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Geology of new localities on Tabarin Peninsula, northern Antarctic Peninsula

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Abstract: New outcrops of Hope Bay Formation and Larsen Basin rocks have been exposed by recent ice-retreat on Tabarin Peninsula, northern Antarctic Peninsula. Quartzose, very low-grade metasedimentary rocks, cropping out at Balegno Nunatak (63°28'53"S, 57°00'31"W) are assigned to the Permian–Triassic Hope Bay Formation, and dioritic rocks are assigned to the Antarctic Peninsula batholith. Sedimentary rocks exposed at Rubulis Nunatak (63°30'52"S, 57°07'29"W) closely resemble Lower Cretaceous sedimentary rocks cropping out at nearby Troilo Nunatak, western Tabarin Peninsula. These rocks are correlated with the lower Gustav Group (?Barremian–Coniacian) of the Larsen Basin. This new record confirms that the Larsen Basin extends over southern Tabarin Peninsula, where basin sediments are thought to be faulted against sediments of the Antarctic Peninsula magmatic arc.

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Introduction

Tabarin Peninsula extends south *c.* 25 km, from the northern tip of the Antarctic Peninsula into the Weddell Sea. The 11 km wide isthmus between Hope Bay and Düse Bay separates Tabarin Peninsula from the main body of the Antarctic Peninsula. The altitude of Tabarin Peninsula is on average 250 m, with a maximum of *c.* 1000 m at Mount Taylor, immediately north of the isthmus (Fig. 1).

Recent ice-retreat in the northern Antarctic Peninsula has exposed new outcrops for geological study. This paper outlines the geology of two new localities on Tabarin Peninsula: Rubulis Nunatak (63°30'52"S, 57°07'29"W) and Balegno Nunatak (63°28'53"S, 57°00'31"W) (Fig. 1), and discusses their significance in a regional geological context.

Regional geology and stratigraphy

Two major lithotectonic units from the northern Antarctic Peninsula (Elliot 1988) are exposed on Tabarin Peninsula:

1) Lithotectonic Unit 1: Mesozoic magmatic arc of the Antarctic Peninsula. Unit 1 occupies the northern part of Tabarin Peninsula, and consists largely of quartzose, very low-grade metasedimentary and igneous rocks (Fig. 1). The metasedimentary rocks were assigned to the Hope Bay Formation (HBF; Hyden & Tanner 1981) of the Permian–Triassic Trinity Peninsula Group (TPG; Hyden & Tanner 1981). They are unconformably overlain by basement-derived, non-marine sedimentary rocks of the Mount Flora Formation (Elliot & Gracanin 1983) of the Early Jurassic Botany Bay Group, (Farquharson 1984), and subaerial, siliceous volcanic rocks of the Kenney Glacier Formation (Birkenmajer 1988). The volcanic rocks are thought to be of Middle Jurassic age (Riley & Leat 1999) and are assigned to the Antarctic Peninsula Volcanic Group (APVG; Thomson 1982). The Triassic to Early Cretaceous plutonic rocks of the Antarctic Peninsula batholith (Leat *et al.* 1995) are divided into three groups by age (Leat *et al.* 1997): 1) Group A: Late Triassic–Early Jurassic, 2) Group B: Early–Late Jurassic, and 3) Group C: Early Cretaceous. At present exposure levels, the plutonic rocks of Tabarin Peninsula are volumetrically dominated by granitoid rocks, with subordinate mafic rocks, including diorites and gabbros (Fig. 1). Dating (Pankhurst 1982) suggests that these rocks may be included in Group C.
2) Lithotectonic Unit 2: back-arc basin sedimentary rocks of the James Ross Basin (Elliot 1988, del Valle *et al.* 1992). This basin was considered by del Valle *et al.* (1992) to be the northern sub-basin of the Larsen Basin (Macdonald *et al.* 1988), which developed behind the then active magmatic arc of the Antarctic Peninsula (Farquharson *et al.* 1984). Table I shows the lithostratigraphy of the Larsen Basin.

Scasso *et al.* (1986) and del Valle *et al.* (1986) reported proximal sedimentary rocks of the Larsen Basin at Troilo Nunatak, Düse Bay, western Tabarin Peninsula (Fig. 1). These were assigned to the Barremian–Santonian lower Gustav Group of Ineson *et al.* (1986), and are thought to be unconformably overlain by Late Cenozoic alkaline basaltic rocks of the James Ross Island Volcanic Group (JRIVG, Nelson 1975), widely exposed on the southern Tabarin Peninsula (Smellie *et al.* 1988) (Fig. 1).

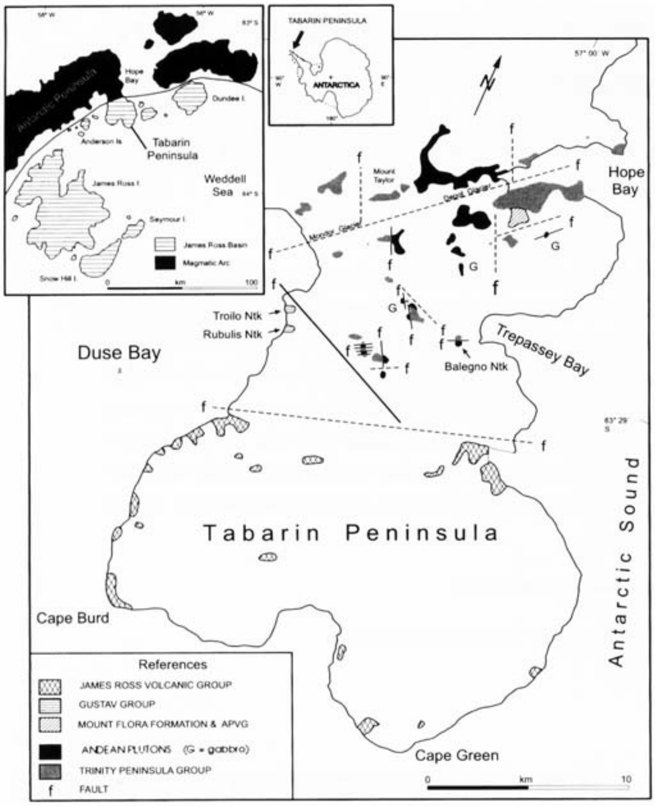

Fig. 1. Sketch geologic map of the Tabarin Peninsula, showing the outcrops and major faults. Intrusive plutonic rocks, including gabbros (G) flanked by Permian–Triassic sediments and/or very low-grade metasediments of the Trinity Peninsula Group, Middle Jurassic volcanic rocks of the Antarctic Peninsula Volcanic Group and Lower Jurassic sedimentary rocks of the Mount Flora Formation are shown in northern part of the peninsula. Rocks assigned to the lower Gustav Group (Lower Cretaceous) and James Ross Island Volcanic Group (Miocene–Recent) are shown at the centre, west and south of the peninsula, respectively. The thick dashed line, indicating a supposed east-south-east fault at the western side of the peninsula marks the boundary proposed in this paper between Larsen Basin sediments and Antarctic Peninsula magmatic arc rocks, exposed at the Tabarin Peninsula. The extreme NW limit of Larsen Basin modified from Farquharson *et al.* (1984), Macdonald *et al.* (1988), and del Valle *et al.* (1992) is displayed in the inset. Limit of outcrops are modified from the Antarctic Digital Database Version 1.0 (British Antarctic Survey *et al.* 1993).

Balegno Nunatak

Balegno Nunatak is located *c.* 150 m above sea level on the coast of Trepassey Bay, eastern Tabarin Peninsula (Fig. 1). Dioritic rocks crop out over most of the nunatak, except to the north-west where *c.* 60 m of steeply-dipping sedimentary rocks are exposed, showing textures weakly thermally altered. Contact relationships between dioritic and sedimentary rocks are obscured by a small frost-debris-filled glacial trench. However, weak thermal metamorphism of the sedimentary rocks suggests that they were probably intruded by dioritie. Nevertheless, sub-vertical north-east-striking faults appears to separate the lithologies (Fig. 1).

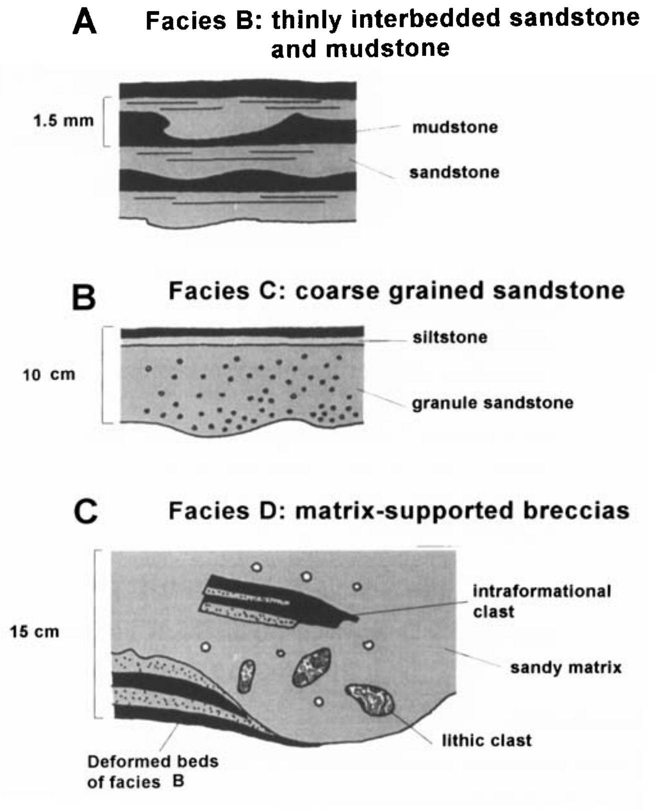

Fig. 2. Sedimentary facies of the Hope Bay Formation (HBF) identified at the Balegno Nunatak (Fig. 1).

The sedimentary succession dips steeply (80–85°) towards the north-west. It consists of mudstones, sandstones and sparse breccias, assigned here to the Hope Bay Formation. Succession base and top are not seen. Four main sedimentary facies were identified (Fig. 2):

1) Facies A, mudstone,
2) Facies B, graded sandstone,
3) Facies C, thinly interbedded sandstone and mudstone,
4) Facies D, matrix supported fine-grained breccia.

Facies A: Uncleaved, dark brownish-grey mudstone with beds 10–25 cm thick, lacking bioturbation, with sharp planar lower contacts. Intense weathering reveals rare silty layers; limonite stain veinlets are very common. These mudstones may represent suspension deposits produced by settling on the sea floor.

Facies B (Fig 2a.): Thinly interbedded graded, coarse- to fine-grained siliciclastic sandstones and dark-grey mudstones. Sandstones are composed of well-sorted, densely packed quartz grains, bed thickness averages 3 mm (range 2 mm–1 cm) with typically sharp, commonly loaded or fluted lower contacts. The mudstones are similar to Facies A. These thinly

Table I. Lithostratigraphy of the Larsen Basin at the James Ross Island–Jason Peninsula area (modified from Sadler 1988, Smellie & Millar 1995, Elliot 1988, Smellie *et al.* 1988, Marenssi *et al.* 1998, Hathway 2000).

Groups	Formations	Age	Observations
James Ross Island Volcanic Group		Miocene–Recent	alkaline basaltic volcanics
	?		
	La Meseta Formation	Eocene	
Seymour Island Group	Cross Valley Formation	Paleocene	regressive megasequence
	Sobral Formation	?Paleocene	
Marambio Group	Lopez de Bertodano Formation	Maastrichtian–Danian	
	Snow Hill Island Formation	Campanian–Maastrichtian	
	Santa Marta Formation	Santonian–Campanian	
	Hidden Lake Formation	Coniacian–Santonian	
	Whisky bay Formation	Albian–Coniacian	– partial basin inverssion
Gustav Group	Kotick Point Formation	Aptian–Albian	
	Lagrelius Point Formation & Pedersen Formation (Sobral Peninsula)	Barremian–Aptian	
	?		
	?		
	?Pedersen Formation (Pedersen Nunatak beds)	?Hauterivian	?regressive megasequence
	?		
	Nordenskjöld Formation	Kimmeridgian–Berriasian	transgressive post-rift megasequence
	Cape Framnes beds (Jason Peninsula)	Kimmeridgian–Tithonian	
	?		
	silicic volcanic rocks	Middle Jurassic	
	?		
	mainly silicic ignimbrites	Middle Jurassic	syn-rift megasequence
Botany Bay Group		Lower Jurassic	
		?latest Triassic–Lower Jurassic	continental breakup
deformation, low- to high-grade metamorphism			unconformably
Trinity Peninsula Group		Permian–Triassic	?accretionary complex, mechanical basement of the basin

interbedded units are thought to represent overbank deposits.

Facies C (Fig. 2b): Poorly sorted granule sized, mainly siliciclastic wackes graded to fine-grained sandstones. Beds average 10 cm thick (from 5–50 cm) with mainly sharp, loaded and fluted lower contacts. They are laterally continuous over *c.* 500 m. In many cases, graded sandstone layers form amalgamated beds, where rare, thin, normally-graded quartz-rich sandy beds have massive basal parts and planar-laminated fine-grained tops. The amalgamated sandstones of this facies may represent shallow, ?meandering channel deposits.

Facies D (Fig. 2c): Poorly sorted, matrix-supported normally graded breccias of angular clasts (from 3–6 cm), "floating" in a sandy siliciclastic matrix. Clasts are dominated by Facies C-like sedimentary rocks (intraformational), with minor schist and strongly weathered silicic ?plutonic rock. Beds are *c.* 20 cm thick (from 15–45 cm), with sharp, commonly fluted and loaded lower contacts. These breccias are thought to represent subaqueous slumps.

Facies A, B and C closely resemble classic turbidite facies of the TPG, including the HBF of Hyden & Tanner (1981). According to this interpretation, they were deposited by submarine fans along a continental margin. Siliceous sandstones and mudstones of Facies B are here assigned to distal turbidites, levée or overbank deposits. The sandstones of Facies C are thought to represent channel deposits, and the mudstones of Facies A may represent a blanket deposit over the fan (Hyden & Tanner 1981). Breccias of Facies D may represent syn-sedimentary slumps.

Rubulis Nunatak

Rubulis Nunatak is *c.* 43–156 m above sea level on the east coast of Düse Bay, western Tabarin Peninsula (Fig. 1). Approximately 100 m of Mesozoic marine sediments are exposed on the western flank of the nunatak, where the beds dip gently (*c.* 5°) towards the south-south-east. The succession base and top are not seen. A 87 m-thick generalized sedimentary log (Fig. 3) was recorded. The succession is composed of *c.* 60% conglomerates (75% clast-supported and 25% matrix-supported conglomerates), 30% mudstones and 10% sandstones. Six sedimentary facies can be distinguished on the basis of grain size, sedimentary structure, composition and palaeontological content. The remaining *c.* 10 m of section is less well exposed, but it is predominantly composed of conglomerates with sandstone and mudstone interbeds.

Facies A (Fig. 3): Massive (6–8 m), strongly bimodal, coarse-grained conglomerates without consistent grading, generally

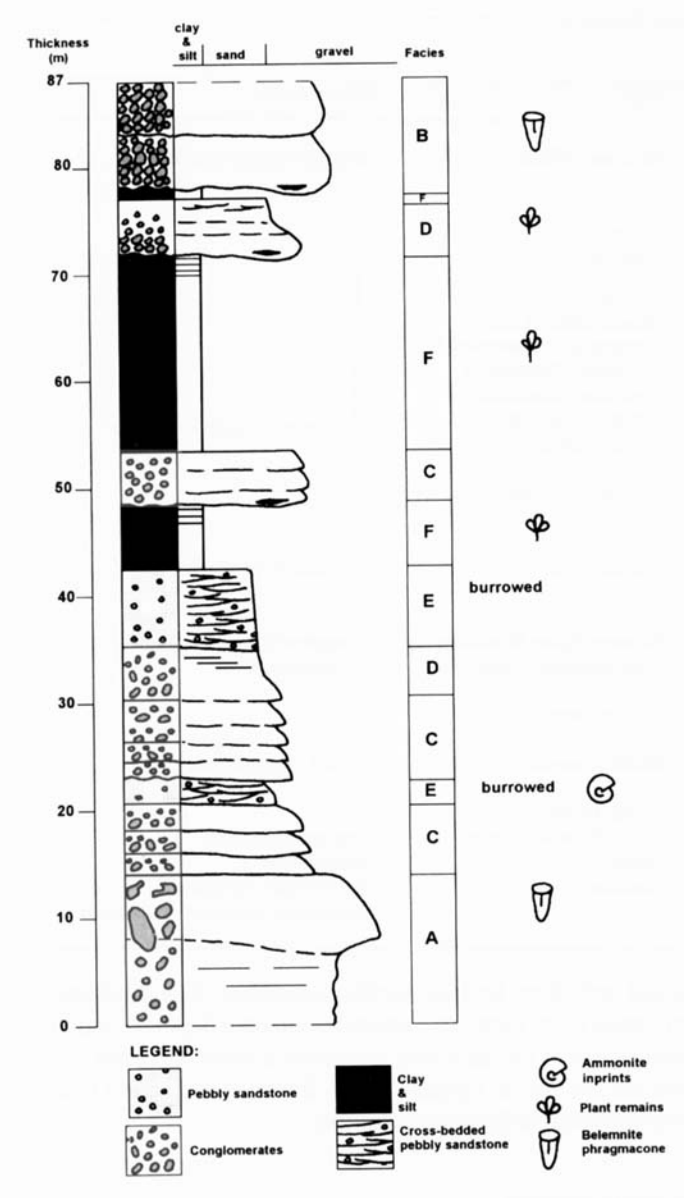

Fig. 3. Sedimentary log through the succession at the western cliff of Rubulis Nunatak (Fig. 1), showing conglomerates interbedded with mudstones and sandstones.

with flat and non-erosional bases. Upper contacts are irregular, commonly with concentrations of protruding large angular blocks. Sub-angular or angular clasts without preferred orientation form *c.* 60% of the rock; grain-sizes range from 10 cm–1.5 m. Clasts are generally siliciclastic sandstones and acid volcanic rocks, assumed to be derived, respectively, from the TPG and APVG, in a matrix, of mud and sand dominantly composed of quartz, and angular fragments of metamorphic rocks. Alternating black shales and tuffs like rocks of the NF form most of the very angular, large blocks. Phragmacones of unidentified belemnites, with long axes frequently vertical, are sparse.

Facies B (Fig. 3): Clast-supported, well-sorted and inverse-to-normally-graded coarse-grained conglomerates. Bed thickness is *c.* 2.5 m with mainly sharp bases, with rare large (1.2 m) tabular mudstone blocks like Facies F (below) in the lower section. Inverse graded units are rarely thicker than 50 cm, and pass up into massive normally graded units. Clast size is 10–35 cm, with dense packing and well-developed α-axis imbrication. The clasts are quartzose, very low-grade metasedimentary (TPG) and scarce silicic volcanic (APVG) in a sandy matrix of quartz and lithic metamorphic angular rock fragments. Clasts are generally very well rounded, suggesting redeposition. Alternating pelites and tuffs (NF) form rare angular boulders mainly within the massive part of beds. Fragments of unidentified belemnites, similar to those from Facies A occur locally.

Facies C (Fig. 3): Clast-supported, well-sorted and normally graded coarse-grained conglomerates representing *c.* 12% of the measured section. Beds show thin ungraded lower portions overlain by a coarse-tail graded upper portion with well-developed clast imbrication. Although internal stratification is absent, most beds are amalgamated graded beds. These conglomerates are petrographically similar to Facies B.

Facies D (Fig. 3): Normally graded conglomerates similar to Facies C, forming *c.* 11% of the measured section, grading to stratified fine-grained conglomerates, and gravely coarse-grained sandstones with flat or oblique stratification. Above the normal-graded part of the beds, stratification is sub-horizontal with alternations of coarse and fine layers, passing up into cross-stratified gravelly sands.

Facies E (Fig. 3): graded pebbly coarse-grained sandstones, representing *c.* 10% of the measured section. Beds are *c.* 1.5 m thick with mostly sharp upper and lower bed contacts, usually forming multiple layer units. Fluted bases are uncommon, and internally stratification is generally irregular, consisting mainly of alternating pebble-rich and pebble-poor layers, 5–10 cm thick, with gradational bases and tops. Medium- to small-scale cross-stratification and dish structures are sparse. Clast size is *c.* 2 cm (from 0.5–3 cm); most are well-rounded, of siliciclastic sedimentary, very low-grade ?metasedimentary (TPG) and volcanic rocks (APVG). The tops of sand-rich layers are commonly burrowed with sparse sole marks and imprints of unidentified ammonites.

Facies F (Fig. 3): Dark grey mudstones and silty claystones forming *c.* 30% of the measured section. These form units that range from 1–18 m thick (average 8 m), with sharp lower contacts. Beds are usually massive, with planar lamination and alternated silt- and clay-rich thin layers. Carbonaceous lenses with leaves and plant stems are frequent, and rare, disseminated, carbonized wood fragments are present.

The facies above resemble lithofacies recognised by Ineson (1989) in the Kotick Point and Whisky Bay Formations, of the Aptian–Coniacian lower Gustav Group. The conglomerates of Facies A resemble the Facies 8 ("breccias and conglomerates with mud matrix") of Ineson (1989), representing deposition probably from subaqueous debris flows. Conglomerates of Facies B, C and D, resemble Facies 7b, 7c and 7d of Ineson (1989), respectively. These may represent resedimented marine conglomerates rapidly deposited from high concentration flows to high-density turbidity currents. The sandstones of Facies E are interpreted to represent rapid deposition from high-density sandy turbidity currents, whereas the mudstones of Facies F are interpreted to represent deposition from suspension.

These facies fit with the model of submarine fan-slope apron deposition proposed by Ineson (1989) to describe Early Cretaceous sedimentary environments in the Larsen Basin. According to this model, mudstone-breccia and conglomerate-pebbly sandstone associations may represent deposition in a slope apron environment and on a coarse-grained submarine fan, respectively.

Conclusions

The 60 m thick steeply-dipping sedimentary succession of interbedded mudstones and quartz-rich sandstones with rare matrix-supported conglomerates at Balegno Nunatak (Fig. 1) is probably part of the Permian–Triassic Hope Bay Formation of the Trinity Peninsula Group. The dioritic rocks are most likely part of the Antarctic Peninsula batholith (Group C: Early Cretaceous; Leat *et al.* 1997, fig. 2).

The *c.* 100 m thick sedimentary succession exposed at Rubulis Nunatak closely resembles the Lower Cretaceous marine sedimentary succession from nearby Troilo Nunatak (Fig. 1) (Scasso *et al.* 1986, del Valle *et al.* 1986). Although diagnostic fossils are sparse, some belemnites from Troilo Nunatak are probably Late Jurassic–Early Cretaceous (del Valle *et al.* 1986). However, palaeontological data are insufficient to permit direct correlation of the beds of Troilo and Rubulis nunataks with Larsen Basin rocks.

The Troilo and Rubulis nunataks strata are dominated by coarse-grained conglomerates probably derived from the TPG, APVG and NF. Sandstones and mudstones are less abundant (*c.* 30% and 10%, respectively). These lithologies are highly reminiscent of much of the ?Berriasian–Coniacian lower Gustav Group of northern James Ross Island (Ineson *et al.* 1986), especially the Kotick Point and Whisky Bay Formations (Table I). Furthermore, large pelitic clasts of NF were noted in the Rubulis Nunatak conglomerates, these clasts are characteristic of the coarse clastics of the lower Gustav Group, but very rare in the upper part. Therefore, on petrological grounds the Rubulis Nunatak beds are probably correlatives of the lower Gustav Group that forms the lower part of the Aptian–Eocene regressive megasequence of the Larsen Basin (Hathway 2000). This correlation confirms that this basin extends onto southern Tabarin Peninsula (e.g. Macdonald *et al.* 1988, del Valle *et al.* 1992). However the basin sediments are thought to be faulted against arc sediments (Fig. 1) so the original extent of the basin cannot be discerned.

Aptian–early Coniacian deposition of a thick, mostly coarse-grained, marginal clastic wedge (e.g. lower Gustav Group of the north-western James Ross Island and equivalent beds) indicates that sedimentation at the western basin margin of the northern Larsen Basin (James Ross Basin) was actively fault-controlled (Farquharson *et al.* 1984, Ineson 1989, Hathway 2000, fig. 5c). A supposed fault-contact between the Lower Cretaceous basin sediments and arc sediments in the western Tabarin Peninsula (Fig. 1), suggests probable post-depositional movements in this area. These movements may be correlated with mid-Cretaceous compression proposed by Vaughan & Storey (1997, event 4), when Coniacian partial basin inversion was accompanied by westward-verging deformation at the western margin of Larsen Basin (Hathway 2000).

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