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Character of basal and intraformational unconformities in the Calypsostranda Group (late Palaeogene), Bellsund, Spitsbergen

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Abstract: There are two important unconformities in the Calypsostranda Group (late Palaeogene) at Bellsund, Spitsbergen. The first one is the basal angular unconformity of the Skilvika Formation against folded and planated Proterozoic metasediments: the author provides evidence for its primary sedimentary character. The second one is an intraformational erosional disconformity/discontinuity expressed by rapid replacement of coal-bearing terrestrial strata (Skilvika Formation) by shallow-marine strata (Renarddodden Formation).

Key words: Arctic, Spitsbergen, late Palaeogene terrestrial and marine strata, basal and intraformational unconformities.

Introduction

The late Palaeogene strata at Bellsund, Spitsbergen (Fig. 1) crop out at Calypsostranda between Renardbreen in the south and Skilvika in the north (Figs 2, 3). They fill the Calypsostranda Graben situated in western part of the Tertiary fold-and-thrust belt (see Dallmann *et al.* 1990, 1993; Harland ed. 1997; Dallmann ed. 1999; Birkenmajer 2004).

The Calypsostranda Graben is a minimum 6 km long and more than 1.5 km wide, its Palaeogene sediment pile exceeds 250 m in thickness. The graben is bounded from the southwest by vertical, NW-SE-trending Calypsostranda Fault, and from the southeast by vertical, NE-SW-trending Josephbukta Fault (Fig. 3). Northeastern and northern boundaries of the graben run under sea level at a junction of Recherchefjorden and Bellsund (Birkenmajer 2004).

The Tertiary sediment fill of the Calypsostranda Graben, formally distinguished as the Calypsostranda Group (Dallmann ed. 1999) has been subdivided

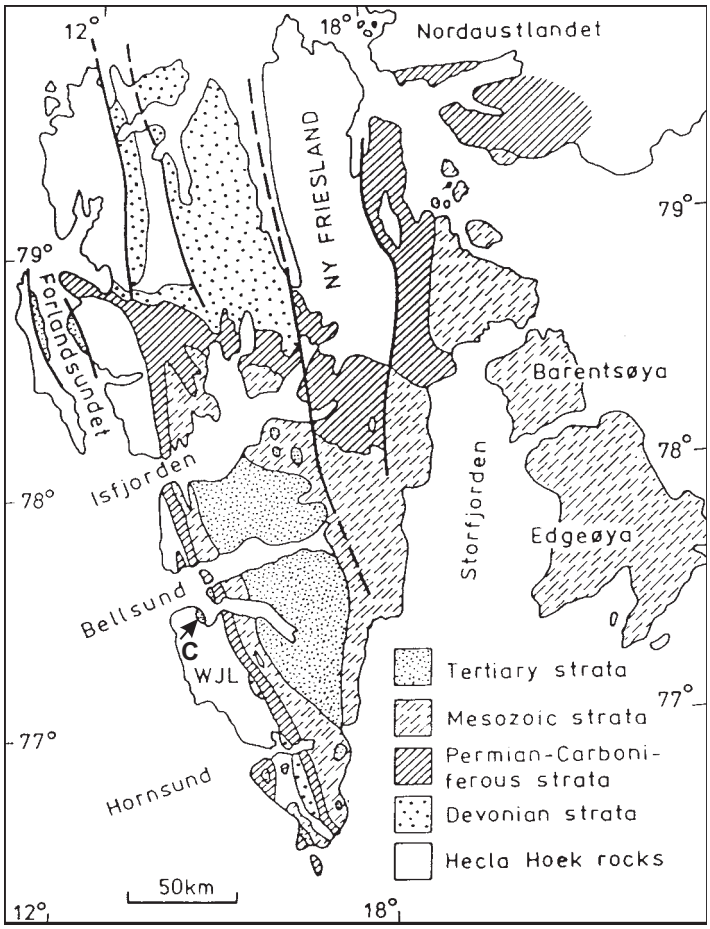

Fig. 1. Simplified geological map of Svalbard (compiled from various sources), C – Calypsostranda (Bellsund), WJL – Wedel Jarslaberg Land.

into two formations: the lower terrestrial Skilvika Formation, and the upper marine Renardodden Formation (see Livšic 1967, 1974; Dallmann *et al.* 1990; Harland ed. 1997; Dallmann ed. 1999).

Terrestrial plant remains (see Manum 1962; Livšic 1967, 1974; Schweitzer 1974; Lehmann *et al.* 1978; Thiedig *et al.* 1979) are indicative of an Oligocene age of the Calypsostranda Group, while dinocysts indicate its Late Eocene–Early Oligocene age (Head 1984; Manum and Throndsen 1986).

Basal unconformity of the Calypsostranda Group at Skilvika

Proterozoic substrate. — At its type section (coastal cliff at Skilvika, south Bellsund coast – see Fig. 3), the Skilvika Formation rests unconformably directly

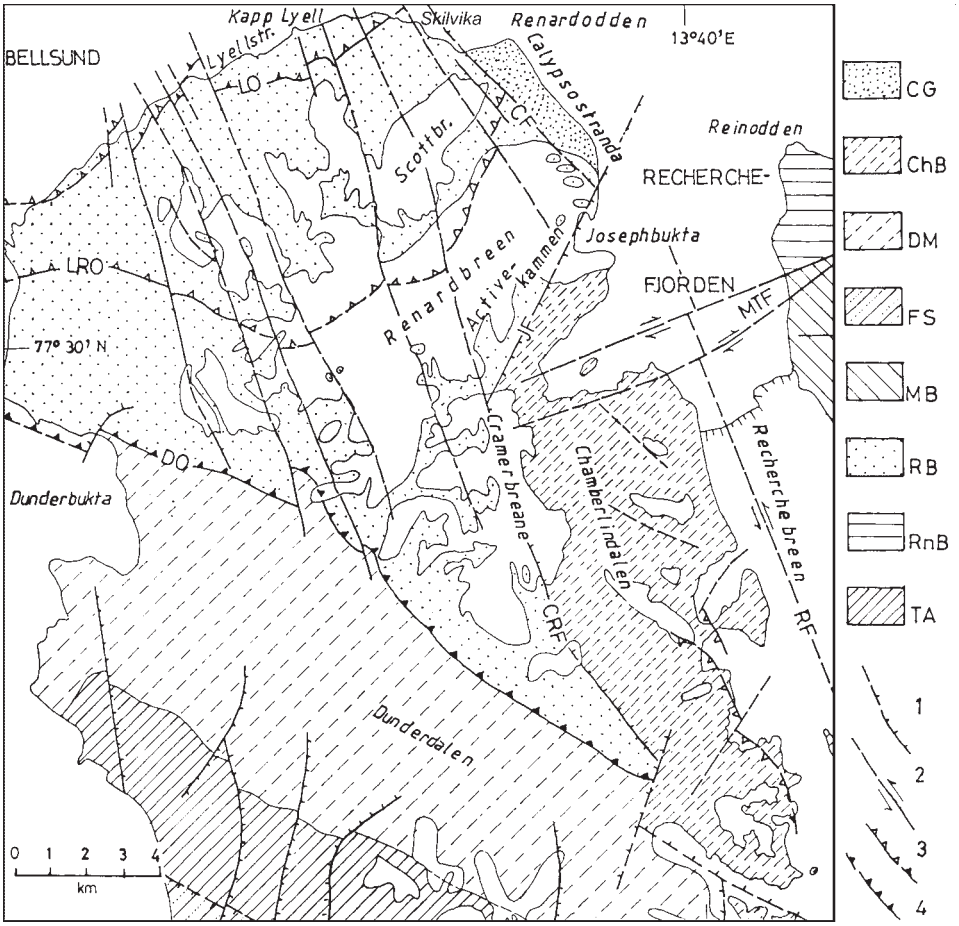

Fig. 2. Major tectonic elements in NW Wedel Jarlsberg Land and location of the late Palaeogene Calypsostranda Group (reinterpreted from Dallmann *et al.* 1990, geological map 1:100,000, and supplemented by Birkenmajer 2004, fig. 9). CG – Calypsostranda Graben (Tertiary deposits), ChB – Chamberlindalen Block (mainly Late Proterozoic rocks), DM – Dunderdalen Monocline (Late Proterozoic metasediments), FS – Fløysletta Synclinorium (?Middle–?Early Proterozoic metasediments), MB – Martinfjella Block (Late Proterozoic–Early Ordovician metasediments), RB – Renardbreen Block (Middle–Late Proterozoic metasediments), RnB – Reinodden Block (Late Palaeozoic–Mesozoic deposits), TA – Thiisfjellet Anticlinorium (Middle Proterozoic rocks), DO – Dunderfjellet Overthrust, LO – Lyellstranda Overthrust, LRO – Lognedalen-Renardbreen Overthrust, C – Calyposostranda Fault, CrF – Cramerbreane Fault, MTF – Maria-Theresiatoppen Faults, 1 – dip-slip faults (barbs on downthrown side), 2 – strike-slip faults (arrows indicate relative movement directions), 3, 4 – overthrusts.

upon Proterozoic metasediments represented by the Kapp Lyell diamictite. There is a controversy whether this contact is sedimentary (Vonderbank 1970; Livšic 1974) or tectonic (Thiedig *et al.* 1979; Dallmann 1989; Kowallis and Hauser – *fide* Dallmann 1989, 1990; Dallmann ed. 1999, fig. 4-49).

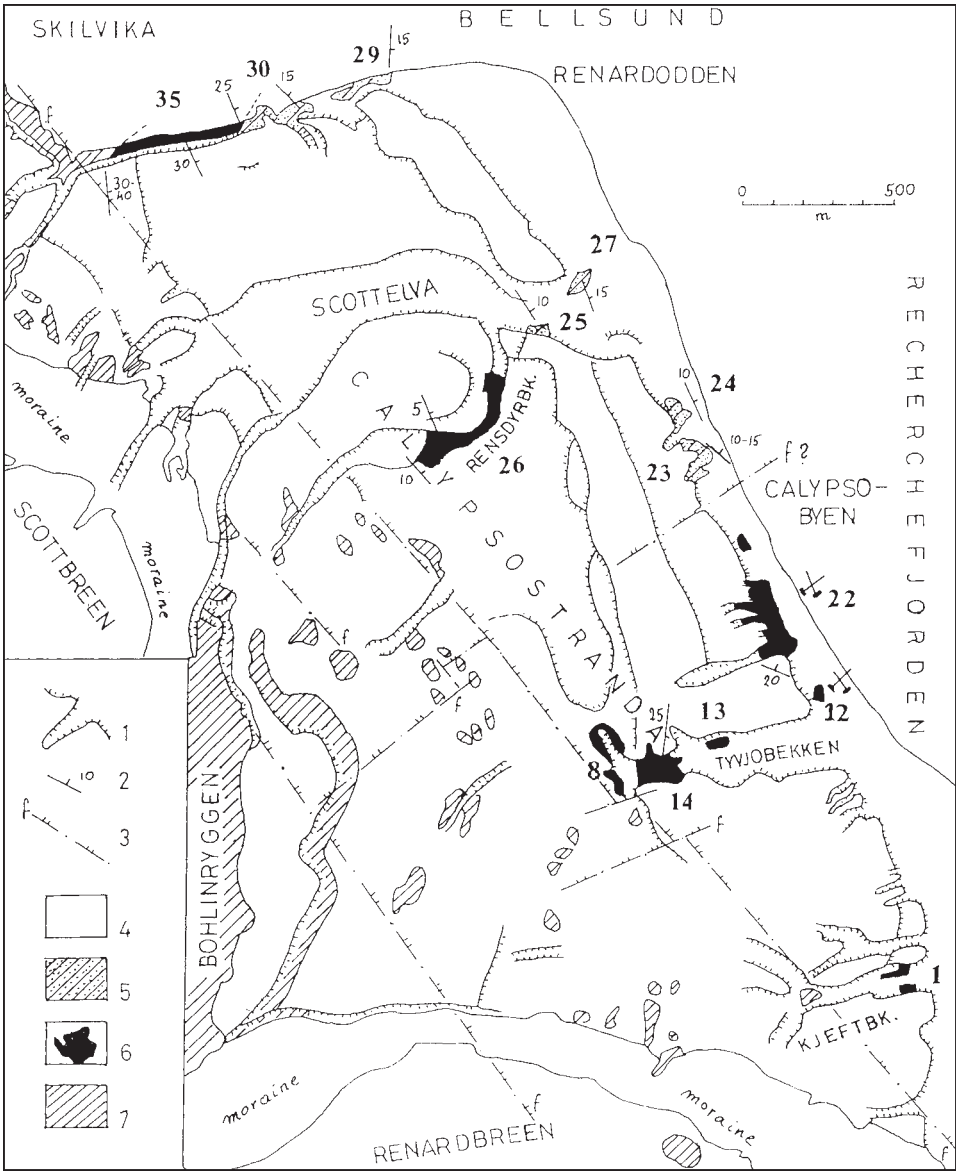

Fig. 3. Exposures of Palaeogene strata at Calypsostranda between Skilvika-Renardodden and Josephbukta. 1 – erosional escarpments, 2 – dips of strata, 3 – faults, 4 – Quaternary cover, 5 – Renardodden Fm. (late Palaeogene), 6 – Skilvika Fm. (late Palaeogene), 7 – Proterozoic metasediments.

The Proterozoic strata (Fig. 4: *1*; Fig. 6A: *1*) consist here of strongly tectonized, folded and faulted, grey to rusty to yellow quartzite-clast-supported diamictite with thin intercalations of quartzite and quartzitic sandstone (yellow diamictite unit of Birkenmajer 2003). Top part of the diamictite is stained yellowish by jarosite coat-

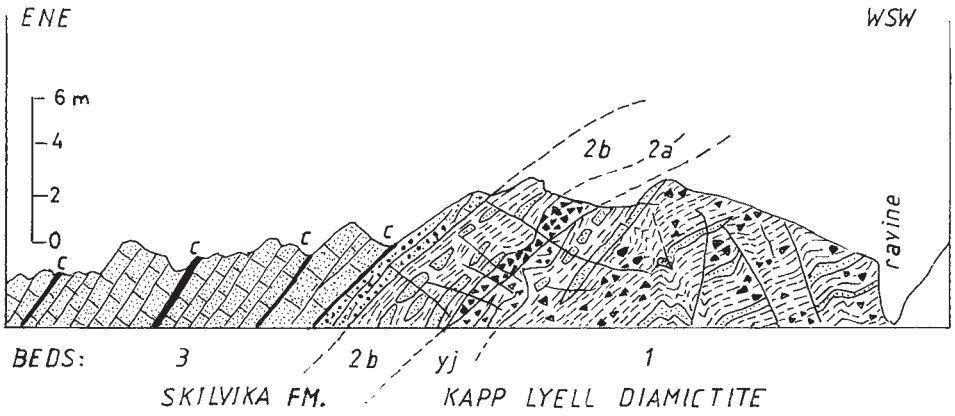

Fig. 4. Coastal cliff section at Skilvika. Contact of the Palaeogene Skilvika Fm. (2a, 2b, 3) with the Upper Proterozoic Kapp Lyell diamictite (1). c – coal intercalations (in black); yj – yellow jarosite coating; stippled sandstone, quartzite; black triangles – clasts and breccia; broken lines – shale and phyllite.

ing (Fig. 4: *yj*; Fig. 6A: *1yj*): this could be a palaeo-weathering surface (cf. Dallmann 1989, p. 142).

The T/Pr contact. — In type section of the Skilvika Formation at Skilvika (Fig. 4), the Proterozoic strata dip at angles of up to 60° due east; farther west, their dips vary between 20 and 60 degrees due NW and SW (see Fig. 3). At Skilvika, the basal unconformity surface (T/Pr) dips due east at 30–40 degrees. The angle of unconfomity between the basal Tertiary strata (Fig. 4: *2a, b*) which directly overlie folded and planated Proterozoic metasediments (Fig. 4: *1*) varies between 5 and 90 degrees.

Rocks below (Fig. 4: *1*) and above (Fig. 4: *2*) the T/Pr contact are cut by numerous small-scale faults. However, contrary to Dallmann (ed. 1999, fig. 4-49, p. 259), no major "fault contact" has been detected to separate the Skilvika Formation from the Kapp Lyell diamictite.

The Skilvika Formation: basal unit. — The Skilvika Formation begins at Skilvika with a 2-m thick unit of rather chaotic "basal breccia" ("Rochesterpynten Formation" of Harland *et al.* 1993, p. 100, and Harland ed. 1997, p. 180) resting in a normal depositional contact upon its Proterozoic substrate.

In lower part, the "basal breccia" (Fig. 4: *2a*; Fig. 6A: *2a*) consists of a thin wedge-shaped bed consisting of angular fragments 1–5 cm in diameter derived from the underlying diamictite. Higher up (Fig. 4: *2b*; Fig. 6A: *2b*), there comes a breccia-like bed consisting of angular fragments 5–20 cm in size of grey, laminated sandstone suspended in shaly-sandy matrix. This "basal breccia" could be regarded a fossilized incipient slump consisting of fragmented sandstone-shale Tertiary basal strata, deposited directly upon weathered and planated Proterozoic rocks.

The Skilvika Formation: overlying strata. — There follow grey to black, fine-grained, often laminated sandstone beds alternating with dark-grey to black shale, clayshale and coalshale, with numerous thin horizons of black shaly coal (Fig. 4: *3*), altogether about 100 m thick. This is a typical fluvio-deltaic to lacustrine development of the Skilvika Formation. The beds uniformly dip at 30–25 degrees NE (Figs 3, 4). The cliff section at Skilvika yielded plant fossils recorded by previous authors (see Manum 1962; Thiedig *et al.* 1979, fig. 3; Dallmann ed. 1999, fig. 4-49).

The Skilvika Formation at Tyvjobekken

Basal beds. — Basal beds of the Skilvika Formation are poorly exposed (mostly as scree) in southern part of Calypsostranda, in head part of the Tyvjobekken valley (informal name – see Birkenmajer and Zastawniak 2005) – Fig. 3. We see there loose blocks of green, fine-grained, platy sandstone and green sedimentary breccia consisting of shale pellets (pellet conglomerate) 0.1–1 cm in diameter. There are also blocks of breccia consisting of phyllite fragments.

Contact of the above rocks with the Kapp Lyell diamictite is covered by a thick layer of raised marine terrace gravel. Small exposures of the Kapp Lyell diamictite (yellow diamictite unit, Birkenmajer 2003) are visible nearby, southwest from outcrops of the the Skilvika Formation (Fig. 3).

Overlying beds. — Further east, down the valley, there are good exposures of the Skilvika Formation composed of a sandstone and shale complex with several coal-seams, with plant-bearing sandstone and siderite intercalations. The beds uniformly dip at 25–30 degrees east (Birkenmajer and Zastawniak 2005).

Disconformity between the Renardodden and the Skilvika formations

The Renardodden Formation consists of shallow marine strata over 150 m thick (see Dallmann ed. 1990, fig. 4-49).

The RF/SF disconformity. — The cliff section at Skilvika exposes a sedimentary contact (RF/SF) between the Renardodden Formation and the underlying Skilvika Formation (Figs 3, 5, 6B). There is a sharp lithological change from terrestrial monotonous repetitive sandstone-shale-coal sequence of the Skilvika Formation to much more lithologically diversified shallow marine deposits of the Renardodden Formation. The RF/SF contact is accepted at the base of well-cemented banded massive sandstone unit some 5.7 m thick which shows the presence of symmetric ripplemarks accentuated by black coal detritus, and of a thin lense of black redeposited coal (Fig. 5: beds 50–52).

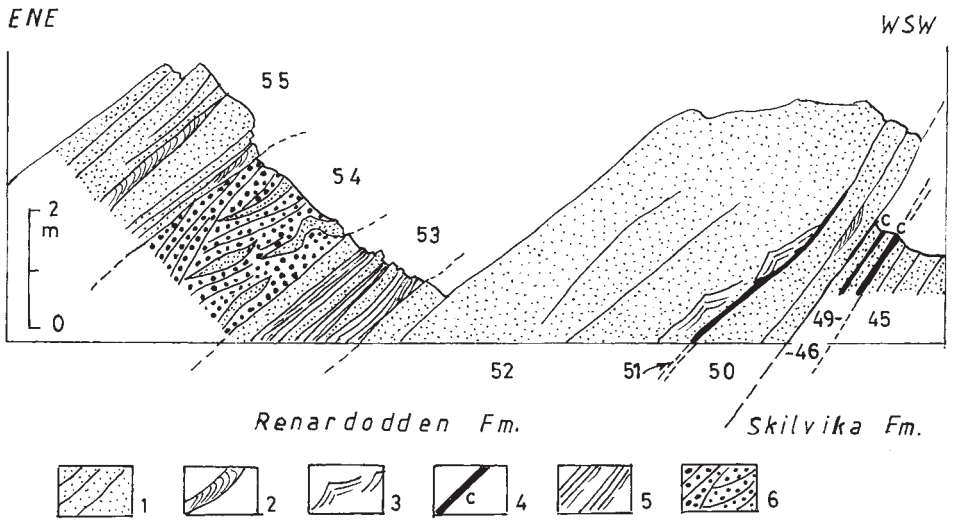

Fig. 5. Coastal cliff section at Skilvika: the RF/SF disconformity. Bed numbers: 45–49 – Skilvika Fm., 50–55 – Renardodden Fm. 1 – sandstone; 2 – convoluted cross-bedding; 3 – megaripples; 4 – coal seams (c); 5 – shale; 6 – gravelly conglomerate.

No angular unconformity has been detected at the RF/SF discontinuity. This witnesses a rapid marine ingression over terrestrial coastal delta, either of local or global dimensions.

Massive grey-greenish sandstone beds at the base of the Renardodden Formation show the presence of vertical *Scolithos*-type burrows (Fig. 8A). They might be considered a beach or shallow foreshore deposit. The overlying alternating sandstone/shale beds, 3.5 m thick (Fig. 5: bed 53) could represent slightly deeper foreshore deposits.

Overlying strata. — There follows a gravelly conglomerate band 1.5 m thick showing coarse cross-bedding, with undulating coarse sandstone intercalations (Fig. 7A–C). The gravel consists mainly of well rounded, isometric or spindle-like quartz and grey quartzite pebbles 0.5–5 cm in diameter, with a few black-coal angular fragments and pebbles 1–3 cm in diameter. It could either be a stormridge-type deposit or a littoral submerged gravel bar. Its material could have derived from weathered Lower Cretaceous conglomeratic and coal-bearing strata (the Helvetiafjellet and Carolinefjellet formations) exposed nearby.

Between Skilvika and Calypsobyen (see Fig. 3), the Renardodden Formation consists of a succession of grey to greenish, massive, usually fine-grained, well-cemented or friable sandstone layers with intercalations of well-rounded quartz and quartzite gravel, sometimes with horizons of carbonate concretions, with infrequent shale intercalations. Plant detritus and fragments of black coal occur in the sandstones. Numerous *Thalassinoides* crab burrows (Fig. 8B) are indicators of shallow-marine conditions of sedimentation in the Renardodden Formation.

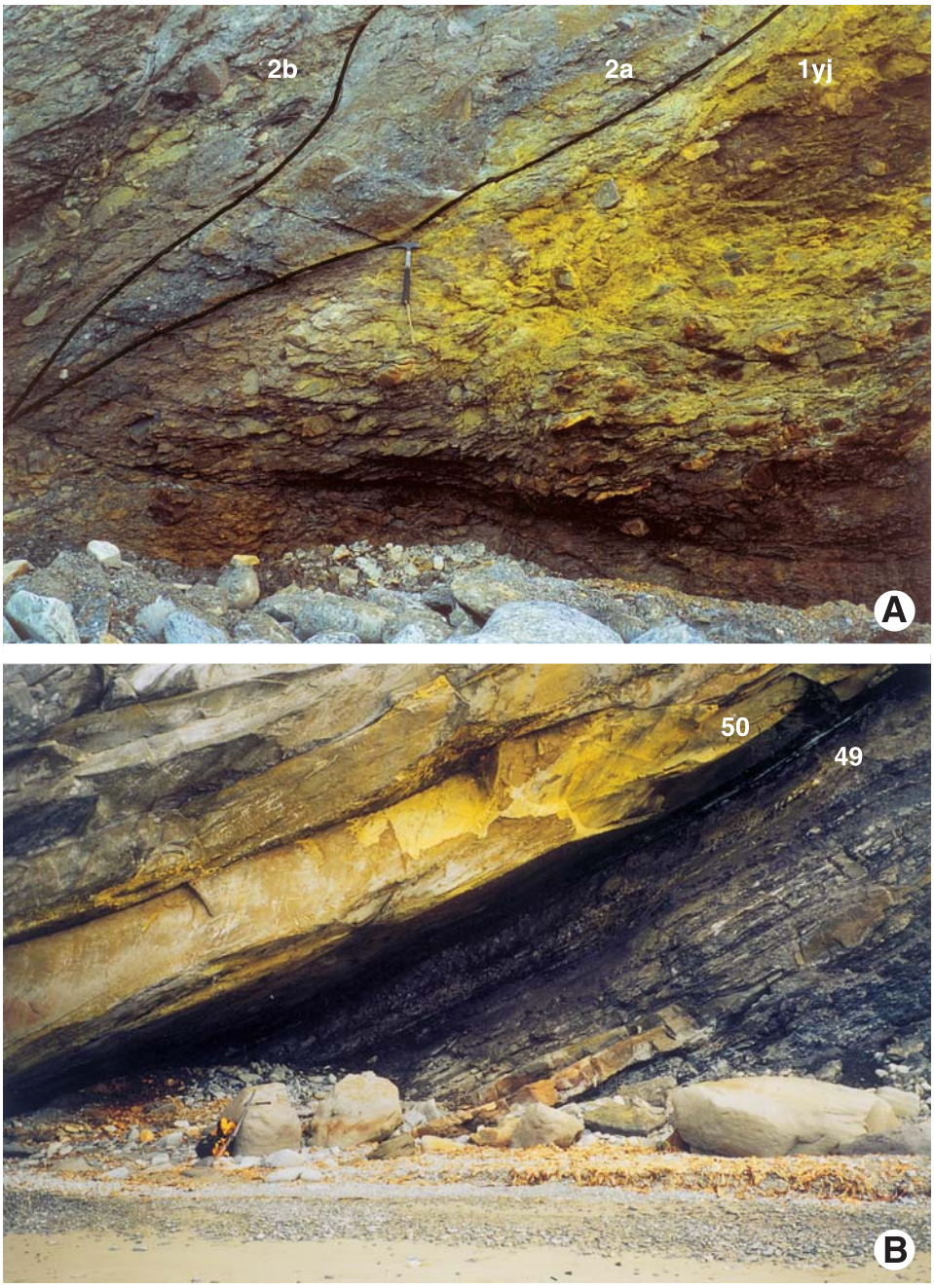

Fig. 6. Coastal cliff section at Skilvika. **A**. Contact of the Skilvika Fm (2a, b) with the Kapp Lyell diamictite (1yj). For explanations – see Fig. 4 and the text. **B**. The RF/SF disconformity (see Fig. 5): 49 – topmost sandstone bed of the Skilvika Fm.; 50 – basal sandstone bed of the Renardodden Fm.

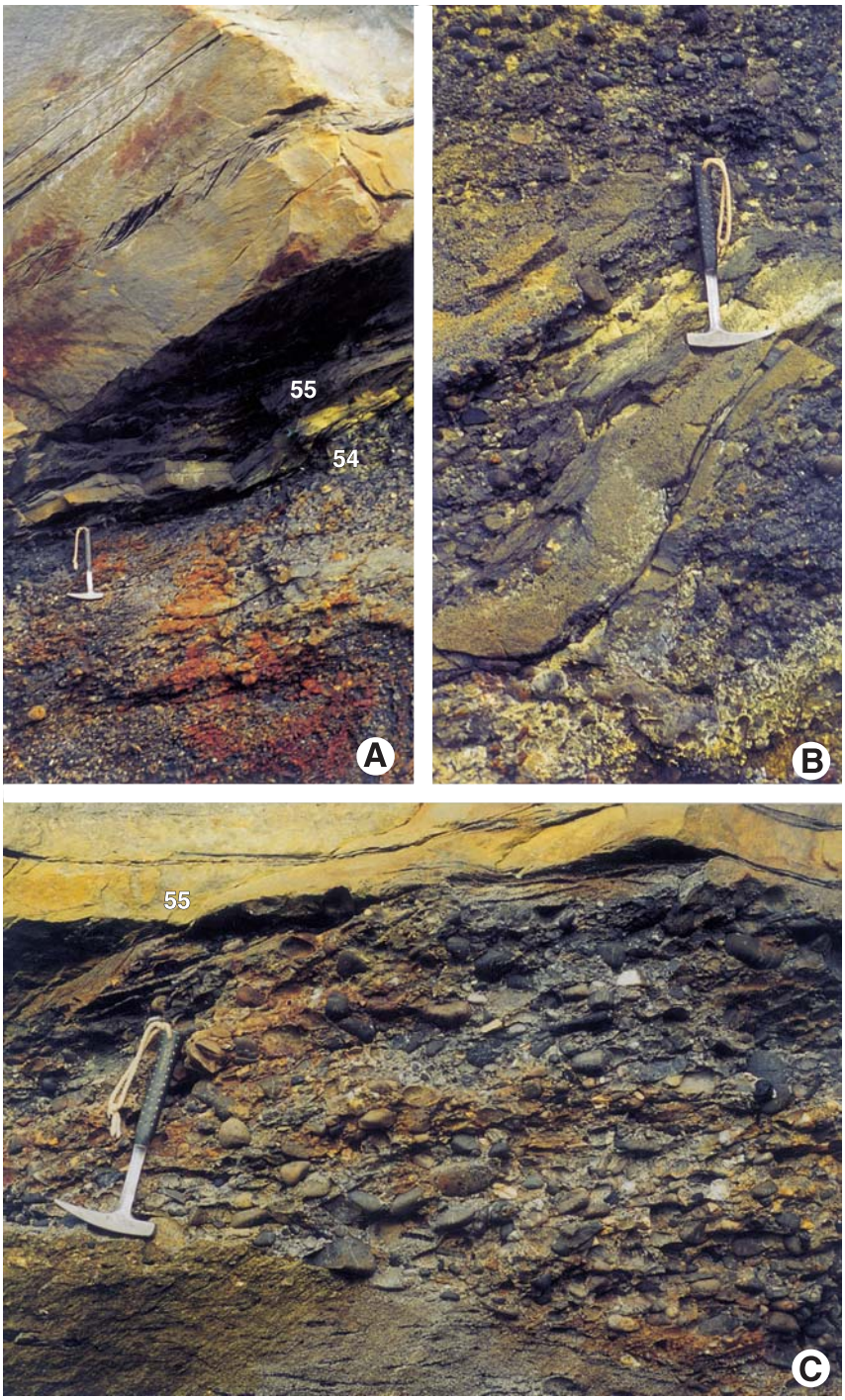

Fig. 7. Coastal cliff section at Skilvika. **A**–**C**. Sedimentary features in basal part of the the Renardodden Fm. (for description see the text), numbers refer to beds as shown in Fig. 5.

Fig. 8. Coastal cliff section at Skilvika. Trace fossils in the Renardodden Fm. **A**. *Scolithos* burrows (scale bar = 9 cm). **B**. *Thalassinoides* burrows.

Some tectonic features of the Calypsostranda Graben

The Calypsostranda Fault, which bounds the Calypsostranda Graben from southwest, is the main tectonic element of the graben exposed at the surface (see Fig. 3). At Skilvika, it dissects the Kapp Lyell diamictite at a distance of about 100 m west (Fig. 3: *f*) from the T/Pr contact. This is well observable at outlet of a creek (gorge) which provides the best way down to sea level from the 55-m high coastal cliff. Two more, similarly trending parallel faults dissect the diamictites further southwestward, between Scottelva and Bohlinryggen. These three faults represent a stepwise, NE-downthrowing gravity fault frame of the Calypsostranda Graben.

Dallmann (1989, p. 142, fig. 2) recognized two parallel faults in western part of Skilvika: the first at the base of a "conglomeratic mica schist" (his site 8) which underlied a 4–5-m thick "basal Tertiary conglomerate" (*sensu* Vonderbank 1970; Livšic 1974; Thiedig *et al.* 1979); and the second one, dissecting the pre-Tertiary rocks (*i.e.*: the "tilloid and quartzite", "mica schists with blocks", and "Orvinfjella conglomerate" – see Dallmann 1989, fig. 2, sites 1–7).

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