REPORT ON ANTARCTIC FIELD WORK

SEDIMENTOLOGY OF ABLATION VALLEY, ALEXANDER ISLAND

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A 4000 m-thick succession of volcaniclastic sedimentary rocks, known collectively as the Fossil Bluff Formation (Taylor and others, 1979) is exposed along the length of the eastern coast of Alexander Island. The purpose of the 1983–4 season's work was to make a detailed sedimentological study of the formation as exposed at Ablation Valley (Fig. 1), in close association with a biostratigrapher, P. J. Howlett. The section is particularly significant because it spans the Jurassic–Cretaceous boundary, corresponding to the time of break-up of Gondwana.

The first geological observations on the Fossil Bluff Formation were made by Adie (1962, 1964), who assigned deposition to a north–south orientated through adjacent to a rejuvenated (?)Carboniferous geosyncline. Following this very generalized account, Taylor (1966, 1971) commenced detailed stratigraphical studies of the Fossil Bluff Formation. Horne (1969) worked on the Lower Cretaceous strata south of Fossil Bluff. He interpreted the whole of the formation as the depositions of deltaic, interdeltaic and shallow shelf environments.

From reconnaissance mapping of Ablation Valley, Elliot (1975) identified tidal flat, sub-littoral and 'deeper water' lithofacies. Bell (1975) also argued for a shallow-water depositional environment, but pointed out that this was a gross oversimplification and that more work was needed. Much of this previous work was discussed by Taylor and others (1979), who envisaged a complex environment approximately corresponding to the 'inter-deltaic' facies of Horne (1969). Edwards (1980) suggested that the sedimentological evidence north of the Grotto Glacier indicated, at least in part, deposition in a deep-water submarine fan environment.

ABLATION VALLEY

The ridge immediately south of Ablation Valley presents a 2500 m uninterrupted section through part of the Fossil Bluff Formation ranging from late Jurassic (Kimmeridgian) to early Cretaceous (Berriasian) age. Four previously unidentified major coarsening-upward cycles (185–700 m thick) crudely grade from a mudstone facies, through a sandstone-dominated succession into thick conglomeratic units (Fig. 2). The top of each cycle characteristically displays a smaller-scale (average 30 m) fining-upward succession grading into the next major coarsening-upward cycle. At the 2515 m level in the measured succession it is truncated by a thrust zone. Displacement is unknown, but there are at least two more major conglomeratic units on the ridge extending further into the Lower Cretaceous. Five principal lithofacies were identified based in part on the classification system adopted by Lowe (1982).

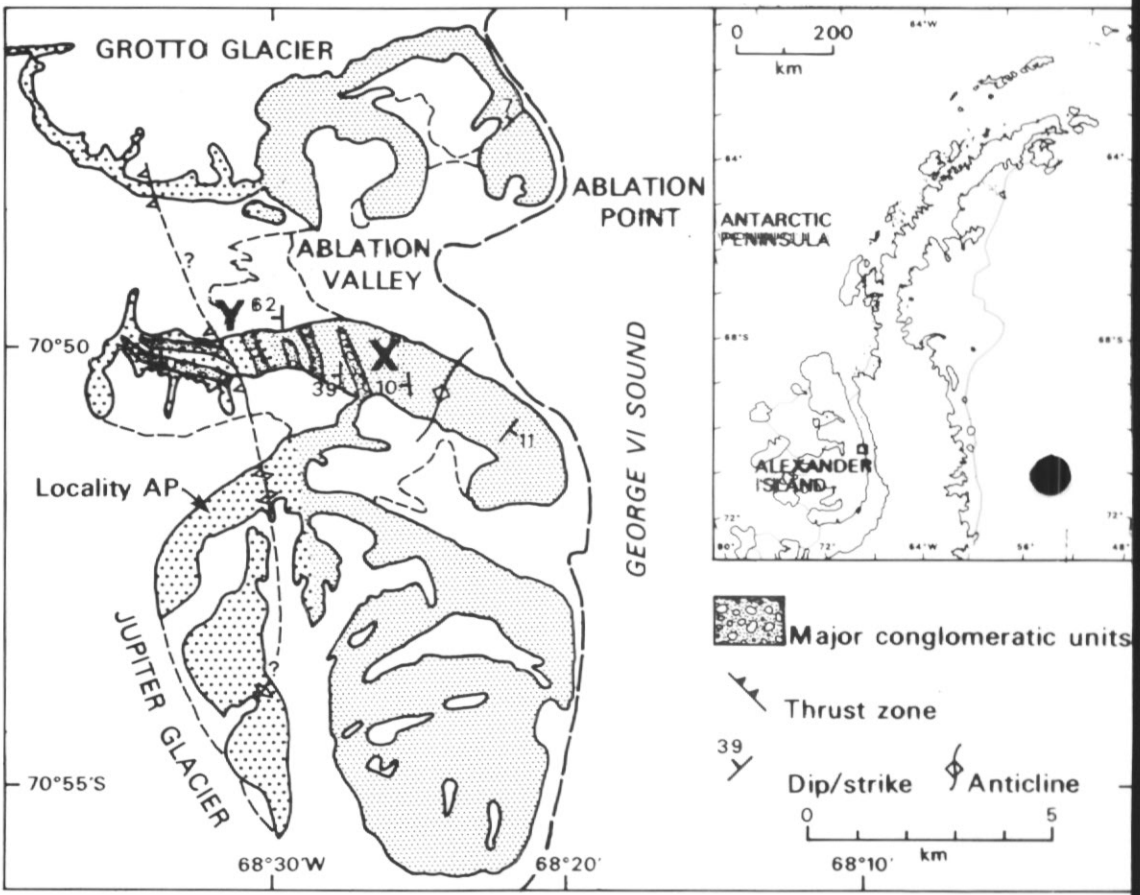


Fig. 1. Location of section (X–Y) across the Jurassic (light stipple)–Cretaceous (heavy stipple) boundary at Ablation Valley, Alexander Island (see inset).

1. Mudstone facies

This facies typically comprises heavily bioturbated, structureless or rarely laminated black silty mudstones, forming blocky weathering beds (average 10 cm) defined by more shaly intervals, thinly interbedded with subordinate (15–20%) massive or rarely graded fine-grained white sandstones (average 4 cm). The sandstone bed boundaries are flat, rippled or undulating with predominantly flat bases. Within the lowermost 700 m, normally graded volcaniclastic sandstones (subfacies 3 a) are also interbedded within facies 1. Synsedimentary deformation, by loading and small-scale normal faulting, is common; rare beds pass laterally into erosional scours (maximum 0.6 mm deep × 3 m wide) causing disruption of internal bedding. However, the most common internal structure within the mudstones is bioturbation. Several different forms of trace fossil were recognized, including *Chondrites*, *Zoophycos*, *Scalarituba*, *Rhizocorallium*, *Planolites*, *Helminthopsis* (?) and *Cosmorhaphe* (?). There is also an abundant shelly fauna, including belemnites, ammonites and bivalves, which are at present being studied to refine the biostratigraphical zonation of the Jurassic–Cretaceous boundary

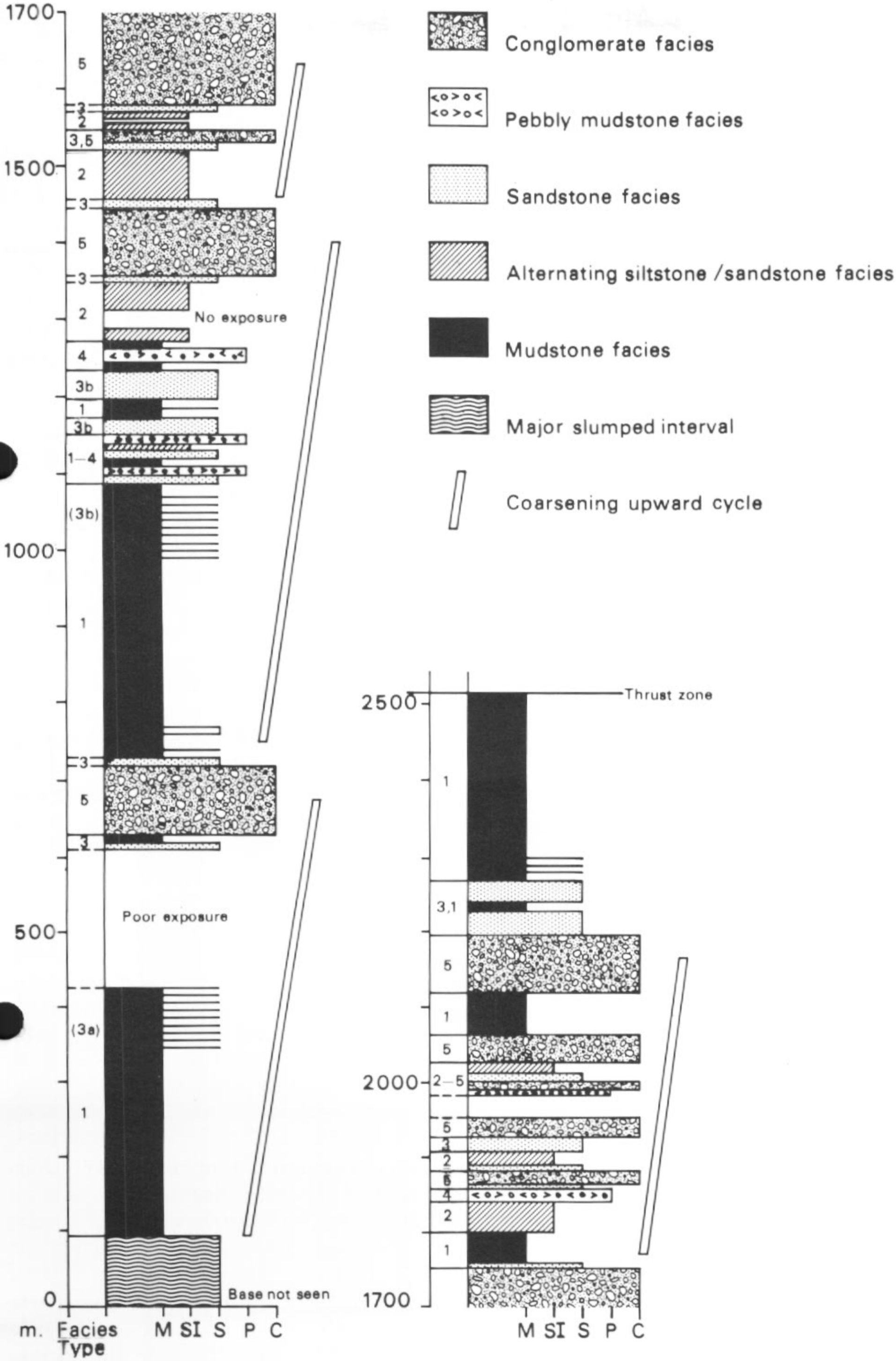


Fig. 2. Schematic section through part of the Fossil Bluff Formation as exposed at Ablation Valley. Note the small-scale superimposed coarsening-upward cycles above the 1460 m level. M, Mudstone; SI, Alternating siltstone/sandstone; S, Sandstone; P, Pebbly mudstone; C, Conglomerate.

at Ablation Valley. Concretion horizons are relatively common, either as individual fawn-coloured, calcium carbonate-rich, ovoid shapes, elongate parallel to bedding (average 1.5 × 0.8 m), or as laterally continuous beds. In both cases, original sedimentary structures are preserved. Much smaller, almost spherical concretions (average 2 cm) occur randomly throughout the succession.

This facies probably represents deposition from suspension in a quiet-water marine environment, with modification by bottom currents to produce ripples. High pore pressures are suggested by the occurrence of synsedimentary faults and load structures. The thin sandstone interbeds are probably attributable to dilute low-density turbidity currents or storm-generated waning bottom currents. The intense bioturbation suggests relatively slow sedimentation rates for the silty mudstones, and oxygenated bottom waters. The trace fossil assemblage is compatible with a low-energy, marine depositional environment (Crimes, 1977). The concretions are presumably diagenetic in origin and formed *in situ*.

2. *Thinly interbedded siltstone/sandstone facies*

Throughout the succession, up to 2025 m, there are thick units (maximum 30 m) of regularly alternating white sandstones (50%) and black siltstones (50%), ranging from < 1 to 10 cm thick. The black siltstones are commonly bioturbated and structureless but rarely display parallel lamination. The fine-grained, white-mottled sandstone beds display sharp basal contacts, which are either slightly undulating or flat, with randomly distributed erosional scour structures (average 1 cm). Upper bed boundaries are commonly rippled or, more rarely, flat, irregular or graded into the overlying siltstone. Low-angle lamination and cross-lamination are common, with infrequent graded or massive beds. In siltstone-dominated intervals, lenticular and flaser bedding may be developed. Both siltstones and sandstones are typically heavily bioturbated although macrofossils are sparse. There is frequent internal deformation by small-scale synsedimentary faulting, and thicker intervals (average 35 cm) of internally slump-folded beds (Fig. 3a). Despite the variable thickness of individual beds, they can be traced laterally over tends to hundreds of metres, where exposure allows.

This facies is interpreted generally as the deposits of turbidity currents. The graded, massive sandstone beds (T_a) may represent episodic high-density flows, the parallel laminated (T_b) or rippled (T_c) sandstones and siltstone interbeds (T_d or T_e) probably reflect deposition from low-density turbidity currents (Lowe, 1982). Alternatively, sandstone beds may represent bedload traction deposition by storm-generated currents. It is envisaged that this facies is transitional between facies 1 and 3, based on bed thickness and regularity of siltstone–sandstone alternations.

3. *Sandstone facies*

Three distinct subfacies of sandstones can be recognized within the succession at Ablation Valley, comprising sand-dominated intervals (75–90% sandstone) or isolated beds within facies 1 (10–20%).

Subfacies 3a. Graded volcaniclastic sandstones

Thin-bedded, medium to very coarse-grained volcaniclastic sandstones (5–25 cm) are common in the basal 600 m of the section within facies 1, displaying sharp, locally erosional basal contacts and flat or graded tops. They characteristically display normally grading (often coarse-tail over the lowermost 5 cm), frequently into parallel laminated or bioturbated siltstone. They are rarely massive. Mineralogically these sandstones are immature, with a high percentage of subangular lithic and feldspathic components.

Subfacies 3b. White dish-structured sandstones

Above 950 m, heavily mottled (laumontitized?) white fine-grained sandstone beds (average 60 cm) are common. These alternate with thin siltstone (average 5 cm) and can be traced laterally over hundreds of metres (Fig. 3b). The sandstones are generally well sorted, and display loaded, erosive or flat bases and tops with sporadic coarse-tail grading over the basal 20 cm, which is usually massive. Throughout the rest of the bed, water escape structures are characteristically developed. Dish structures are defined by differential mottling and commonly become more convex up through the bed (Fig. 3c), although they vary in shape and form laterally within any one bed. Pipe development is generally poor. There are also frequent ellipsoidal 'hollow' concretion layers and mudflake (intraclast) horizons. The top 10 cm is commonly finer grained, and distorted by convolute laminations. Many of the thinner white sandstones (those < 20 cm) are so heavily altered by zeolitization (laumontite?) that original structures are obscured.

Subfacies 3c. Arkosic pebbly sandstones

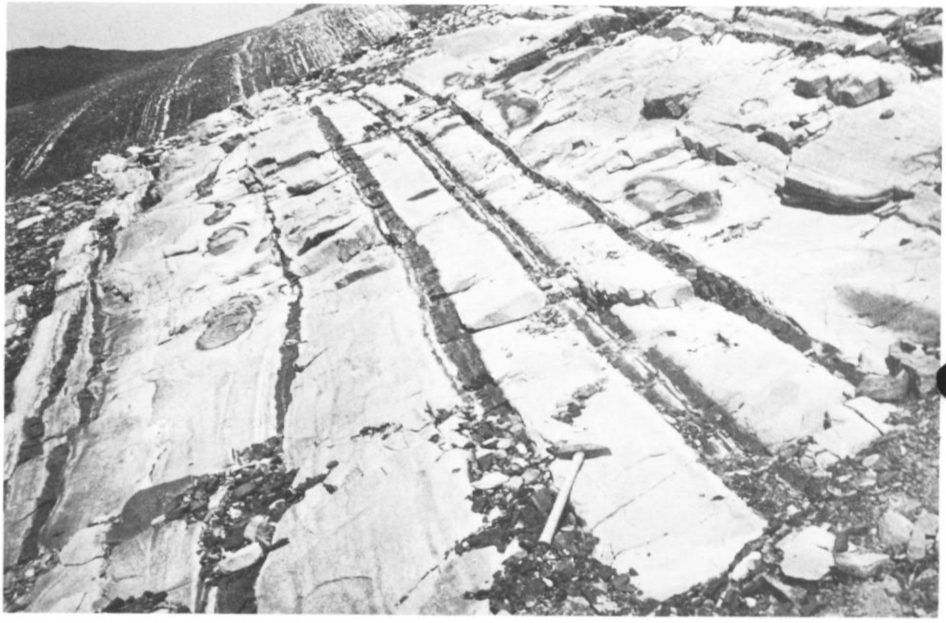
White medium to very coarse-grained volcaniclastic 'arkosic' sandstones occur sporadically throughout the succession as individual beds (0.3–2.5 m thick). These frequently contain small pebbles (up to 25%) of volcanic origin within a predominantly angular, poorly sorted, structureless feldspathic sandstone matrix. In the thicker beds there are often poorly developed shallow channel structures of up to 5 m lateral extent. Two beds contained abundant brownish calcareous concretions (average 0.8 m diameter) similar to the 'cannonball' concretions of Horne and Taylor (1969).

All three sandstone subfacies probably represent deposition by high-density turbidity currents. Subfacies 3a forms the characteristic S_3/T_a type deposit of Lowe (1982). Subfacies 3b possesses the diagnostic criteria of S_3 type liquefied flows, where the sediment is not fully supported but is partially settling through its pore fluid, displacing it upwards. Subfacies 3c represents an immature deposit, probably corresponding to the S_1-type surging high-density turbidity current described by Lowe (1982). Overall the sandstone facies is preliminarily interpreted as resulting from deposition from sediment gravity flows either by traction (S_1) or directly by high-density suspension sedimentation (S_3). Alternatively, some sandstones, especially subfacies 3a, may be formed as a result of waning bottom currents, possibly generated by storm events, periodically washed out into the sedimentary basin and deposited in an essentially quiet-water (facies 1) environment.

4. *Pebbly mudstone facies*

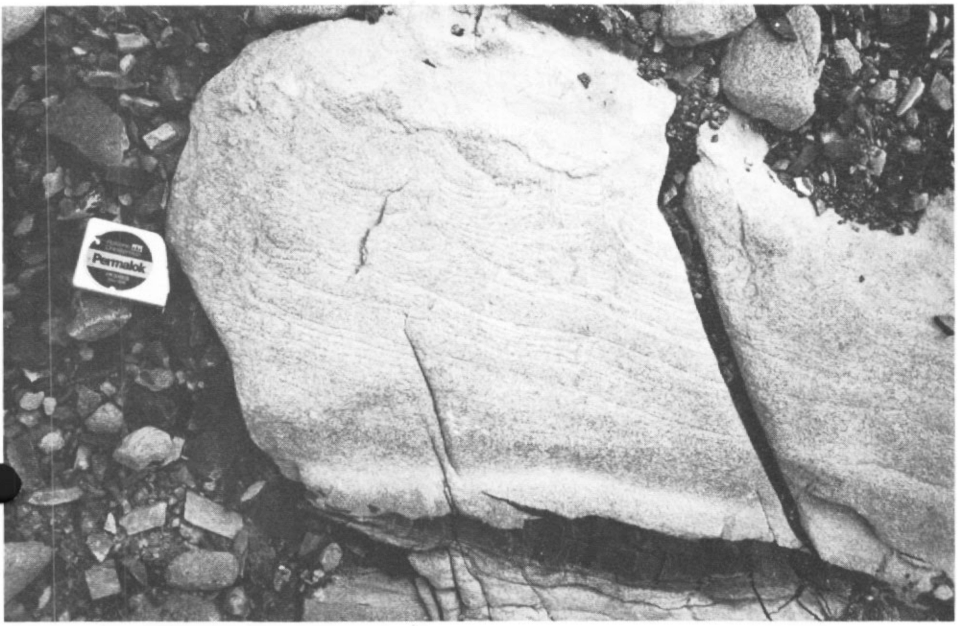
Thick-bedded pebbly mudstones (average 8 m) first appear at 1050 m and become progressively more common up to 2000 m. Bed thickness varies from 0.3 to 25 m but those < 1 m thick are typically eroded or pinched out laterally over tens of metres into facies types 2, 3 and 5. In each bed, the basal and upper portions are generally massive with subordinate sandy flowage structures, containing up to 20% subrounded to rounded pebbles within a mudstone/volcaniclastic matrix. Pebbles are poorly sorted (1–40 cm) and comprise randomly distributed plutonic, metamorphic and intraclastic sandstone lithologies (similar to those within the conglomerate facies). The central zone of each bed has fewer pebbles than the margins, but contains large

a.



b.

Fig. 3. a. Thinly interbedded siltstone/sandstone facies (2) with two zones of synsedimentary deformation: the lowermost zone contains irregularly folded and 'rafted' sandstone within a siltstone matrix, whereas the top zone displays regularly distributed slump folds with eroded tops. Lens cap is 4.5 cm across. b. Dish-structured white sandstone (subfacies 3b) with thin silstone interbeds and concretion horizons. Note lateral continuity (> 300 m). Hammer shaft is 35 cm long.



c.

d.

Fig. 3 (*cont.*) c. Dish-structured white sandstone (subfacies 3b) displaying an erosional base with mudflake intraclasts within a (?) prehnite halo and structureless, graded top. Note the upward-increasing convexity of dish structures and the development of pipes through the bed. Base of tape measure is 6.5 cm long. d. Conglomerate with well-rounded clasts and abundant interlensed sandstone. Note the inverse grading (centre left) and abrupt normal grading into the overlying massive sandstone. Bed boundaries are generally sharp and lateral continuity of bedding is limited, due to erosion and amalgamation of beds.

intraclasts as folded or non-folded rafts of facies 2, or more rarely facies 3 b (maximum 5 × 2 m).

This facies possesses the diagnostic criteria of a true cohesive debris flow or mudflow (see Lowe (1979) for a review) where the larger clasts are fully supported by a cohesive mud matrix. The formation of a central semi-rigid 'floating' plug is compatible with development within a subaqueous mass flow with zones of shear above and below (Middleton and Hampton, 1973, 1976). The rounded clasts resemble those of the conglomerate facies (facies 5), and may reflect remobilization of conglomerates in the local mud- rather than sand-dominated environment.

5. *Conglomerate facies*

There are four thick conglomeratic units (80–170 m thick) exposed throughout the succession up to the thrust zone (Fig. 1). The lowermost quarter of each major unit often displays an erosional basal contact (average 1 m relief) and contains abundant interbedded or more commonly lenticular pebbly sandstones (average 0.4 × 15 m). The central zone of each unit is characteristically devoid of any sandstone lenses. The uppermost quarter typically displays a relative thin (average 30 m) fining-upward succession, where the proportion of conglomerate decreases up section relative to pebbly sandstones, mudflake breccias (often with scour structures) and rare pebbly mudstones before grading into the base of the next major cycle (typically facies 1).

Individual conglomerate beds (average 2.5 m thick) exhibit very well-rounded clasts over the whole size range from granule (-1ϕ) to large boulders (-11ϕ). They are predominantly poorly sorted and display an overall trend from volcanic- to plutonic-dominated clasts up the section. The matrix is variable but predominantly subangular medium and fine-grained sandstone. Bed amalgamation is common, and subdivision into original beds is often difficult, but within any conglomeratic unit three distinct subfacies can be identified based on the presence or type of grading.

5*a*. Disorganized and non-graded, often with pebbly sandstone lenses with flat, undulating and sporadically erosional bases. They are dominantly matrix supported (after Clifton, 1973).

5*b*. Normally graded with undulating to flat bases. Largest clasts are often aligned.

5*c*. Inverse to normal grading with flat bases. Often clast supported.

Lateral continuity is difficult to define due to the steep nature of the exposure, but where observed, individual conglomerate beds were often lenticular and discontinuous (average 20 m) due to deposition within erosive based channels or erosion by an overlying bed.

The interbedded and lenticular pebbly sandstone beds (average 0.4 m) commonly display grading and pebble cross-stratification. Basal boundaries are both sharp and graded with irregular to undulating contacts, except where they are locally affected by small-scale load and scour structures. They typically have sharp flat tops (Fig. 3d).

The conglomerate facies comprises a wide spectrum of depositional types, ranging from true sandy mass flow deposits to high-density gravelly turbidity currents (Lowe, 1982). The rounding of extrabasinal clasts was presumably accomplished on land by either a fluvial or beach system before incorporation into subaqueous mass flow deposits. The disorganized ungraded matrix-supported beds probably represent a sandy debris flow origin (abundant mud is not a prerequisite for debris flows (Pierson, 1981)). The two graded sub-facies were probably deposited by turbulent gravelly high-density turbidity currents by tractive carpet (R_2) or suspension (R_3) processes (Lowe, 1982). Where the largest clasts are aligned, this presumably reflects dispersive grain pressure as an important grain support mechanism, although there is almost certainly no one grain support mechanism operating in any particular bed.

The interbedded and lenticular pebbly sandstones are preliminarily interpreted as sandy high-density turbidity currents that deposited S_1 and S_3-type units, either as distinct sand-dominated events or as the final phase in the deposition of the underlying conglomerate bed. However, traction of clasts by bedload was also an important mechanism in the deposition of some pebbly sandstones, giving rise to cross-stratification and scour structures.

Discussion

The Fossil Bluff Formation has been interpreted as the deposits of a seismically active fore-arc basin that accumulated contemporaneously with a main phase of magmatic arc activity (Saunders and others, 1982). A wide spectrum of slope-related processes predominate in facies 2–5, including deposition from sliding and sediment gravity flows over the whole range from low-density turbidity currents to cohesive debris flows, as discussed by Lowe (1979, 1982). Sediment accumulation is envisaged within submarine fans on an unstable slope below wave base in a well-oxygenated environment, supporting a shelly benthic fauna and infauna. Facies 1 represents quiet-water background sedimentation away from the main areas of sediment input. It is possible that facies 1 and 2 (and maybe facies 3) are storm generated, but this cannot be the case with facies 4 and 5. Consequently, the simplest explanation involves slope-related processes (essentially gravity flows) rather than shallow-water processes. The large coarsening-upward cycles could be due to fan or lobe progradation. This preliminary interpretation is in direct contrast to that put forward by previous authors, suggesting that the succession was deposited in shallow water, as no wave-generated structure was recognized. Further work is envisaged during the 1984–5 season to extend the section into the Lower Cretaceous at locality AP (Fig. 1).

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