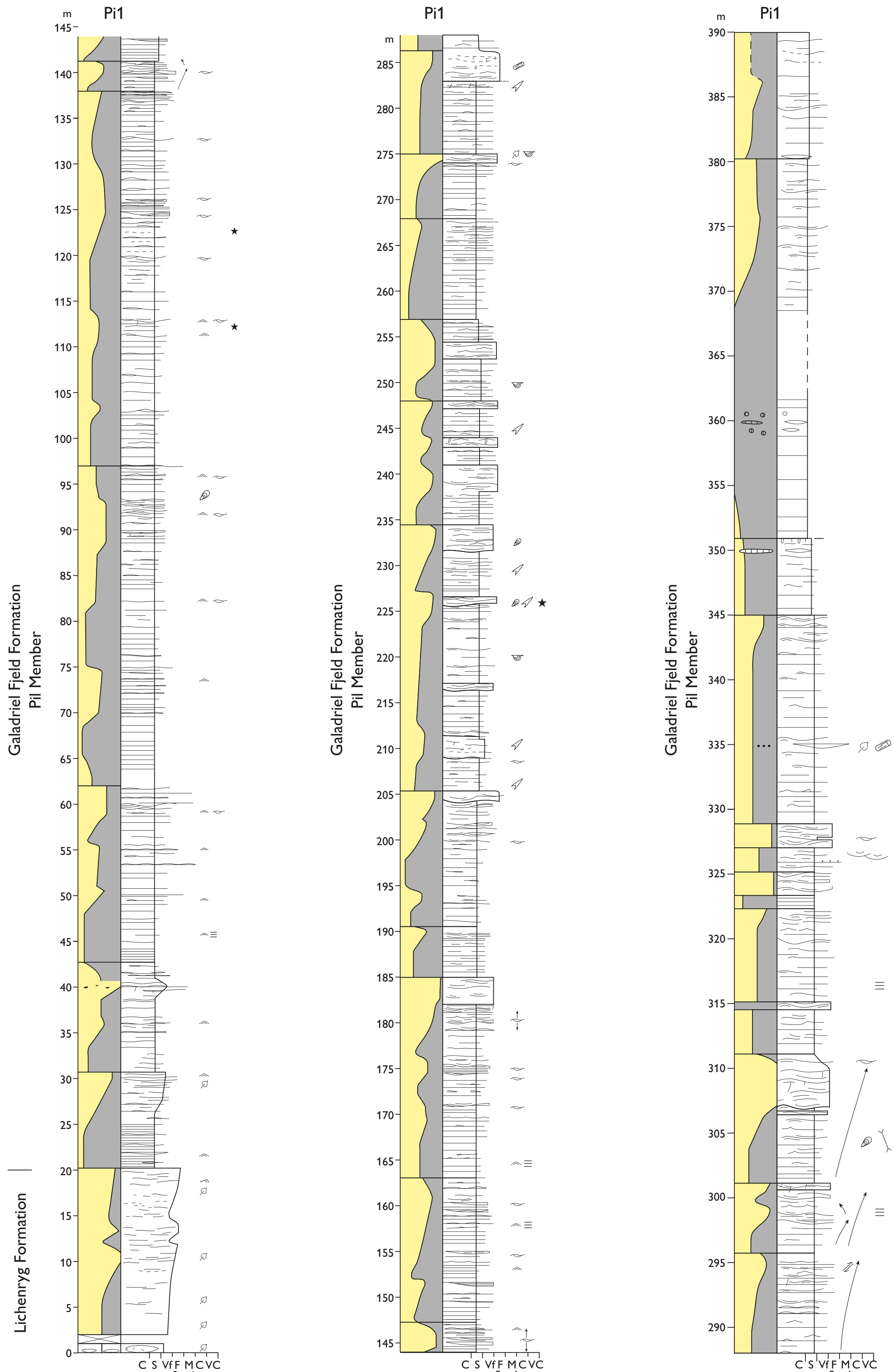


Fig. 19. Sedimentological log Pi1 representing the Pil Member type section. For location of the log see Figs 3, 18.

numbers. Both species indicate a middle to late middle Albian age when correlated to Svalbard, North-East Greenland and Arctic Canada (Stolley 1912; Woods 1912; Donovan 1953; Imlay 1961; Jeletzky 1964, 1968; Pchelina 1965; Pergament 1965; Crame 1985). Additional fossils include rare endemic belemnites and one fragment of a heteromorph, crioconic ammonite.

Lithological description. The deposits consist of mudstone-dominated upwards coarsening successions showing very fine- to fine-grained sandstone laminae/beds. The sandstone structures and facies include pinch-and-swell lamination, wave ripples and hummocky cross-stratified beds. Typical trace fossils include *Phycosiphon* isp., *Nereites* isp., *Chondrites* isp. and *Gyrophyllites* isp. (see also Håkansson *et al*. 1993; Heinberg & Håkansson 1994; Håkansson *et al*. 1994; Dypvik *et al*. 2002). The tops of the upwards coarsening successions show a higher trace fossil diversity. Moreover, the deposits are also characterised by glendonites, which occur locally as clusters of radiating pseudomorphs up to *c*. 5 cm in diameter. Glendonites are also reported from the probably time equivalent Invincible Point Member of the Christopher Formation, and in the Valanginian in the older upper Deer Bay Formation in the Sverdrup Basin (Schröder-Adams *et al*. 2014; Grasby *et al*. 2017). Likewise, glendonites occur in the probably equivalent Carolinefjellet Formation, and in the Valanginian in the older Rurikfjellet Formation on Svalbard (Price & Nunn 2010; Mutrux *et al*. 2008; Vickers *et al*. 2016).

Depositional environment. The distribution of storm and fair weather deposits coupled with the trace fossil content indicate deposition in lower offshore – upper offshore environments.

Stenbræk Member

New member

Name and history. The member was previously referred to as the upper member by Pedersen (1991) and Håkansson *et al*. (1994) (Fig. 5). It is named after the Saxifrage plant group (*Saxifraga* in Latin, Stenbræk in Danish), which is represented by seven species that flower at Kilen (Håkansson *et al*. 1993, their table 1). See also Dypvik *et al*. (2002).

Distribution. The member crops out in Kilen Fjelde in the Kuglelejet, Dromledome, and Birkelund Fjeld areas, as well as south of Dromledome (Figs 3, 18, 20).

Type section. The area south of Dromledome forms the type section (Fig. 20). The section illustrates the lithological characteristics of the member (see logs St1 and St2, Fig. 21), but the boundaries are not visible. The base of section St1 is located at 81°14′27.3″N, 013°50′58.9″W.

Reference sections. The Galadriel Fjeld and Kuglelejet areas constitute the reference sections (Figs 3 and 18). The Kuglelejet area includes the lower boundary of the member.

Boundaries. The lower boundary to the Pil Member is gradational and demarcated by the appearance of several metre thick amalgamated sandstone successions, which form the base of the Stenbræk Member. The upper boundary is not exposed as the member is truncated by the present-day subaerial surface.

Thickness. The exact thickness of the Stenbræk Member is unknown. Photogeological mapping suggests that the unit is more than 200 m thick.

Fossils and age. Fossils include inoceramid- and non-age indicative bivalves such as pectinid-, nucula- and macoma-type bivalves. *Inoceramus cadottensis,* which is also recorded in the Pil Member, indicates the late middle Albian (Woods 1912; Donovan 1953; Pergament 1965; Kauffman 1977; Crame 1985). This age is confirmed by the presence of *Inoceramus* cf. *labiatiformis* and *I. spitzbergensis,* which by correlation to Svalbard and Europe suggests a middle Albian age (Stolley 1912; Woods 1912; Pchelina 1965; Crame 1985).

Lithological description. Sand-dominated, upwards coarsening successions characterised by amalgamated hummocky cross-stratified beds, gutter casts and other channelised storm beds. Typical trace fossils include *Lockeia* isp. and *Gyrochorte* isp. (see also Håkansson *et al*. 1993; Heinberg & Håkansson 1994; Dypvik *et al*. 2002).

Depositional environment. The distribution of storm and fair weather deposits coupled with the trace fossil content indicate deposition in storm-dominated upper offshore – lower and middle shoreface environments. In particular, the trace fossil assemblage of the fair weather deposits, where preserved, records archetypal and proximal *Cruziana* ichnofacies and deposition above fair weather wave base in the top of the upward coarsening successions.

Valmue Member

New member

Name and history. The unit was previously referred to

Fig. 20. Type section of the Valmue and Stenbræk Members (Galadriel Fjeld Formation), to the south of the Dromledome anticline. View towards the north-west. The contact between the members (dashed line) is a fault (Fig. 3). The outcrops of the sandstone-dominated Stenbræk Member form a belt, which is *c.* 200 m wide in the photo.

as part of the lower member by Pedersen (1991) and Håkansson *et al*. (1994). It is named after the plant Arctic poppy (*Papaver radicatum* in Latin or Fjeld-valmue in Danish), which flowers in Kilen (Håkansson *et al*. 1993: their table 1).

Distribution. The Valmue Member is present in the Kuglelejet area, Lille Hondal and Mågensfjeld, Kilen Fjelde (Fig 3).

Type section. The Kuglelejet area constitutes the type section (Fig. 20). The sedimentological log Va1 illustrates the type section (Figs 3, 22). The base of the section is located at 81°14′18.4″N, 013°50′12.8″W.

Thickness. The exact thickness of the Valmue Member is unknown. Photogeological mapping suggests a thickness of more than 250 m (Svennevig *et al*. 2016; Fig. 6).

Boundaries. The unit is fault-bounded, see Fig. 3.

Fossils and age. The Valmue Member is of late Aptian–early Albian age, based on foraminifera. The foraminifer fauna includes *Conorboides umiatensis*, *Quadrimorphina albertensis* and *Serovaina loetterlei*, which also characterise the lower part of the Pil Member (see above; Sheldon *et al*. 2017). The member also contains coalified wood.

Lithological description. A black shale/mudstone succession that locally grades into sandy mudstone and heterolithic interlaminated sandstone with pinch-and-swell lamination, wave-ripple cross-lamination and rare thin hummocky cross-stratified sandstone beds. The deposits are also characterised by common large concretions which weather bright yellow. Glendonites and *Teredolites* isp. (bored wood) occur locally. Other typical trace fossils include common *Nereites* isp and

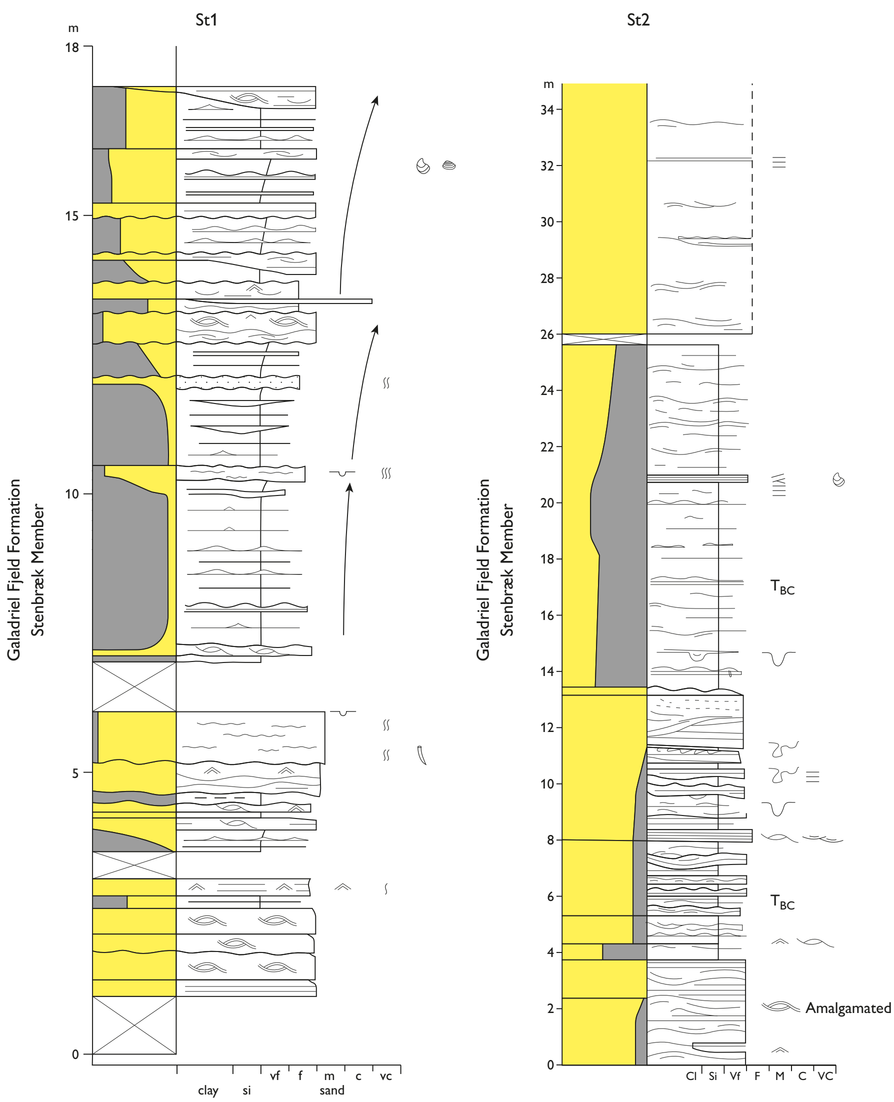
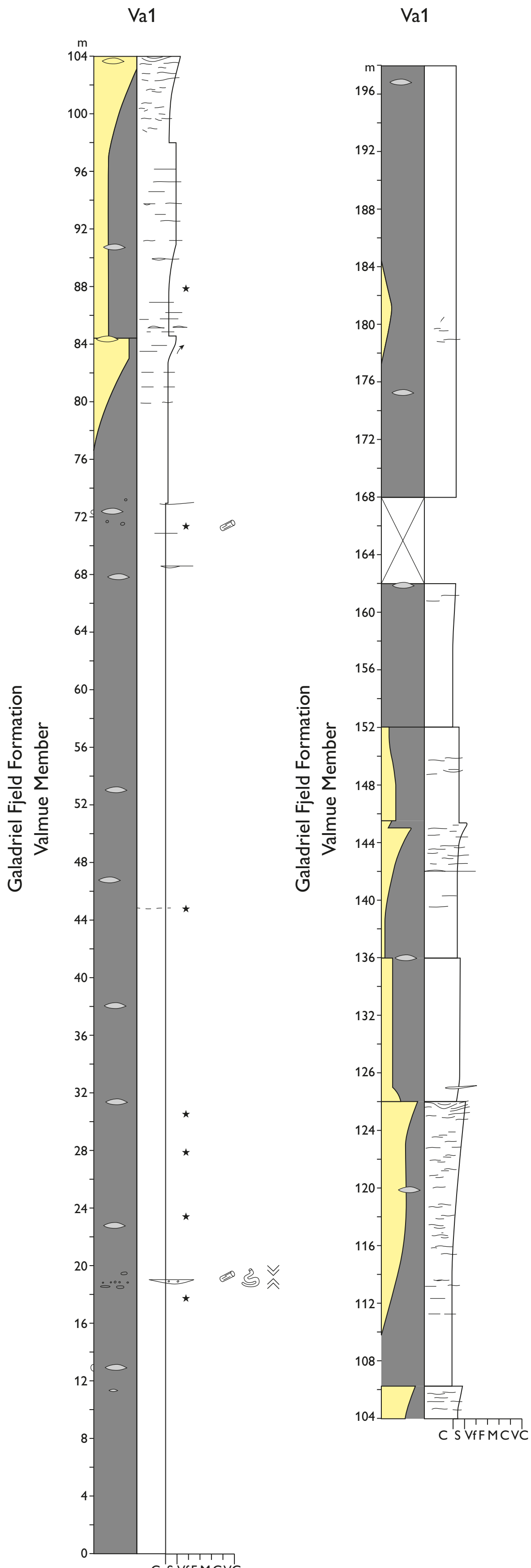


Fig. 21. Sedimentological logs St1 and St2 from the Stenbræk Member type section. The type section is intensively faulted and it is therefore not possible to measure a continuous section through the member. For this reason, the stratigraphic relationship of the measured logs is not clear. For location of the logs see Fig. 3.



Helminthopsis isp. The Valmue Member differs from the coeval Pil Member in grain size (the Valmue Member is more fine-grained) and diagenesis (the characteristic concretions).

Depositional environment. The distribution of storm and fair weather deposits coupled with the trace fossil content indicate deposition in shelf (below maximum storm wave-base) and offshore environments.

Hondal Member

New member

Name and history. The member comprises the successions that were previously described as the Hondal and Dipperne Formations of Håkansson *et al*. (1994). Their distribution was mapped by Pedersen (1991).

Distribution. The Hondal Member crops out in Kilen Fjelde. The member is exposed in Lille Hondal as well as in northernmost Kilen Fjelde at Saddelfjeld and in nunataks in Flade Isblink (Dipperne area) (Fig. 3). The distribution of the Hondal Member was mapped by Svennevig (2018a).

Type section. Lille Hondal (Fig. 23A). Three consecutive sedimentological logs, Hd1–Hd3, represent the type section (Figs 24–25), located in Figs 3 and 23A. The position of the base of Hd1 is 81°16′27.6″N, 013°54′23.13″W.

Reference section. Dipperne (Fig. 23B). The sedimentary logs Hd4 and Hd5 (Fig. 26) cover the lower part of the outcrop area at Dipperne; the top remains unstudied. The stratigraphic relationship between Hd1–Hd3 and Hd4–Hd5 is unclear due to lack of age diagnostic fossils from sections Hd4 and Hd5.

Thickness. A thickness of *c*. 600 m was suggested by Svennevig *et al*. (2016). The measured type section covers 370 m of the Hondal Member, with unexposed sections below and above (Fig. 23A). Håkansson *et al*. (1994) estimated a thickness of 550 m for the Dipperne area.

Boundaries. In Lille Hondal, the lower boundary to the Valmue Member is a thrust fault (Svennevig 2018a; Figs 3, 23A). The upper boundary to the Skalbæk Member of the Sølverbæk Formation is not exposed (Fig. 23A); however, an approximate position of the

Fig. 22. Sedimentological log Va1 illustrating the lithological characteristics of the Valmue Member. Lower part of the type section, for location of the log see Fig. 3.

boundary is indicated by an abrupt change in topography, which suggests a change from dominantly sandstone to mudstone. This upper boundary of the Hondal Member constitutes the upper boundary of the Galadriel Fjeld Formation in the Kilen Fjelde area.

In the northern Kilen Fjelde, the lower boundary is observable in the Saddelfjeld area, where the member directly overlies the Sølverbæk Formation with a thrust fault contact (Svennevig 2018a). The upper boundary is the present-day subaerial erosion surface.

Fossils and age. The Hondal Member is middle to late Albian (Fig. 6), based on inoceramids and ammonites. The Hondal Member is partly coeval with the Stenbræk and the Kangoq Ryg Members of the Galadriel Fjeld Formation on the basis of the faunal assemblages. Age indicative inoceramids include *Gneisoceramus comancheanus* and *Inoceramus anglicus*, which indicate a middle to late Albian age based on correlations to the Western Interior Basin (Walaszczyk & Cobban 2016), East Greenland (Donovan 1953) and Central Europe (Crame 1985). Ammonites include an assemblage of late middle Albian hoplitinids including *Euhoplites lautus*, *Euhoplites truncatus* and *E.* aff. sp. *subtuberculatus*, and gatroplitinids including *Pseudogastroplites draconensis* and *Pseudopulchellia flexicostata, P.* cf. *ballkwilli* (Alsen 2018a). The ammonite fauna also includes slightly younger latest middle Albian *Stelckiceras liardense* and earliest late Albian *Gastroplites* cf. *cantianus*. Other fossils include *Panopea*-type and pectinid bivalves, brachiopods, ophiuroids, asteroids and scaphopods.

Lithological description. The member is characterised by upwards coarsening successions of interbedded mudstone and sandstone (Figs 24–25). The type section (see logs Hd1–Hd3) demonstrates an overall development from mudstone- to sandstone-dominated facies with trace fossils mainly of the *Cruziana* ichnofacies. Few thin beds of medium- to coarse-grained sandstone occur. Multidirectional trough cross-bedding is locally present in the upper parts of the upward coarsening successions in Dipperne (section Hd5). The Hondal Member differs from the Stenbræk Member by the local presence of medium- to coarse-grained sandstone, trough cross-bedding and the trace fossil *Zoophycos* isp.

Depositional environment. The distribution of storm and fair weather deposits coupled with the trace fossil content indicate deposition in proximal offshore to shoreface environments. The multidirectional trough cross-bedding coupled with occurrences of trace fossil *Macaronichnus* suggest that the environment locally reached the surf zone of the upper shoreface.

Tågekyst Member

New member

Name and history. The member includes some of the sediments that were formerly referred to the Tågekyst Formation (Pedersen 1991; Håkansson *et al*. 1994).

Distribution. The member is mapped from aerial photos across large parts of Gåseslette (Pedersen 1991; Svennevig *et al*. 2015; Svennevig 2018a). It is exposed in low cliffs adjacent to the Anduin river (Fig. 4). The deposits in the Tågekyst area, which were formerly mapped as the Tågekyst Formation (Pedersen 1991), are now referred to the Kangoq Ryg Member.

Type section. The outcrops along the northern part of the Anduin river form the type section (Fig. 27D). A short sedimentological log Tk1 is shown in Fig. 28; this includes neither the lower nor the upper boundary of the member. The position of the base of Tk1 is 81°12′08.2″N, 013°10′51.99″W.

Reference section. The little known outcrops along the southern part of the Anduin river constitute the reference section (Fig.27D).

Thickness. Photogeological modelling indicates that the member is at least 800 m thick in the type section (Svennevig *et al*. 2016).

Boundaries. The lower boundary is unknown. The upper boundary towards the Kangoq Ryg Member is unknown. Figure 4 shows a fault boundary between the Tågekyst Member and the Sølverbæk Formation at the Anduin river.

Fossils and age. No fossils have yet been found in the Tågekyst Member, and this is considered a significant difference from the Kangoq Ryg Member. Due to the lack of fossils, the age of the Tågekyst Member is unknown. The member is tentatively placed in the lower part of the Galadriel Fjeld Formation, but it is not possible to suggest a correlation with the Pil or Valmue Members.

Lithological description. Sandy, commonly bioturbated mudstones interbedded with fine- to medium-grained sandstone (Fig. 27A). The sandstone may show hummocky cross-stratification and wave-ripples. Coarse-grained sandstone beds occur locally in the area containing the section Tk1 (Figs 27B, C and 28). A diverse trace fossil assemblage represents the *Cruziana* ichnofacies. A strong diagenetic overprint in the Anduin river area is indicated by growth of authigenic minerals along joints.

Fig. 23. A: Type section of the Hondal Member (Galadriel Fjeld Formation) in Lille Hondal (Fig. 3), view towards the west. The type section consists of three consecutive logs, Hd1, Hd2 and Hd3 (Figs 24, 25). The log Hd2 is ~40 m long. The lower boundary to the Valmue Member is tectonic (dashed line). The upper boundary to the Skalbæk Member of the Sølverbæk Formation is not exposed; the approximate location is indicated with a dashed line. **B**: Lower part of the reference section of the Hondal Member at Dipperne (Fig. 3), view towards the north-east. The sedimentological logs Hd4 and Hd5 (Fig. 26) were measured in the lower part of the reference section. Section Hd5 overlies section Hd4. The log Hd5 covers part of the exposure, whereas the log Hd4 represents an underlying exposure not included in the photo. Field of view is *c*. 100 m.

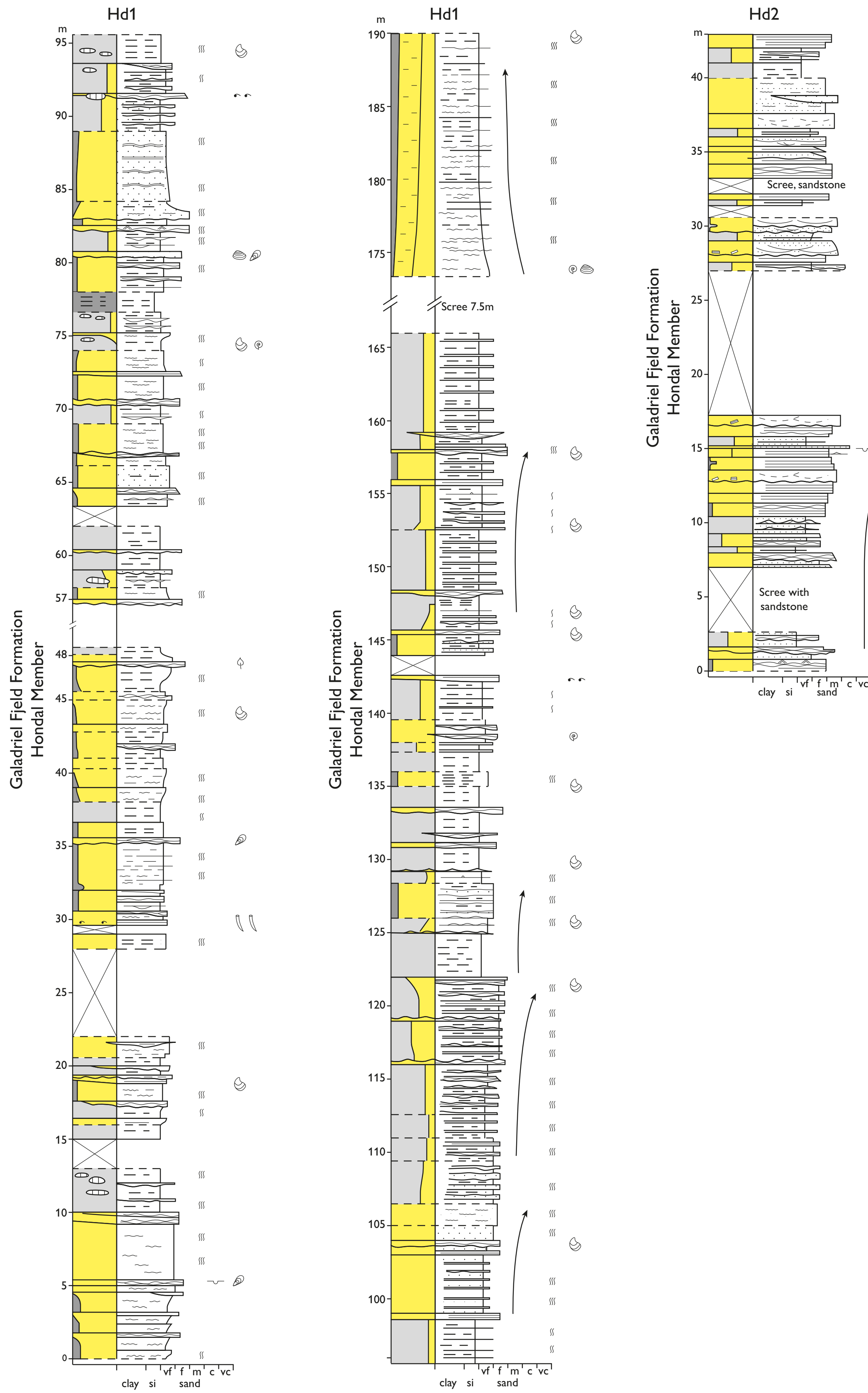


Fig. 24. Lower part of the type section of the middle to upper Albian Hondal Member (Galadriel Fjeld Formation) in Lille Hondal (Fig. 23). Inoceramid bivalves are fairly common in Hd1. For location see Figs 3, 23A.

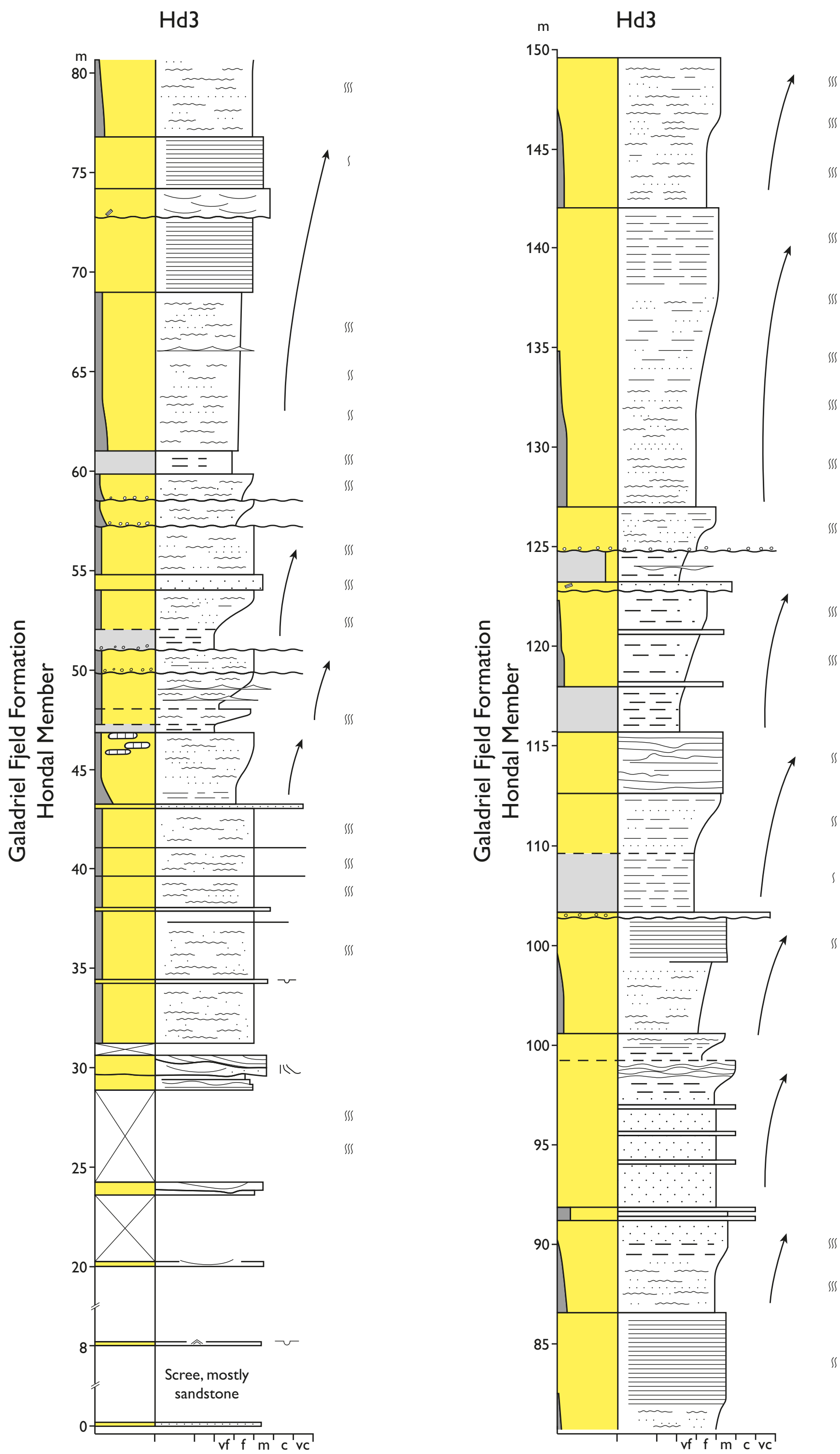


Fig. 25. Upper part of the type section of the middle to upper Albian Hondal Member (Galadriel Fjeld Formation) in Lille Hondal (Fig. 23). For location see Figs 3, 23A.

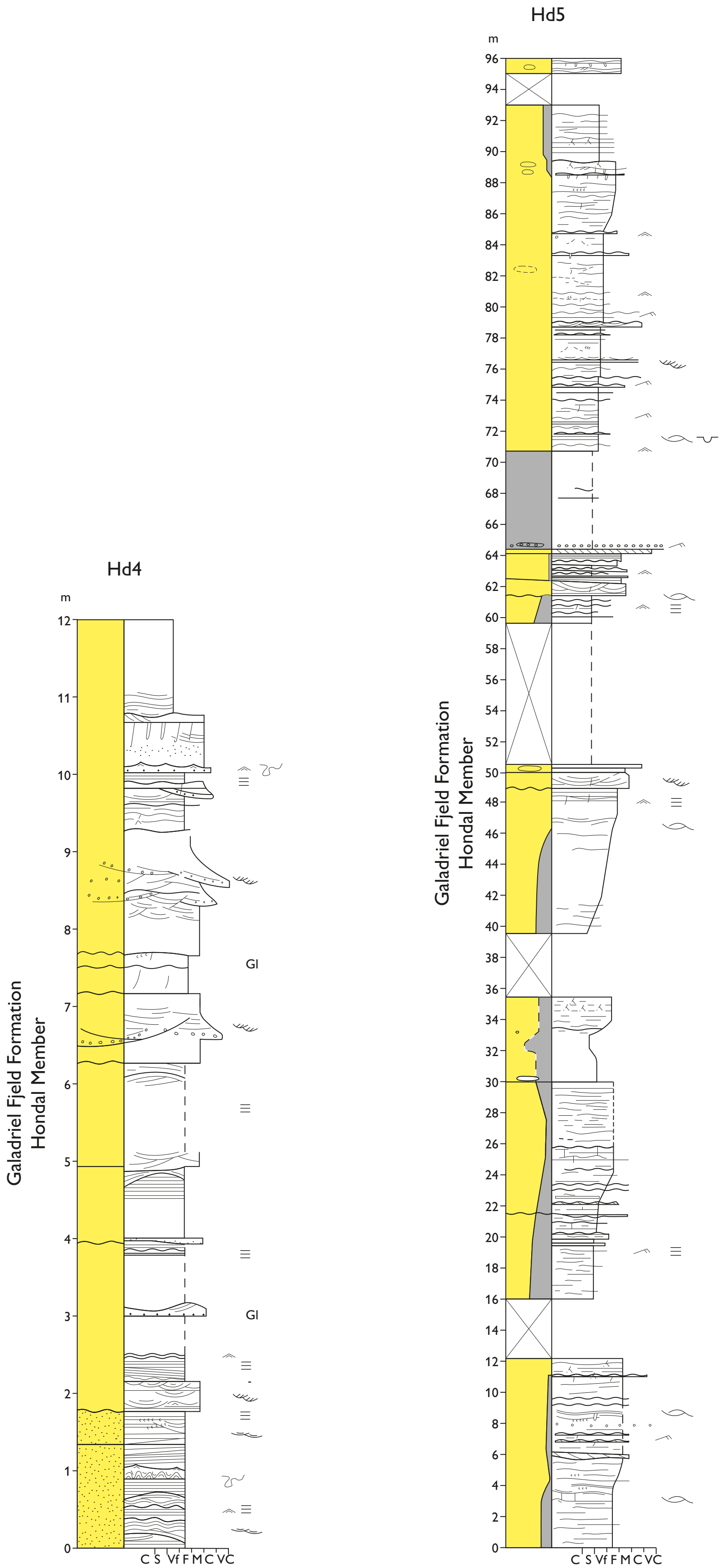


Fig. 26. Sedimentological logs Hd4 and Hd5, illustrating the reference section of the Hondal Member at Dipperne. Hd4 represents the lower part of the member and is stratigraphically overlain by section Hd5. For location see Fig. 3, and text for coordinates.

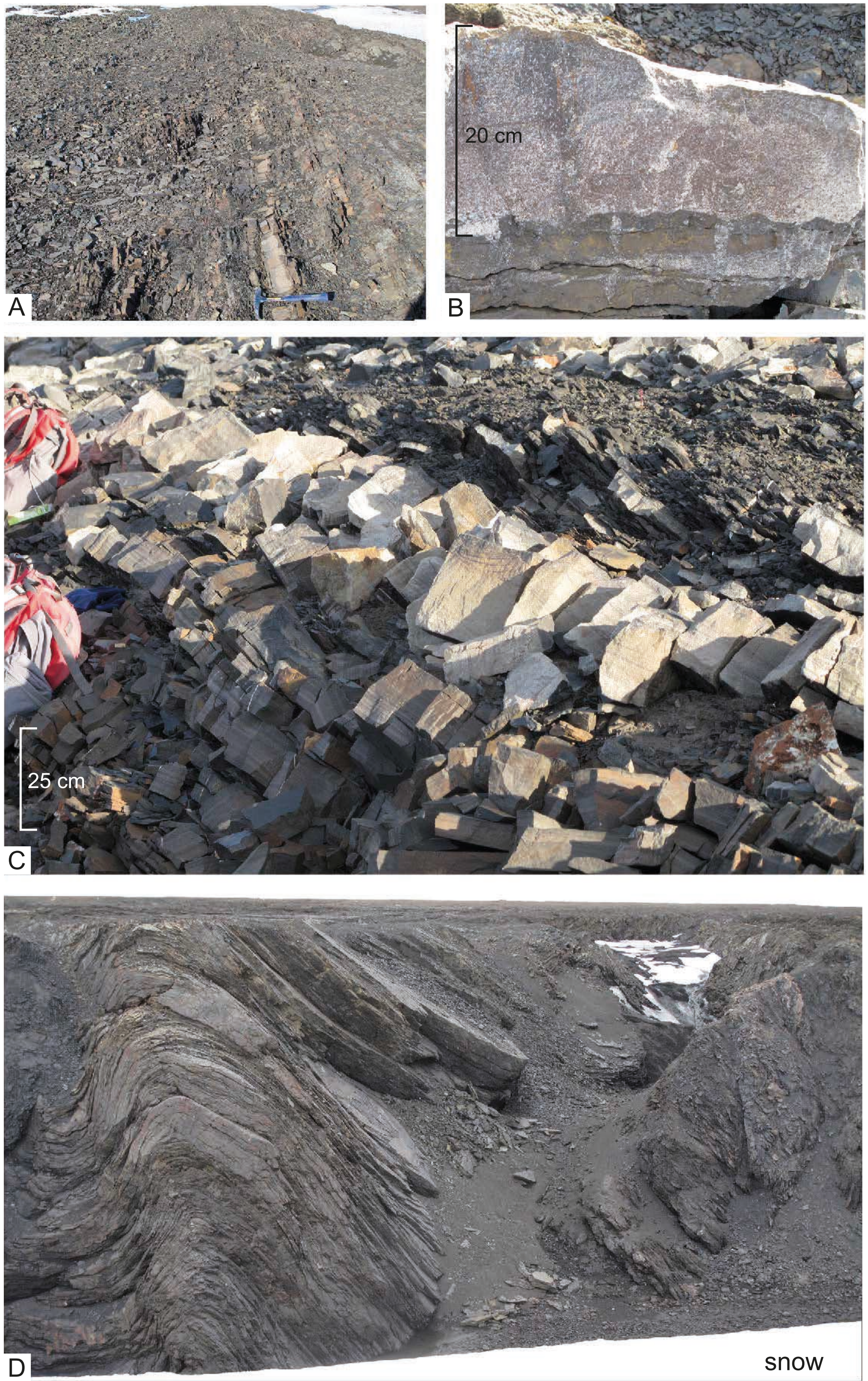


Fig. 27. Outcrops of the Tågekyst Member of the Galadriel Fjeld Formation close to the Anduin river (Fig. 4). **A**: Steeply dipping, interbedded mudstone and sandstone (see also Fig. 28). **B**: Mudstone overlain by *c.* 20 cm thick, medium- to coarse-grained sandstone bed with erosive base. Galleries of vertical and horizontal burrows are passively filled by sand. **C**: Short upwards coarsening succession of parallel laminated, medium-grained sandstone overlain by coarse-grained white sandstone with trough cross-bedding. A–C are from the area close to the type section (Fig. 28). **D**: Folded silt- and sandstones, height of exposure 10–15 m, Tågekyst Member along the southern part of the Anduin river.

Depositional environment. The distribution of storm and fair weather deposits coupled with trace fossil content indicate deposition in upper offshore to shoreface environments.

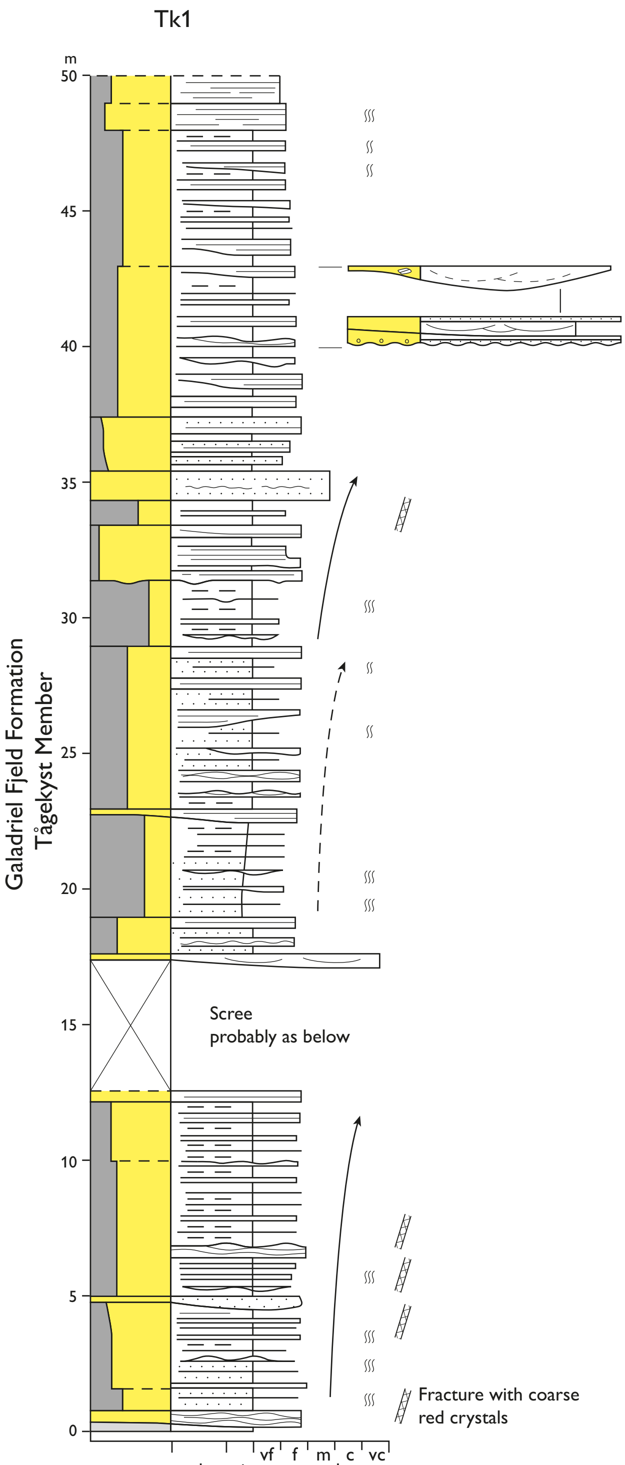


Fig. 28. Sedimentological log Tk1 that illustrates the type section of the Tågekyst Member (Galadriel Fjeld Formation) close to the Anduin river. The section is located in Fig. 4.

Kangoq Ryg Member

New member

Name and history. The member comprises the successions that were previously described as the Iver Pynt, the Tågekyst (in part) and the Kangoq Ryg Formations (Håkansson *et al*. 1994). Their distributions were mapped by Pedersen (1991).

Distribution. The member occurs at Iskap (formerly Iver Pynt), Gåseslette and the southern part of Flagellarisslette (Figs 3, 4). The member is exposed along the Sølverbæk river, in the Tågekyst area, and at Iskap. The distribution of the member in Gåseslette and Flagellarisslette has been mapped on aerial photos (Pedersen 1991; Svennevig *et al*. 2015; Svennevig 2018a).

Type section. Outcrops along the central part of the Sølverbæk river (sections KR1, KR2) constitute the type section (Figs 4, 29A–C, 30, 31). The section KR2 is stratigraphically above KR1; KR2 is based on reconnaissance work. The position of the base of KR1 is 81°09′07.87″N, 013°26′42.96″W.

Reference section. The outcrops along the southern part of the Sølverbæk river constitute the reference section. Only the very top of the member has been logged sedimentologically at this locality (Fig. 32), for location see Fig. 4. The Iskap area has only been visited briefly, and the lithologies are poorly known (Fig. 29D).

Thickness. The strata exposed along the Sølverbæk river are steeply dipping (Fig. 29A) and affected by repeated small-scale thrusting, which makes it difficult to measure the thickness of the Kangoq Ryg Member in outcrop. The structural model based on photogeological mapping suggests a thickness of 650 m (Svennevig *et al*. 2016). The thickness of the Kangoq Ryg Member at Iskap is unknown.

Boundaries. The lower boundary of the Kangoq Ryg Member is not exposed. The upper boundary is recorded as a change from sandstone to a thick mudstone succession (the Sølverbæk Formation) in the reference section (Figs. 29B, 32). The approximate position of the upper boundary is indicated in section KR2 (Fig. 31). The upper boundary of the Kangoq Ryg Member is the best constrained boundary between the Galadriel Fjeld and the Sølverbæk Formations (Fig. 6A, B).

Fossils and age. Ammonites, inoceramids, other bivalves, ophiurids and scaphopods occur in the Kangoq Ryg Member. Dinoflagellate cysts are preserved in

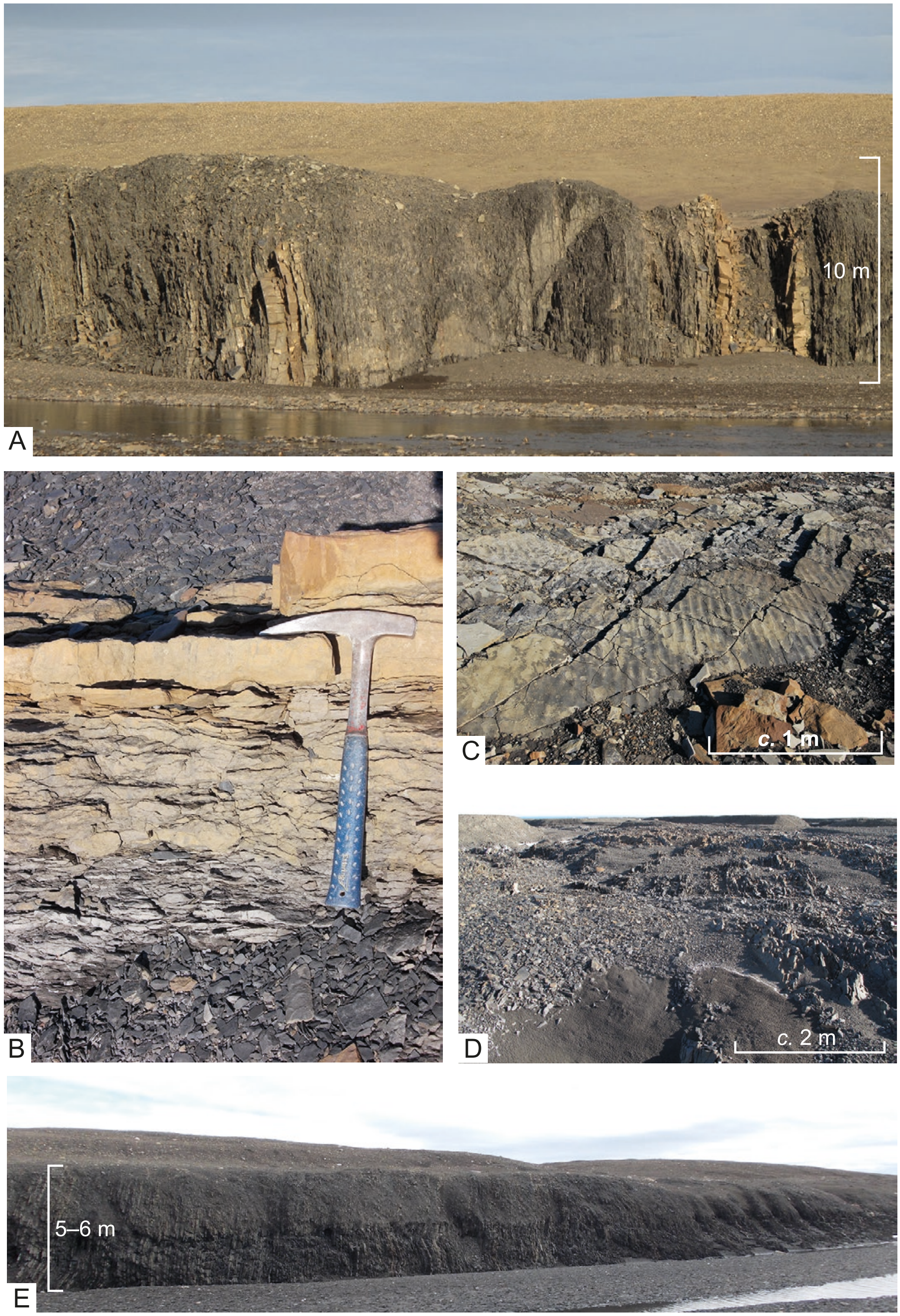


Fig. 29. Type section of the Kangoq Ryg Member (Galadriel Fjeld Formation) and the Sølverbæk Formation in Gåseslette (Fig. 4). **A**: Vertical strata (stratigraphic up to the right) of the Kangoq Ryg Member in cliffs along the Sølverbæk river. The heterolithic sandstones are interbedded with thick yellowish sandstones with hummocky cross-stratification. The photo shows the lower part of the type section KR1 (Fig. 30), located in Fig. 4. **B**: Boundary between the Kangoq Ryg Member and the overlying Sølverbæk Formation, southern Sølverbæk river (Figs 4, 32). **C**: Bedding surface with wave-ripples, Kangoq Ryg Member, southern part of the Sølverbæk river. **D**: The Kangoq Ryg Member at Iskap (formerly Iver Pynt). **E**: Steeply dipping dark grey mudstones. Part of the type section of the Sølverbæk Formation at the Sølverbæk river (SB2–SB4 in Fig. 33).

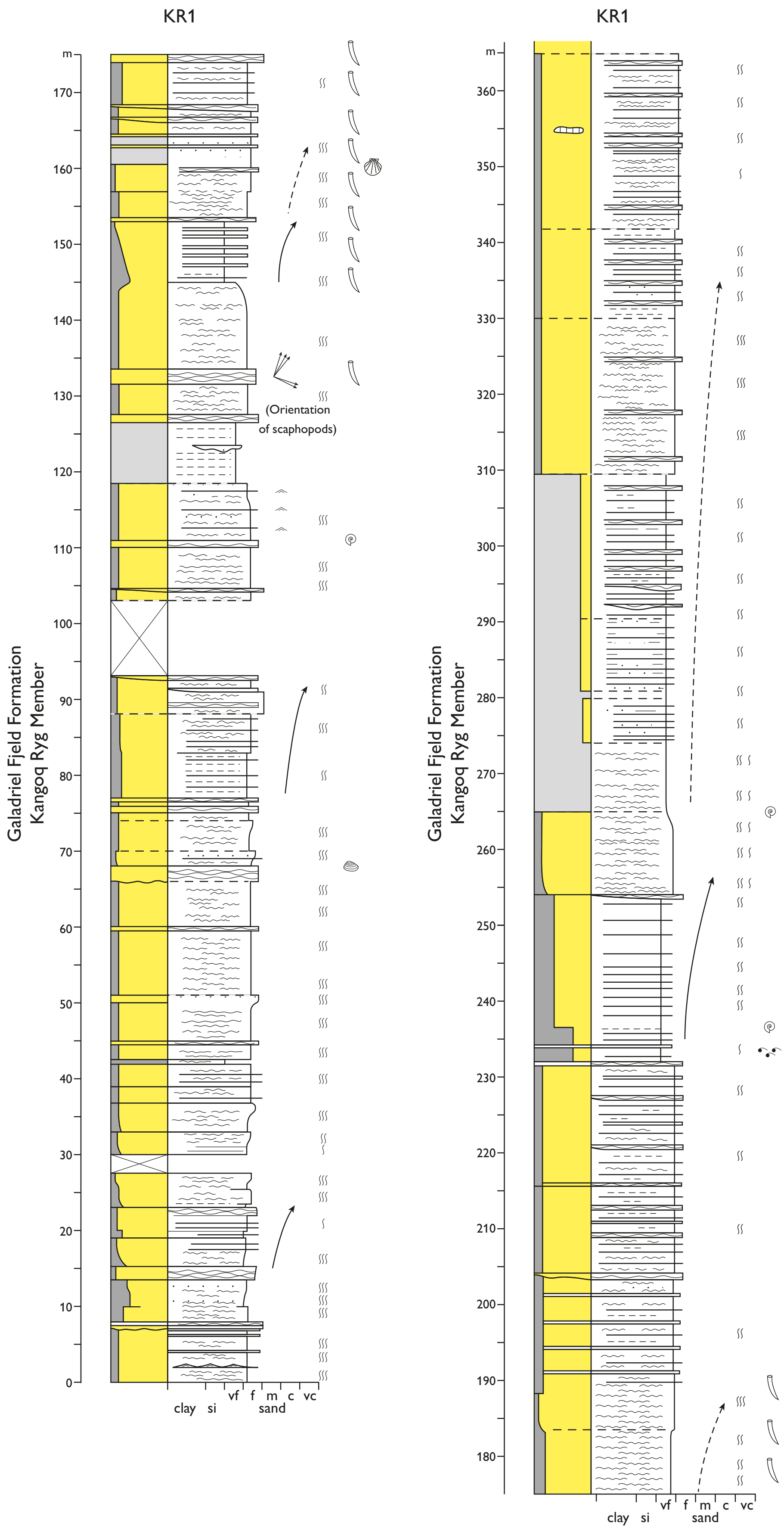


Fig. 30. Sedimentological log KR1, the type section of the Kangoq Ryg Member at the Sølverbæk river (Figs 4, 29A). The section is characterised by interbedded silty mudstones and fine-grained sandstones. The lower boundary of the member is not exposed, the upper boundary is seen in Figs 29B and 32.

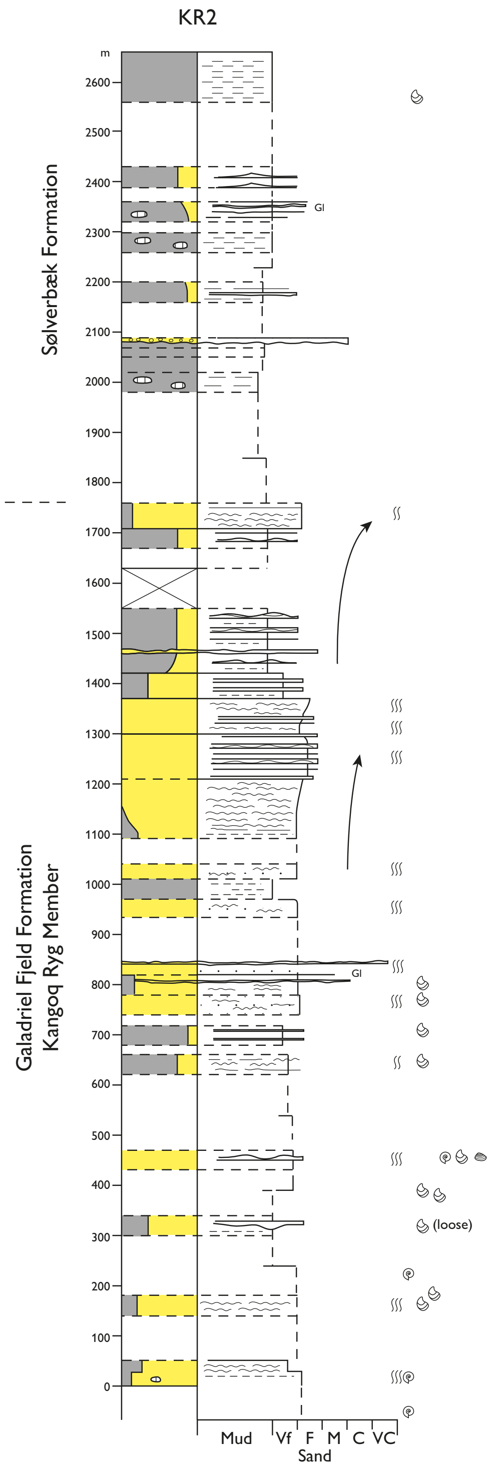


Fig. 31. Sedimentological log KR2 measured during reconnaissance field work at the Sølverbæk river (Fig. 4). The scale indicates horizontal distance instead of bed thicknesses. The strata are steeply dipping, 60–90°. The log covers the upper part of the Kangoq Ryg Member (0–1750 m) and part of the overlying Sølverbæk Formation. Unfortunately the succession 1750–1975 m was inaccessible in the cut bank of the river. The position of the boundary between the Kangoq Ryg Member and the Sølverbæk Formation is therefore uncertain.

samples from the south-eastern part of Gåseslette and provide the most detailed biostratigraphic information (Fig. 6B). The older part of the Kangoq Ryg Member is middle Albian to middle upper Albian based on the presence of *Rhombodella paucispina* and *Chichaouadinium vestitum* (late middle Albian age; Subzone IV2 of Nøhr-Hansen 1993), the presence of *Subtilisphaera kalaalliti* and *Wigginsiella grandstandica* (early late Albian age; Subzone V1 of Nøhr-Hansen 1993) and by the presence of *Odontochitina ancala* (middle late Albian age; Subzone V2 of Nøhr-Hansen 1993). The upper Albian succession of the Kangoq Ryg Member seems to be unconformably overlain by an upper lower to possibly middle Cenomanian succession, indicated by the presence of *Endoceratium ludbrookiae*.

The ammonite fauna contains early Albian *Arcthoplites* including A. *jachromensis* or *nikitini* and *A. probus* and middle Albian *Beudanticeras glabrum*, *Pseudopulchellia flexicostata*, *Gastroplites* sp., *Stelckiceras* sp. and *Hoplites dentatus*. Scattered inoceramids are represented by *Gnesioceramus comancheanus*, *G.* cf. *bellvuensis* and *Inoceramus anglicus* of middle to late Albian age (Woods 1911–1912; Pergament 1965; Kauffman 1977; Crame 1985; Walaszczyk & Cobban 2016).

The Kangoq Ryg Member is correlated to the Hondal Member of the Galadriel Fjeld Formation, as both members contain the inoceramid species *G. comancheanus* and *I. anglicus.* An imprint of an ammonite fragment from Iskap (Heinberg & Håkansson collection) represents a middle Albian genus, which supports the assignment of the former Iver Pynt formation to the Kangoq Ryg Member.

Lithological description. Interbedded sand-streaked mudstone and fine-grained sandstone with mud-drapes form upward coarsening successions, 30–50 m thick (Fig. 30). The ratio of mudstone to sandstone is high in the Iskap area (Fig. 29D), nearly equal in other areas, and low in the outcrops in the southern part of the Sølverbæk river (Fig. 29C). Generally the member is strongly bioturbated, and the diverse trace fossil assemblage represents the *Cruziana* ichnofacies. The thick sandstone beds (0.5–1 m) show parallel lamination, hummocky cross-stratification and locally wave-ripple cross-stratification. Locally, large numbers of *Dentalium* shells occur as intraformational clasts in fine- to medium-grained sandstones.

Depositional environment. The distribution of storm and fair weather deposits coupled with the trace fossil content indicate deposition in proximal offshore to lower shoreface environments.

Sølverbæk Formation

Name and history. The formation is named after the Sølverbæk river and was originally mapped by Pedersen (1991) and described by Håkansson *et al*. (1993, 1994). Here the formation is formalised and expanded significantly to comprise most of the Upper Cretaceous of Kilen (Figs 5, 6). In the Gåseslette area, the Sølverbæk Formation has been expanded by a previously unknown succession at the Anduin river. In the Kilen Fjelde area, the Sølverbæk Formation now includes the sediments that formerly were referred to the Anduin, Skalbæk, Røde Bakker, Flagellarisslette, Scaphitesnæse and Saddelfjeld Formations of Håkansson *et al*. (1993, 1994), see Fig. 5. Consequently, all of these former formations are merged into a single formation. The deposits of the former Anduin, Skalbæk and Røde Bakker Formations are now referred to the Skalbæk Member, which includes the Røde Bakker Beds. The deposits of the former Flagellarisslette, Scaphitesnæse and Saddelfjeld Formations are now referred to the Scaphitesnæse Member, which includes the Flagellarisslette mudstone (Figs 5, 6).

Subdivision. In Kilen Fjelde, the Sølverbæk Formation is subdivided into the Skalbæk and Scaphitesnæse Members. The Skalbæk Member contains the Røde Bakker Beds in the Røde Bakker area. The Scaphitesnæse Member contains the informal Flagellarisslette mudstone in the north-eastern Kilen Fjelde area. In the Gåseslette area, the Sølverbæk Formation is not subdivided (Figs 3, 5).

Distribution. The formation occurs at Gåseslette, Flagellarisslette and Kilen Fjelde (Figs 3, 4).

Type section. The outcrops along the Sølverbæk river form the type section (Fig. 29E). The logs are measured in cliffs along *c.* 1.8 km of the Sølverbæk river (Figs 4, 29E): The stratigraphic thickness is *c.* 1.4 km including numerous small-scale faults and folds. The sedimentological logs SB3–SB2–SB4–SB5–SB1 constitute a composite type section (Figs 32, 33). In parts of the type section, between the measured logs, the formation is inaccessible in the cut-bank of the river. The position of the base of SB3, just below the lower boundary of the formation, is 81°06′31.54″N, 013°20′07.76″W. The logs SB3–SB5 are nearly continuous. The youngest beds in the type section are encountered between SB5 and SB1. The accessible part of this stretch of the river constitutes section SB8, at 81°07′16.73″N; 013°22′32.03″W. SB8 is located in the axis of the syncline (Fig. 4), and no sedimentological log was measured in this tectonically complex section.

Reference sections. The type sections for the Skalbæk and Scaphitesnæse Members are reference sections for the Sølverbæk Formation in Kilen Fjelde (Figs 34–39). The outcrops of the formation along the Anduin river constitute a reference section for the youngest part of the Sølverbæk Formation.

Thickness. In the type section the formation is exposed as steeply dipping beds separated by numerous small-scale thrusts (Fig. 29E), which makes it difficult to measure the thickness in outcrops. The modelled minimum thickness of the formation is 600 m in the type section and *c*. 750 m in Kilen Fjelde (Svennevig *et al*. 2018; Fig. 6).

Boundaries. The lower boundary is placed at a sharp transition from sandstone, at the top of the Hondal and Kangoq Ryg Members, to mudstone. The boundary is exposed in section SB3, indicated in section KR2, and inferred below Sk1 (Figs 31, 32, 34A). The upper boundary is the present-day subaerial erosion surface, locally overlain by a thin cover of recent deposits.

Fossils and age. The fossils include inoceramids, dinoflagellate cysts and ammonites. Dinoflagellate cysts in the lower part of the Sølverbæk Formation date it as early late to late Cenomanian based on the presence of *Isabelidinium magnum* and *Trithyrodinium suspectum* and by the presence of *Cauveridinium membraniphorum.* The middle to upper part of the Sølverbæk Formation is Turonian based on the presence of *Heterosphaeridium difficile* and *Chatangiella* spp., by the presence of *Odontochitina* aff. *rhakodes* and by the presence of *Senoniasphaera* aff. *turonica.* The upper part of the Sølverbæk Formation is Coniacian based on the presence of *Xenascus gochtii* and by the presence of *Canningia* aff. *macroreticulata.* The inoceramids are represented by an abundant and diverse fauna of 34 species and 281 specimens. They represent strata from the early Turonian to early Coniacian (e.g. Tröger 1967; Keller 1982; Walaszczyk 1992). Examples are *Inoceramus apicalis* (from early middle Turonian), *Inoceramus lamarcki*, (from middle Turonian), *Mytiloides striaconcentricus* (from late Turonian–early Coniacian) and *Inoceramus lusatiae* (from late Turonian–early Coniacian). The four examples listed are found in large numbers at localities both at Gåseslette and Kilen Fjelde.

The youngest deposits (late Santonian to possibly early Campanian) are restricted to outcrops along the Anduin river dated by findings of *Sphenoceramus* species. Ammonites are subordinate for dating this unit. Scaphitids locally occur in high abundances, crushed and fragmented, in hard siderite concretions, both in Kilen Fjelde and in the Gåseslette area. They appear to represent a locally evolved, endemic fauna with affinity to *S. geinitzi* as suggested by Birkelund

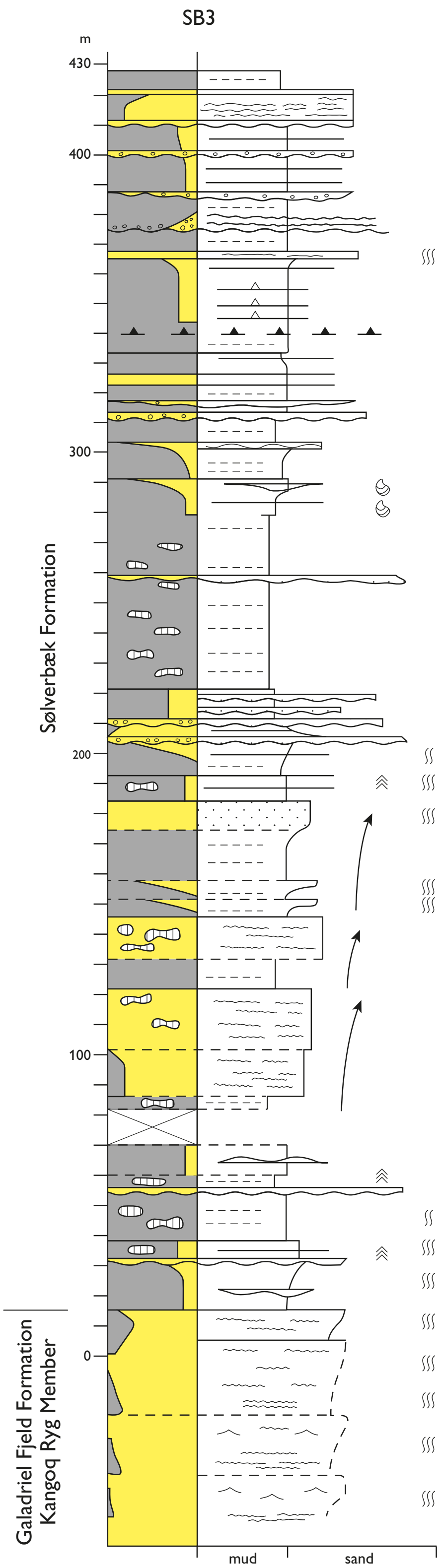


Fig. 32. Lower part of the type section of the Sølverbæk Formation. The section SB3 includes the top of the Kangoq Ryg Member (middle Cenomanian) and the lower boundary of the Sølverbæk Formation. The overlying Sølverbæk Formation is here upper Cenomanian and lower Turonian (Fig. 6). For location of the log see Fig. 4.

& Håkansson (1983). In addition, specimens of long-ranging *Puzosia* (*Mesopuzosia*) are relatively common.

Lithological description. The formation is dominated by mudstone, commonly with streaks of siltstone or very fine-grained sandstone. Siderite concretions are fairly common in the mudstones of the type section. Interbedded mudstones and fine-grained sandstones occur in 10–50 m thick, upwards coarsening successions. The proportion of sandstone is higher in the Skalbæk and Scaphitesnæse Members than in the type section. Siderite-cemented, intraformational conglomerates occur in the sections in Kilen Fjelde and are locally present in the Gåseslette area. The trace fossil assemblages are varied and mainly represent the *Cruziana* ichnofacies. The *Glossifungites* ichnofacies is locally present in association with siderite-cemented conglomerates of the Skalbæk Member.

Depositional environment. Most of the formation represents shelf and offshore environments; nearshore depositional settings occur locally (see below).

Skalbæk Member

New member

Name and History. The member comprises the sediments that were previously mapped and described as the Anduin, Skalbæk, and Røde Bakker Formations by Pedersen (1991) and Håkansson *et al*. (1994). The Skalbæk Member is referred to the Sølverbæk Formation (Figs 5, 6).

Subdivision. The Røde Bakker Beds (formerly the Røde Bakker Formation) are a subunit of the Skalbæk Member in northern Kilen Fjelde (Fig. 3).

Distribution. The Skalbæk Member occurs in the Kilen Fjelde area (Fig. 3).

Type section. The Hondal syncline, west of the Hondal river, Kilen Fjelde (Figs 3 and 34). The sedimentological logs Sk1–Sk3 cover the type section (Figs 35–36). The position of the base of Sk1 is 81°16′47.4″N, 013°55′47.7″W.

Reference section. The Skalbæk and Røde Bakker areas, northern Kilen Fjelde (Fig. 34B). The sedimentological log RB1 illustrates part of the reference section of the Skalbæk Member (Fig. 37).

Thickness. The member is estimated to be up to 565 m thick (Svennevig *et al*. 2016). The exposed part of the type section covered by the logs Sk1–Sk3 is *c*. 350 m.

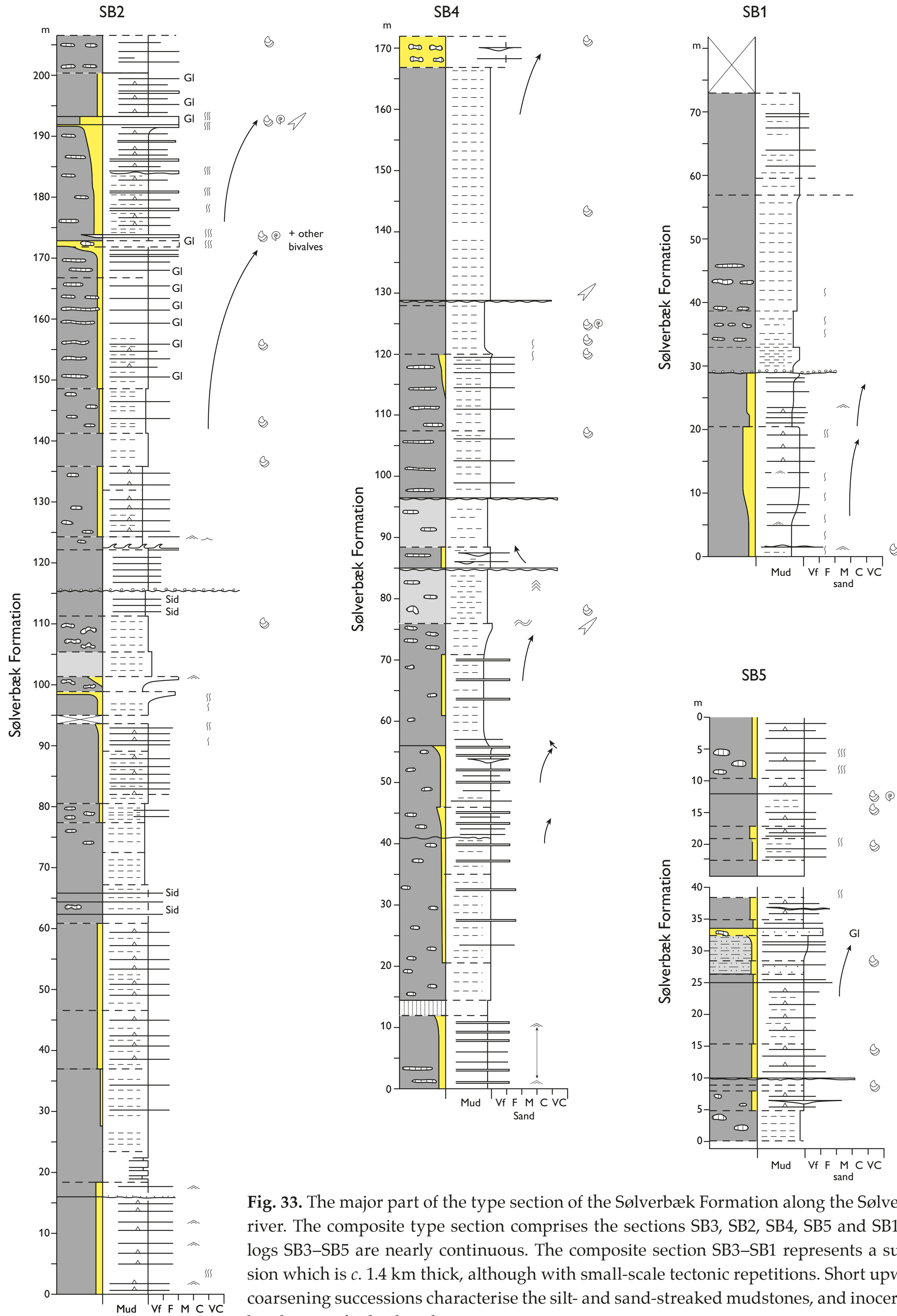


Fig. 33. The major part of the type section of the Sølverbæk Formation along the Sølverbæk river. The composite type section comprises the sections SB3, SB2, SB4, SB5 and SB1. The logs SB3–SB5 are nearly continuous. The composite section SB3–SB1 represents a succession which is *c.* 1.4 km thick, although with small-scale tectonic repetitions. Short upwards coarsening successions characterise the silt- and sand-streaked mudstones, and inoceramid bivalves are fairly abundant.

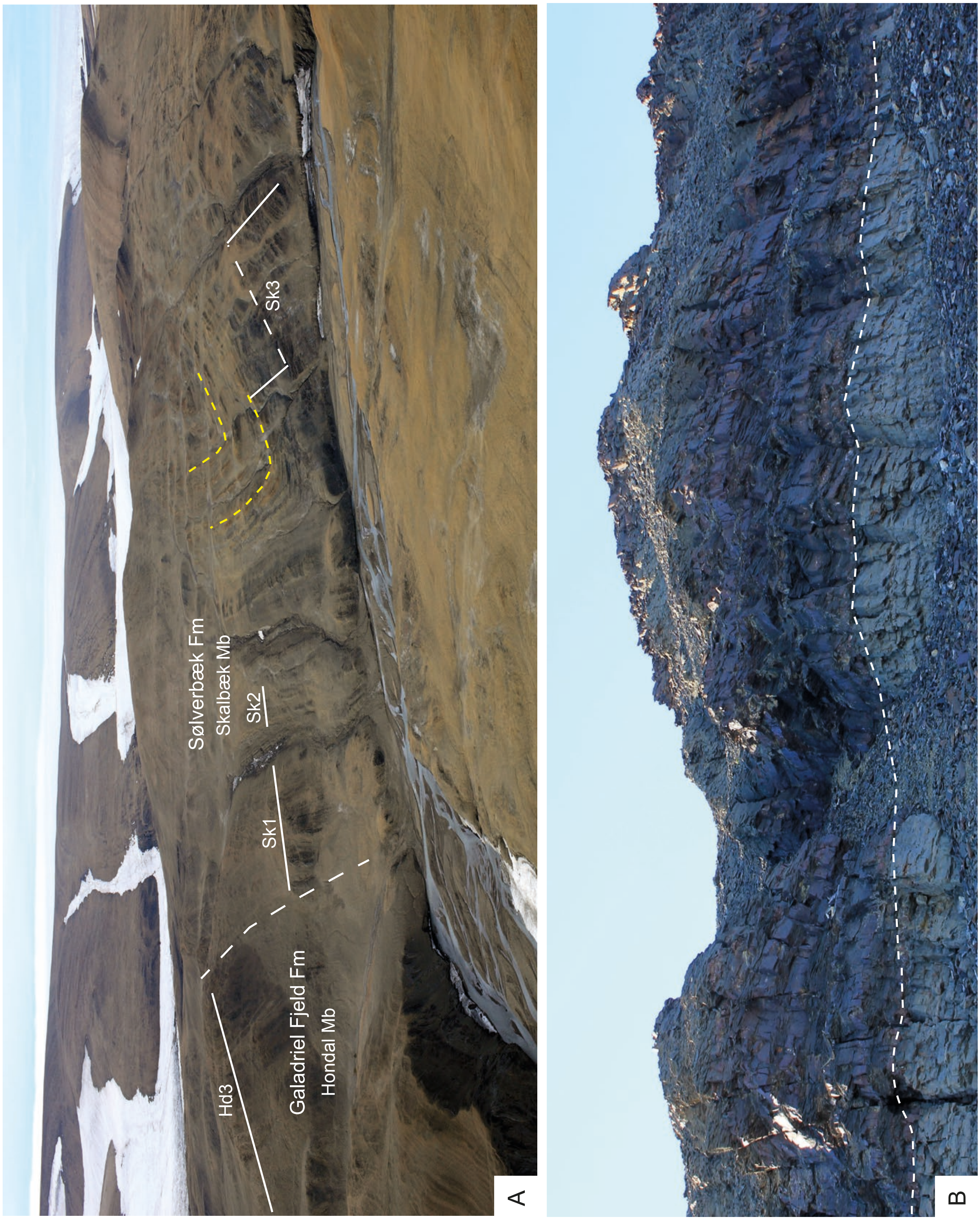


Fig. 34. Type and reference sections of the Skalbæk Member of the Sølverbæk Formation. **A**: Type section of the Skalbæk Member, north of Lille Hondal, view towards the west. The yellow dashed lines outline a distinct syncline. Locations of the sedimentological logs Sk1–Sk3 (Figs 3, 35, 36) are shown; they form a nearly continuous section through the lower part of the Sølverbæk Formation in Kilen Fjelde (Figs 5, 6). Section Sk3 is *c*. 160 m thick and consists of two parts correlated by a white dashed line. The boundary between the Hondal Member and the Skalbæk Member is also a formation boundary. It is covered by scree, but the approximate position is indicated by a white dashed line. **B**: Type section of the Røde Bakker Beds at Røde Bakker, Kilen Fjelde. The 17 m long sedimentological log RB1 (Fig. 37) covers the exposure. View towards the east-southeast.

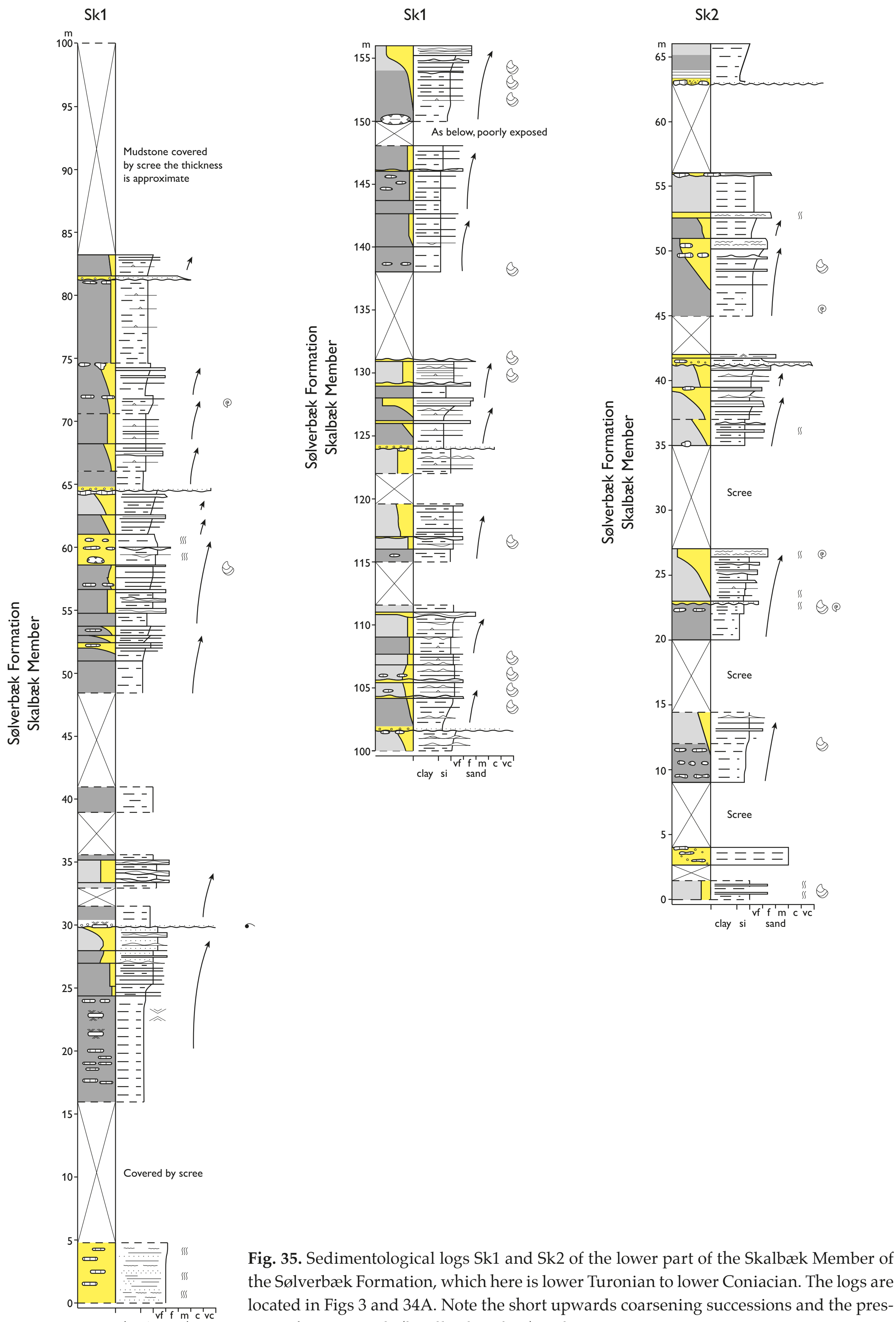
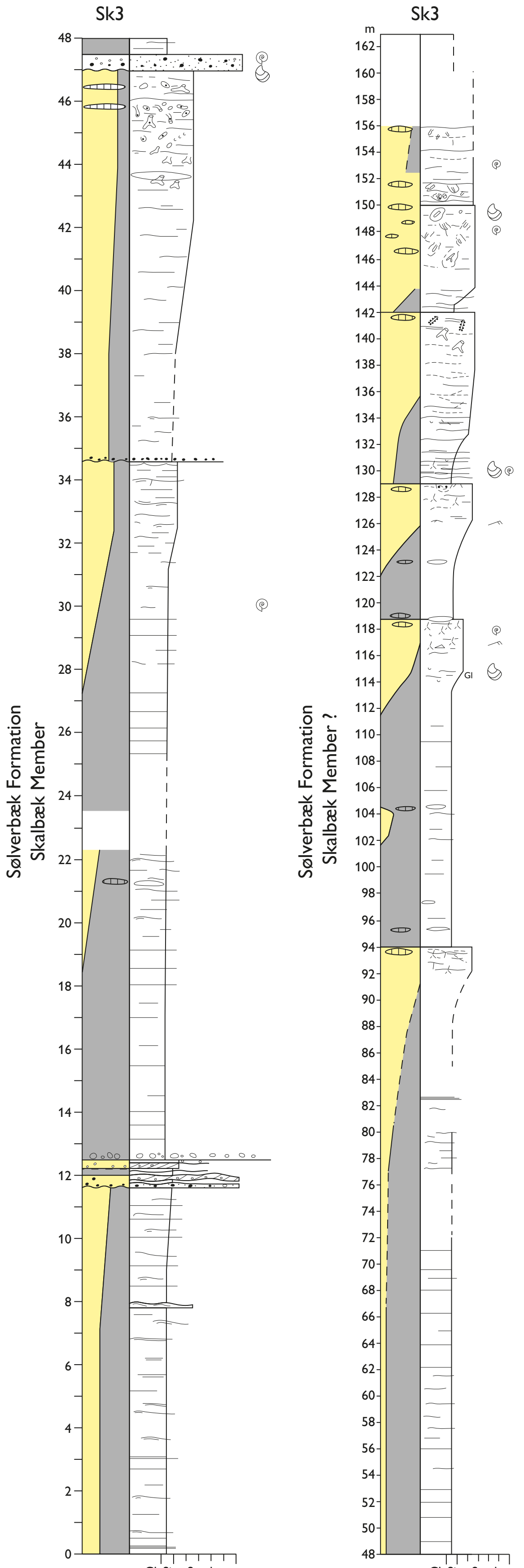


Fig. 35. Sedimentological logs Sk1 and Sk2 of the lower part of the Skalbæk Member of the Sølverbæk Formation, which here is lower Turonian to lower Coniacian. The logs are located in Figs 3 and 34A. Note the short upwards coarsening successions and the presence of inoceramids (locally abundant) and ammonites.



Boundaries. The lower boundary of the Skalbæk Member is also the lower boundary of the Sølverbæk Formation in Kilen Fjelde. The upper boundary is placed at the occurrence of dark mudstone (the Flagellarisslette mudstone) above a prominent siderite-rich sandstone interval (Røde Bakker Beds).

Fossils and age. The member is early Turonian to early Coniacian based on a very rich and diverse inoceramid fauna with 18 species and 99 specimens. Examples of inoceramids encountered are *Inoceramus apicalis* (from early middle Turonian), *Inoceramus lamarcki*, (from middle Turonian), *Mytiloides striaconcentricus* (from late Turonian–early Coniacian) and *Inoceramus lusatiae* (from late Turonian–early Coniacian) (Tröger & Christensen 1991, Walaszczyk & Wood 1998, Walaszczyk & Cobban 2016, among others). These species are also known from the Sølverbæk Formation at Gåseslette. Examples of common younger species are *Mytiloides africanus* and *Inoceramus annulatus*. These two species are also encountered at Gåseslette. Ammonites including worn specimens possibly of *Scaphites planus* indicate an early to middle Turonian age.

Lithological description. The Skalbæk Member comprises a number of upward coarsening successions, 5–50 m thick, ranging from fissile mudstone with siderite concretions, through sand-streaked mudstone and fine-grained sandstone to siderite-cemented conglomerates with intraformational clasts of mudstone and fragments of fossils (sections Sk1–Sk3, Figs 35, 36). The typical trace fossils represent the *Cruziana* ichnofacies.

Depositional environment. The fine grain size and the distribution of storm- and wave-generated structures, coupled with the fully marine fossils, the high bioturbation intensity and the trace fossil content, point to low wave energy and suggest that most of the Skalbæk Member was deposited in offshore to lower shoreface environments. The succession is overall shallowing-upwards, and the siderite-bearing conglomerates with their distinctive trace fossils indicate deposition in nearshore environments.

Røde Bakker Beds

New unit

Name and history. The Røde Bakker Beds include some of the sediments that were previously referred to the Røde Bakker Formation (Pedersen 1991; Håkansson

Fig. 36. Sedimentological log Sk3 of the upper part of the Skalbæk Member of the Sølverbæk Formation. The upper part of the type section west of the Hondal river. For location see Figs 3 and 34A. Section Sk3 overlies sections Sk1 and Sk2 (Figs 34A, 35).

et al. 1994). New biostratigraphic data suggest that the original formation may have included beds from various stratigraphic levels. Here the unit is revised to include only beds that crop out in the Røde Bakker–Skalbæk area and on the southern flank of the Saddelfjeld hill. The Røde Bakker Beds are included in the Skalbæk Member.

Distribution. The beds occur in Røde Bakker, at Skalbæk and at Saddelfjeld, in the north-eastern part of Kilen Fjelde (Fig. 3). It is possible that the Røde Bakker Beds occur in the Hondal syncline, but the limited exposures do not allow conclusive recognition of characteristic lithologies or stratigraphic trends.

Type section. The sedimentological log RB1 covers the type section at Røde Bakker (Figs 34B and 37). The base of the section is located at 81°18′35.3″N, 013°56′18.7″W.

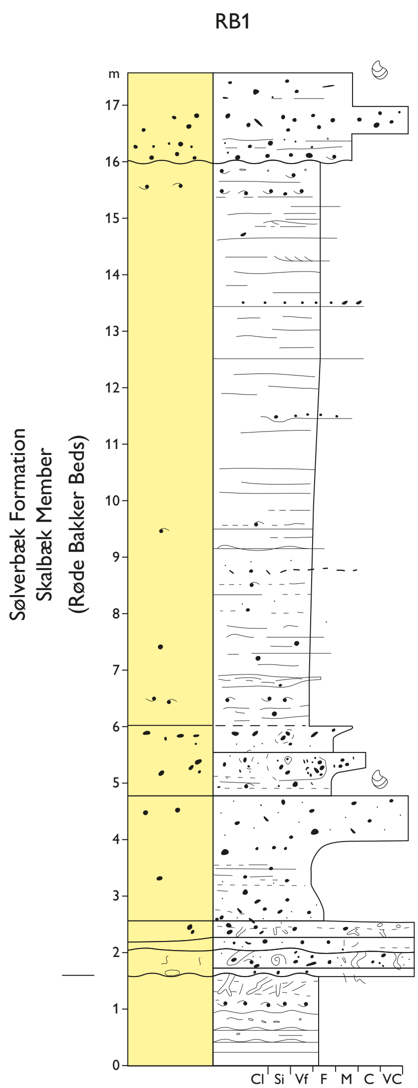


Fig. 37. Sedimentological log RB1 of the Røde Bakker Beds at the type section.

Thickness. The unit is 10–15 m thick.

Boundaries. The lower boundary is placed at the sharp transition from grey sandstone to red, siderite-cemented pebble and conglomerate beds (Fig. 34B). The upper boundary is placed at the first occurrence of black mudstone (the Flagellarisslette mudstone) at the base of the Scaphitesnæse Member.

Fossils and age. Fossils include inoceramids and ammonites. Four species of inoceramids exemplified by *Tethyoceramus wandereri* indicate an early Coniacian age when compared to Tröger & Christensen (1991), Walaszczyk (1992), and Walaszczyk & Wood (1998) (Fig. 6). The ammonite fauna is characterised by very large *Puzosia* specimens (Håkansson *et al*. 1993, their 'Unit 3'), whereas scaphitids are few.

Lithological description. The beds comprise reddish to greyish sandstones, pebbly sandstones and intraformational conglomerates with clasts of mudstone, carbonate and glauconite, and reworked clasts of apatite-cemented, fine-grained sediments (Håkansson *et al*. 1994; R. Weibel, personal communication 2017). A surface containing the *Glossifungites* ichnofacies demarcates the lower boundary of the Røde Bakker Beds.

Depositional environment. The unit is interpreted to represent a nearshore marine environment. The *Glossifungites* ichnofacies and associated intraformational conglomerates point to the formation of a hiatal surface and development of a firm ground surface.

Notes. Correlation of the Røde Bakker Beds from the Røde Bakker area with the type section of the Skalbæk Member in the Hondal area is uncertain at present. The unit may correlate with a siderite-cemented interval in the core of the Hondal syncline and/or an interval on the flank of the syncline (around 47 m in section Sk3, Fig. 36). If either of these occurrences proves to be Røde Bakker Beds in future studies, the lithological character of the Røde Bakker Beds is laterally variable.

Scaphitesnæse Member

New member

Name and history. The Scaphitesnæse Member includes the sediments that were previously referred to the Flagellarisslette and Scaphitesnæse Formations by Pedersen (1991) and Håkansson *et al*. (1994). The Scaphitesnæse Member is the uppermost member of the Sølverbæk Formation in the Kilen Fjelde area.

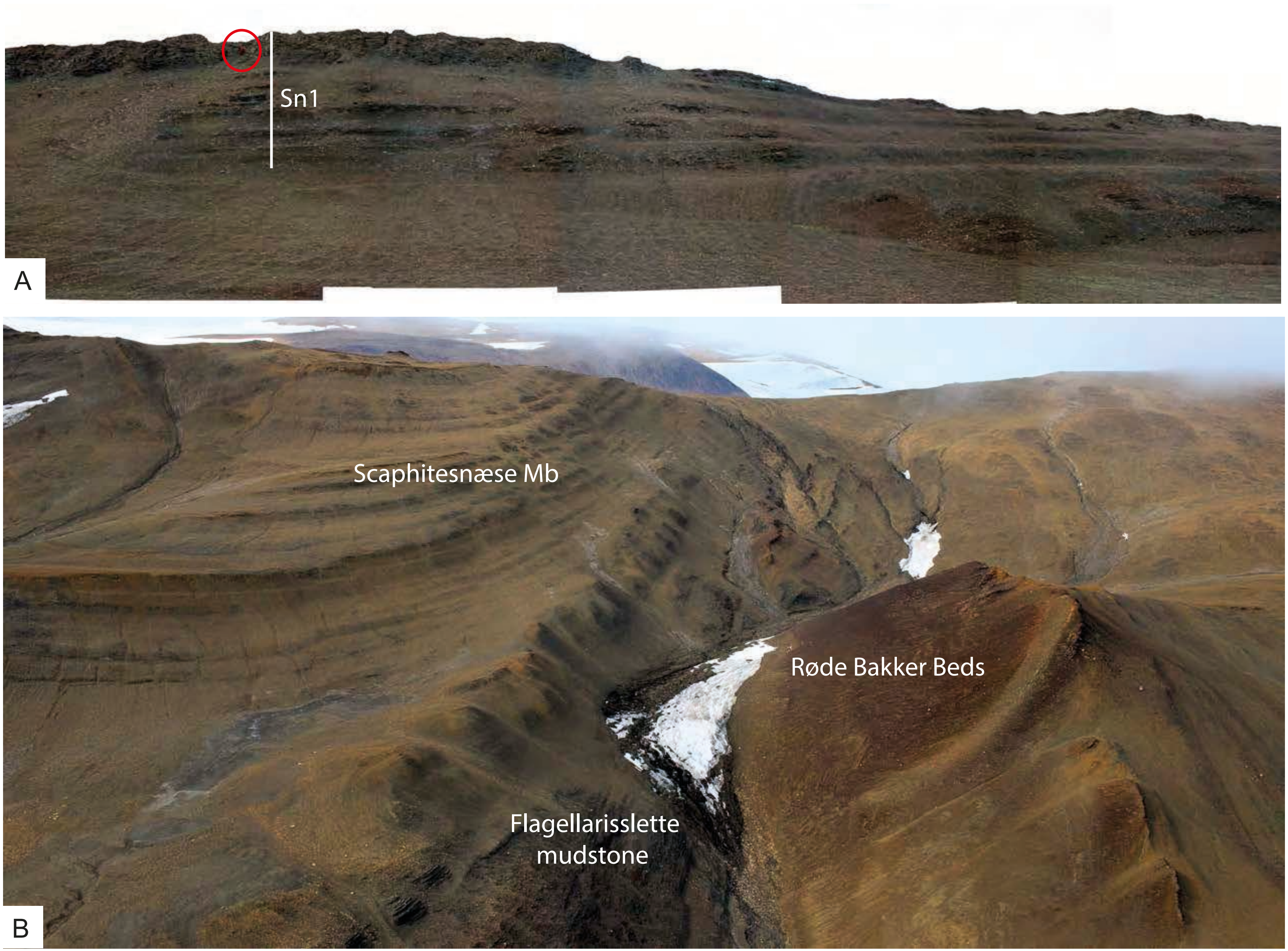


Fig. 38. A: Type section of the Scaphitesnæse Member (Sølverbæk Formation), Saddelfjeld area, northernmost part of Kilen. View towards the north. Person (encircled) as a scale. The approximate location of the log Sn1 is shown. **B**: Reference section in the Scaphitesnæse–Saddelfjeld area. View towards the west. The Scaphitesnæse Member (including the Flagellarislette mudstone) is *c*. 280 m thick.

Subdivision. The Flagellarisslette mudstone constitutes the lower 130 m of the Scaphitesnæse Member in the Kilen Fjelde area.

Distribution. The Scaphitesnæse Member occurs in the north-eastern part of the Kilen Fjelde area (Fig. 3).

Type section. The Saddelfjeld area forms the type section (Fig. 38). The sedimentological log Sn1 illustrates the type section (Fig. 39). The base of the section is located at 81°19′42.6″N, 013°56′31.92″W.

Reference section. The Røde Bakker and Scaphitesnæse areas are the reference sections. The member is stratigraphically more complete here than in the type section but has not been logged.

Thickness. The member is more than 280 m thick (Svennevig *et al*. 2016).

Boundaries. Photogeological mapping shows that the Flagellarisslette mudstone overlies the Røde Bakker Beds of the Skalbæk Member (Svennevig 2018a). The lower boundary is placed at the first appearance of the mudstone succession on the top of siderite cemented conglomerates. The upper boundary is the present subaerial erosion surface.

Fossils and age. Inoceramids and ammonites are present. Håkansson *et al*. (1994) reported rich faunas, dominated by *Scaphites* and inoceramid bivalves, concentrated in the top of the glauconitic sandstones. The present study presents nine inoceramid species, some with relatively long ranges but indicating an early to middle Coniacian age when compared to Walaszczyk (1992). Examples are *Cremnoceramus crassus* (early Coniacian) and *Inoceramus seitzi* (early to middle Coniacian), which are recorded in both the Kilen Fjelde and the Gåseslette areas. The ammonite fauna, which can be rich in some horizons, includes scaphitids of *S*. ex. gr. *geinitzi* and *Kossmaticeras* (Alsen 2018b).

Lithological description. The member consists of interbedded mudstones and sandstones which form 20–30 m thick, upwards coarsening successions. Glauconite-rich, green sand intervals occur locally (Håkansson *et al*. 1994). The upper part of the member shows wave ripple cross-lamination, hummocky and swaley cross-stratification. The trace fossils represent the *Cruziana* ichnofacies.

Depositional environment. Based on the distribution of storm-generated sediment structures, the fossils as well as trace fossil characteristics, the Scaphitesnæse

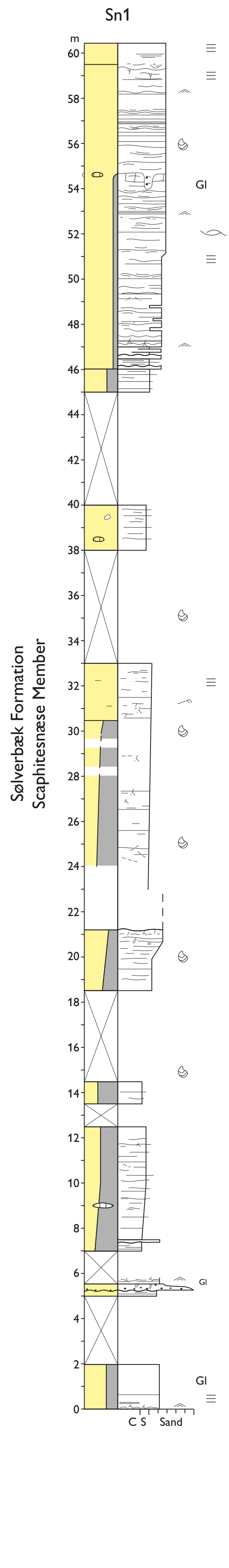


Fig. 39. Sedimentological log Sn1 of the Scaphitesnæse Member illustrating the upper part of the member in the type section at Saddelfjeld. For location of the log see Fig. 3.

Member is interpreted to represent storm-dominated offshore–shoreface environments.

Notes. The lower half of the Scaphitesnæse Member, including the basal fine-grained Flagellarisslette mudstone (see below), was not studied in the type section during the present study. Future work should include detailed documentation of the boundary between the Skalbæk and the Scaphitesnæse Members in the Røde Bakker area in order to gain better understanding of this stratigraphic interval. Furthermore, future work is needed to test whether the lower part of the Scaphitesnæse Member is present in the Hondal syncline (interval ~48–156 m in log Sk3, Fig. 36).

Flagellarisslette mudstone

Name and history. The Flagellarisslette mudstone is an informal lithostratigraphic unit which includes the sediments formerly referred to the Flagellarisslette Formation (Pedersen 1991; Håkansson *et al*. 1994). The name derives from the plant *Saxifraga flagellaris,* which grows on the plain (Håkansson *et al*. 1993, their table 1). The unit constitutes the lower part of the Scaphitesnæse Member. It was not studied during the recent field work and is therefore not formalised.

Distribution. Identical to the distribution of the Scaphitesnæse Member (see Fig. 3).

Type section. The Røde Bakker area.

Thickness. The Flagellarisslette mudstone is 130 m thick (Svennevig *et al*. 2016).

Boundaries. The lower boundary is identical to the lower boundary of the Scaphitesnæse Member. The upper boundary is located at the top of a *c*. 10 m thick sandstone.

Fossils and age. Inoceramids and ammonites were reported by Håkansson *et al*. (1994). The unit is thought to range from early to middle Coniacian? (Fig. 6).

Lithological description. The lithological description is adapted from Håkansson *et al*. (1994) without changes: "Very uniform upwards coarsening sequence of greyish silty mudstone with storm-sand layers throughout. Topped by *c*. 10 m thick sandstone." (Håkansson *et al*. 1994, p. 7).

Depositional environment. The unit is tentatively interpreted to represent a storm-dominated offshore environment due to the distribution of tempestites (Håkansson *et al*., 1994) and the sedimentary facies of the overlying part of the Scaphitesnæse Member (see above).

Implications

The Wandel Sea Basin – and Kilen in particular – is a key area for the understanding of the Mesozoic stratigraphy of the Arctic. Together with the biostratigraphic advances, the new lithostratigraphic scheme allows a more straightforward correlation to other arctic areas and forms a robust basis for future sequence stratigraphic and tectonostratigraphic interpretations.

The main changes to the previous lithostratigraphic schemes include a simplification of the 'mid' to Upper Cretaceous lithostratigraphy of Kilen (Fig. 5). Previously the strata in Kilen Fjelde were referred to two groups and fifteen formations, while the strata in the Gåseslette area constituted four formations in one group. The new data on lithologies and fossils have allowed a correlation from Kilen Fjelde to Gåseslette, and all the late Aptian to Santonian strata throughout Kilen are now referred to the Galadriel Fjeld and Sølverbæk Formations. Other key changes include the assignment of the Mågensfjeld Formation to the Middle Jurassic instead of the Upper Cretaceous, the recognition of a new Gletscherport Formation below the upper Bajocian interval, and the dating of the Galadriel Fjeld Formation. The redefined Mågensfjeld Formation can be directly correlated with the Pelion Formation in North-East Greenland (e.g. Engkilde & Surlyk 2003), whereas the Galadriel Fjeld Formation correlates closely with the Carolinefjellet Formation on Svalbard (Grundvåg & Olaussen 2017) and the Christopher Formation of the Sverdrup Basin (Schröder-Adams *et al*. 2014; Sheldon *et al*. 2017). The redefined Sølverbæk Formation correlates with the Kveite Formation on the Barents shelf, see e.g. Nøttvedt *et al*. (2008).

Finally, there are several significant lithological boundaries that may prove useful in future regional correlations. These include the boundary between the Galadriel Fjeld Formation and the overlying Sølverbæk Formation, where there is a major change in lithology from upper offshore to middle shoreface deposits, dominated by sandstones, to shelf mudstone. Future studies may show faunal changes across this boundary, which would strengthen the value of the Sølverbæk Formation for regional correlation. It is possible that the flooding can be correlated to the extensive late Cenomanian transgression in northern Canada, the Western Interior Seaway and Baffin Bay (Schröder-Adams *et al.* 2014).

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References

Alsen, P. 2018a: A hoplitinid–gastroplitinid ammonite assemblage in North Greenland - linking the upper middle Albian in the Arctic with NW Europe. In: Bengtson, P. (ed.), Cretaceous Ammonites: A volume in Memory of Richard A. Reyment (1926–2016), Cretaceous Research, 9 pp, in press. https://doi.org/10.1016/j.cretres.2017.10.018.

Alsen, P. 2018b: *Kossmaticeras* in North Greenland. In: Bengtson, P. (ed.), Cretaceous Ammonites: A volume in Memory of Richard A. Reyment (1926–2016), Cretaceous Research, 10 pp, in press. https://doi.org/10.1016/j.cretres.2017.10.010.

Alsen, P., McRoberts, C., Svennevig, K., Bojesen-Koefoed, J., Hovikoski, J. & Piasecki, S. 2017: The Isrand Formation: a Middle Triassic *Daonella*-bearing, black shale unit in Kilen, North Greenland (with a note on the Triassic in Amdrup Land). Newsletters on Stratigraphy 50(1), 31–46.

Bengaard, H.J. & Henriksen, N. 1986: Geological map of Greenland 1:500 000, Sheet 8, Peary Land. Copenhagen: Geological Survey of Greenland.

Birkelund, T. & Håkansson, E. 1983: The Cretaceous of North Greenland – a stratigraphic and biogeographical analysis. Zitteliana 10, 7–25.

Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. 2013 (updated 2017): The ICS International Chronostratigraphic Chart. Episodes 36, 199–204.

Crame, J.A. 1985: Lower Cretaceous Inoceramid bivalves from the Antarctic Peninsula region. Palaeontology 28, 475–525.

Dallmann, W.K. *et al*. 1999: Lithostratigraphic Lexicon of Svalbard: Review and Recommendations for Nomenclature Use: Upper Palaeozoic to Quaternary Bedrock. Tromsø: Norsk Polarinstitutt, 318 pp.

Dawes, P. & Soper, J. 1973: Pre-Quarternary history of North Greenland. In: Pitcher, M.G. (ed.), Arctic Geology. Memoir of the American Association of Petroleum Geologists 19, 117–134.

Donovan, D.T. 1953: The Jurassic and Cretaceous stratigraphy and palaeontology of Traill Ø, East Greenland, Meddelelser om Grønland 111, 150 pp.

Dypvik, H., Håkansson, E. & Heinberg, C. 2002: Jurassic and Cretaceous palaeogeography and stratigraphic comparisons in the North Greenland–Svalbard region. Polar Research 21(1), 91–108.

Engkilde, M. & Surlyk, F. 2003: Shallow marine syn-rift sedimentation: Middle Jurassic Pelion Formation, Jameson Land, East Greenland. In: Ineson, J.R. & Surlyk, F. (eds), The Jurassic of Denmark and Greenland. Geological Survey of Denmark and Greenland Bulletin 1, 813–863.

Grasby, S.E., McCune, G.E., Beauchamp, B. & Galloway, J.M. 2017: Lower Cretaceous cold snaps led to widespread glendonite occurrences in the Sverdrup Basin, Canadian High Arctic. GSA Bulletin 129(7/8), 771–787, doi: 10.1130/B31600.1.

Grundvåg, S.A. & Olaussen, S. 2017: Sedimentology of the Lower Cretaceous at Kikutodden and Keilhaufjellet, southern Spitsbergen: implications for an onshore–offshore link. Polar Research 36(1), 20 pp. doi: 10.1080/17518369.2017.1302124.

Håkansson, E. 1979: Carboniferous to Tertiary development of the Wandel Sea Basin, eastern North Greenland. In: Report on the 1978 Geological Expedition to the Peary Land Region, North Greenland. Rapport Grønlands Geologiske Undersøgelse 88, 73–83.

Håkansson, E. 1994: Scaphitid ammonoids and inoceramids bivalves from Upper Cretaceous strata in North Greenland. In: Håkansson, E. (ed.), Wandel Sea Basin: Basin analysis. EFP-91, project No. 0012, Geological Institute, University of Copenhagen, Scientific report 14, 8 pp.

Håkansson, E. & Pedersen, S.A.S. 1982: Late Paleozoic to Tertiary tectonic evolution of the continental margin in North Greenland. In: Embry, A.F. & Balkwill, H.R. (eds), Arctic Geology and Geophysics: Proceedings of the Third International Symposium on Arctic Geology. Canadian Society of Petroleum Geology, Calgary, 331–348.

Håkansson, E. & Pedersen, S.A.S. 2015: A healed strike-slip plate boundary in North Greenland indicated through associated pull-apart basins. Geological Society, London, Special Publications 413, 143–169.

Håkansson, E. & Stemmerik, L. 1984: Wandel Sea Basin: the North Greenland equivalent to Svalbard and the Barents Shelf. In: Spencer A.M. (ed.), Petroleum geology of the North European margin. Proceedings of symposium organised by the Norwegian Petroleum Society, 97–107. London: Graham and Trotman.

Håkansson, E. & Stemmerik, L. 1989: Wandel Sea basin: A new synthesis of the late Paleozoic to Tertiary accumulation in North Greenland. Geology 17, 683–686. doi:10.1130/0091-7613(1989)017<0683.

Håkansson, E., Birkelund, T., Piasecki, S. & Zakharov, V. 1981a: Jurassic–Cretaceous boundary strata of the extreme arctic (Peary Land, North Greenland). Bulletin of the Geological Society of Denmark 30, 11–42.

Håkansson, E., Heinberg, C. & Stemmerik, L. 1981b: The Wandel Sea basin from Holm Land to Lockwood Ø, eastern North Greenland. In: Report on the 1980 Geological Expedition to the Peary Land Region, North Greenland. Rapport Grønlands Geologiske Undersøgelse 106, 47–63.

Håkansson, E., Heinberg, C. & Stemmerik, L. 1991: Mesozoic and Cenozoic history of the Wandel Sea Basin area, North Greenland. In: Peel, J. S. & Sønderholm, M. (eds), Sedimentary Basins of North Greenland. Bulletin Grønland geologiske Undersøgelse 160, 153–164.

Håkansson, E., Birkelund, T., Heinberg, C., Hjort, C., Mølgaard, P. & Pedersen, S.A.S. 1993: The Kilen Expedition 1985. Bulletin of the Geological Society of Denmark 40, 9–32.

Håkansson, E., Heinberg, C. & Pedersen, S.A.S. 1994: Geology of Kilen. In: Håkansson, E. (ed.), Wandel Sea Basin: Basin analysis. EFP-91, project No. 0012, Geological Institute, University of Copenhagen, Scientific report 16, 13 pp.

Heinberg, C. & Håkansson, E. 1994: Late Jurassic – Early Cretaceous stratigraphy and depositional environment. In: Håkansson, E. (ed.), Wandel Sea Basin: Basin analysis. EFP-91, project No. 0012, Geological Institute, University of Copenhagen, Scientific report 12, 8 pp.

Henriksen, N. 2003: Caledonian Orogen, East Greenland 70°–82° N. Geological Map 1:1 000 000. Copenhagen: Geological Survey of Denmark and Greenland.

Imlay, R.W. 1961: Characteristic Lower Cretaceous megafossils from northern Alaska. U.S. Geological Survey Professional Paper 335, 74 pp.

Jeletzky, J.A. 1964: Illustrations of Canadian fossils. Lower Cretaceous marine index fossils of the sedimentary basins of western and Arctic Canada. Geological Survey of Canada Papers 64-11, 1–101.

Jeletzky, J.A. 1968: Macrofossil zones of the marine Cretaceous of the Western Interior of Canada and their correlation with the zones and stages of Europe and the Western Interior of the United States. Geological Survey of Canada Papers 67-72, 1–66.

Kauffman, E.G. 1977: Illustrated guide to biostratigraphically important Cretaceous macrofossils, Western Interior Basin, USA. Mountain Geologist 14, 225–274.

Keller, S. 1982: Die Oberkreide der Sack-Mulde bei Alfeld (Cenoman – Unt-Coniac), Lithologie, Biostratigraphie und Inoceramen. Geologisches Jahrbuch, A64, 3–171.

Kelly, S.R.A., Whitham, A.G., Koraini, A.M. & Price, S.P. 1998: Lithostratigraphy of the Cretaceous (Barremian–Santonian) Hold with Hope Group, NE Greenland. Journal of the Geological Society, London 155, 993–1008.

Mutrux, J., Maher, H., Shuster, R. & Hays, T. 2008: Iron ooid beds of the Carolinefjellet Formation, Spitsbergen, Norway. Polar Research 27, 28–43, doi:10.1111/j.1751-8369.2007.00039.x

Nielsen, E. 1941: Remarks on the map and the geology of Kronprins Christians Land. Meddelelser om Grønland 126(2), 34 pp.

Nøhr-Hansen, H. 1993: Dinoflagellate cyst stratigraphy of the Barremian to Albian, Lower Cretaceous, North-East Greenland. Bulletin Grønlands Geologiske Undersøgelse 166, 171 pp.

Nøttvedt, A., Johannessen, E.P. & Surlyk, F. 2008: The Mesozoic of Western Scandinavia and East Greenland. Episodes 31(1), 59–65.

Pchelina, T.M. 1965: Mesozoyskiye otlozhcniya rayona Van Kcylcnf'orda (Zapadnyy Shpitsbergen) [Mesozoic deposits around Van Keulenfjorden, Vestspitsbergen]. In: Sokolov. V.N. (ed.), Muteriuly pogeologii S hpitsbergenu [Materials on the geology of Spitsbergen]. Nauch. Isslcd. lnstitut Geologii Arktiki, Leningrad.

Pedersen, S.A.S. 1991 (compiled 1989): Geological map of Kilen, Kronprins Christian Land, North Greenland, 1:100 000 (unpublished). In the archives of the Geological Survey of Denmark and Greenland (GEUS), Copenhagen. http://data.geus.dk/geusmapmore/get_binary_mapdb.jsp?digitalmap_id=4313.

Pedersen, S.A.S. & Håkansson, E. 2001: Kronprins Christian Land Orogeny, deformational Styles of the End Cretaceous Transpressional Mobile Belt in Eastern North Greenland. Polarforschung 69, 117–130.

Pemberton, S.G., MacEachern, J.A., Dashtgard, S.E., Bann, K.L., Gingras, M.K. & Zonneveld, J.-P. 2012: Shorefaces. Developments in Sedimentology 64, 563–603.

Pergament, M.A. 1965: Inocerams and Cretaceous stratigraphy of the Pacific region. Trudý Inst. Geol. Nauk. Moskva 118, 1–102.

Piasecki, S., Nøhr-Hansen, H. & Dalhoff, F. 2018: Revised stratigraphy of Kap Rigsdagen beds, Wandel Sea Basin, North Greenland. Newsletters on Stratigraphy, published online February 2018, doi: 10.1127/nos/2018/0444, 15 pp.

Piepjohn, K. & von Gosen, W. 2001: Polyphase deformation at the Harder Fjord Fault Zone (North Greenland). Geological Magazine 138(4), 407–434.

Price, G.D. & Nunn, E.V. 2010: Valanginian isotope variation in glendonites and belemnites from Arctic Svalbard: Transient glacial temperatures during the Cretaceous greenhouse. Geology 38, 251–254, doi:10.1130/G30593.1.

Rolle, F. 1981: Hydrocarbon source rock sampling in Peary Land 1980. Rapport Grønlands Geologiske Undersøgelse 106, 99–103.

Røhr, T.S., Andersen, T. & Dypvik, H. 2008: Provenance of Lower Cretaceous sediments in the Wandel Sea Basin, North Greenland. Journal of the Geological Society, London 165, 755–767.

Schröder-Adams, C.J., Herrle, J.O., Embry, A.F., Haggart, J.W., Galloway, J.M., Pugh, A.T. & Harwood, D.M. 2014: Aptian to Santonian foraminiferal biostratigraphy and paleoenvironmental change in the Sverdrup Basin as revealed at Glacier Fiord, Axel Heiberg Island, Canadian Arctic Archipelago. Palaeogeography, Palaeoclimatology, Palaeoecology 413, 81–100, doi:10.1016/j.palaeo.2014.03.010.

Sheldon, E., Lauridsen, B.W. & Alsen, P. 2017: Lower Cretaceous Biostratigraphy of Kilen and Peary Land, Wandel Sea Basin, North Greenland, and its implications for correlation with the Sverdrup Basin, Arctic Canada. Abstract, AAPG 3P (Polar Petroleum Potential) Conference, London, October 15th–18th 2017.

Soper, N.J., Higgins, A. & Friderichsen, J.D. 1980: The North Greenland fold belt in eastern Johannes V. Jensen Land.

Rapport Grønlands Geologiske Undersøgelse 99, 89–98.
Stemmerik, L., Dalhoff, F., Larsen, B.D., Lyck, J., Mathiesen, A. & Nilsson, I. 1998: Wandel Sea Basin, eastern North Greenland. Geology of Greenland Survey Bulletin 180, 55–62.
Stolley, E. 1912: Über die Kreideformation und ihre Fossilien auf Spitzbergen. Kungliga Svenske Vetenskapsakademens Handlinger 47(11), Stockholm, 1–29.
Surlyk, F. & Zakharov, V. 1982: Buchiid bivalves from the Upper Jurassic and Lower Cretaceous of East Greenland. Palaeontology 25(4), 727–753.
Svennevig, K. 2018a: Geological map of Kilen - eastern North Greenland 1:100.000, Kilen 81 Ø.1 Syd. Copenhagen: Geological Survey of Denmark and Greenland, in press.
Svennevig, K. 2018b: Update of the seamless 1:500 000 scale geological map of Greenland based on recent fieldwork in the Wandel Sea Basin, eastern North Greenland. Bulletin of the Geological Survey of Danmark and Greenland 41, 4 pp, in press.
Svennevig, K., Guarnieri, P. & Stemmerik, L. 2015: From oblique photogrammetry to a 3D model – Structural modeling of Kilen, eastern North Greenland. Computers & Geosciences 83, 120–126, doi: 10.1016/j.cageo.2015.07.008.
Svennevig, K., Guarnieri, P. & Stemmerik, L. 2016: Tectonic inversion in the Wandel Sea Basin: a new structural model of Kilen (eastern North Greenland). Tectonics 35, 1–34, doi: 10.1002/2016TC004152.
Svennevig, K, Guarnieri, P. & Stemmerik, L. 2017: 3D restoration of a Cretaceous rift basin in Kilen, eastern North Greenland. Norwegian Journal of Geology 97, 21–32, doi: 10.17850/njg97-1-02.
Svennevig, K., Alsen, P., Guarnieri, P., Hovikoski, J., Lauridsen, B.W., Pedersen, G.K., Nøhr-Hansen, H. & Sheldon, E. 2018: Descriptive text to the Geological map of Kilen, eastern North Greenland 1:100 000, Kilen 81 Ø.1 Syd. Geological Survey of Denmark and Greenland Map Series 8, in press.
Tröger. K.-A, 1967: Zur Paläontologie, Biostratigraphie und faziellen Ausbildung der unteren Oberkreide (Cenoman bis Turon). Teil 1. Paläontologie und Biostratigraphie der Inoceramen des Cenomans und Turons Mitteleuropas. Abhandlung Staatliche Museum Mineralogie und Geologie 12, 13–207.
Tröger, K.-A. & Christensen, W.K. 1991: Upper Cretaceous (Cenomanian – Santonian) inoceramid bivalve faunas from the island of Bornholm, Denmark. Danmarks Geologiske Undersøgelse, Serie A 28, 1–47.
Vickers, M.L., Price, G.D., Jerrett, R.M. & Watkinson, M. 2016: Stratigraphic and geochemical expression of Barremian–Aptian global climate change in Arctic Svalbard: Geosphere 12(5), 1594–1605, doi:10.1130/GES01344.1.
Walaszczyk, I. 1992: Turonian through Santonian deposits of the Central Polish Uplands; their facies development, inoceramid palaeontology and stratigraphy. Acta Geologica Polonica 42, 122 pp.
Walaszczyk, I. & Wood, C.J. 1998: Inoceramids and biostratigraphy at the Turonian/Coniacian boundary; based on the Salzgitter-Salder Quarry, Lower Saxony, Germany, and the Slupia Nadbrzezna section, Central Poland. Acta Geologica Polonica 48, 395–434.
Walaszczyk, I. & Cobban, W.A. 2016: Inoceramid bivalves and biostratigraphy of the upper Albian and lower Cenomanian of the United States Western Interior Basin. Cretaceous Research 59, 30–69.
Woods, H. 1911–1912: A monograph of the Cretaceous Lamellibranchia of England, Vol II, parts VII and VIII. Palaeontographical Society, London, 261–284 and 285–340.