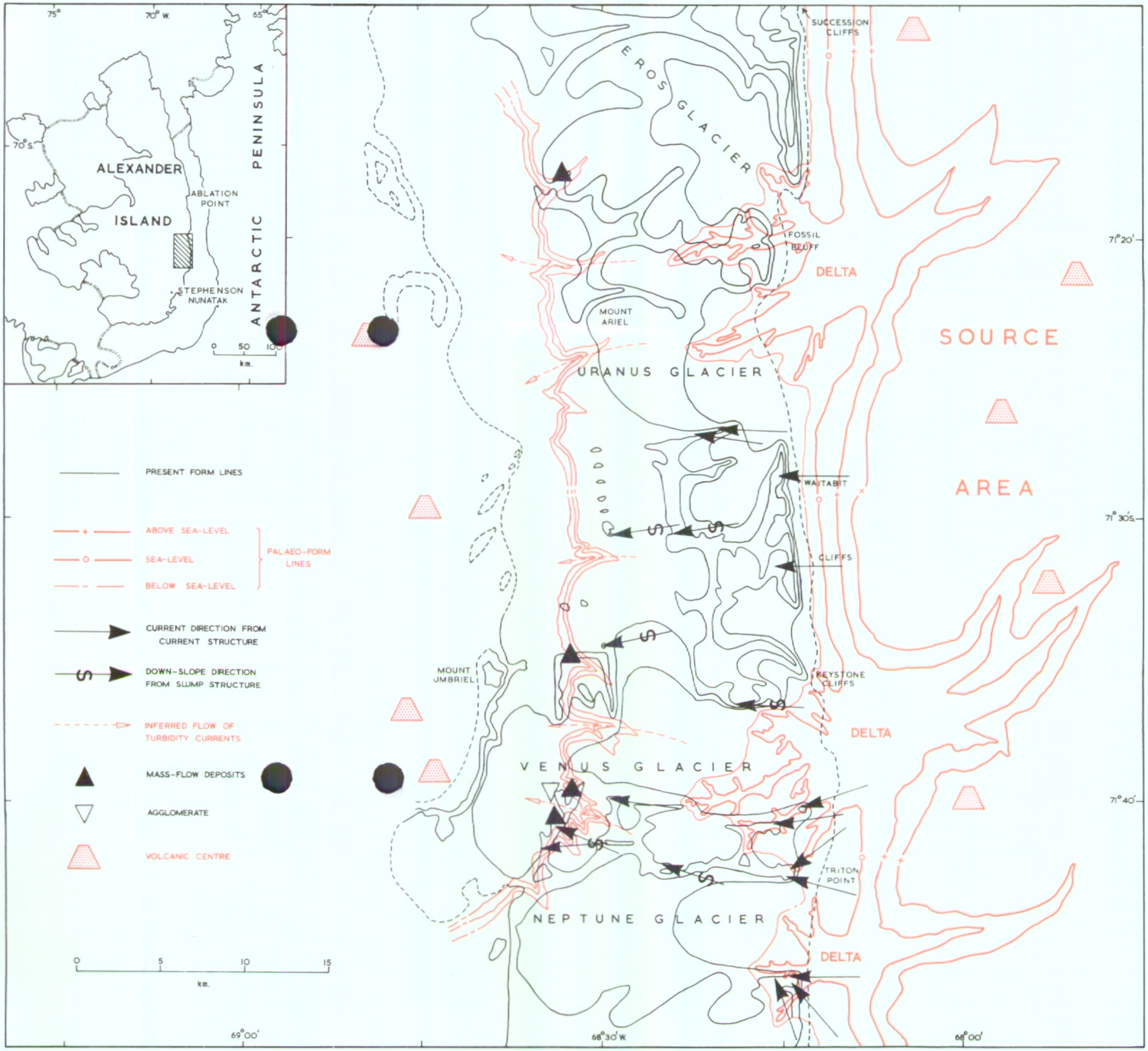


Fig. 1. A palaeogeographical map of south-eastern Alexander Island in late Aptian times.

SEDIMENTOLOGY AND PALAEOGEOGRAPHY OF THE LOWER CRETACEOUS DEPOSITIONAL TROUGH OF SOUTH-EASTERN ALEXANDER ISLAND

By R. R. HORNE

ABSTRACT. The sedimentation patterns and mechanisms and palaeogeography of the mid-Jurassic to Aptian trough of south-eastern Alexander Island are reconstructed on the basis of the environmental significance of the lithology, syn- and post-depositional structures, and the fauna and flora of the sediments. A continuous facies series from inshore, deltaic and richly fossiliferous inter-deltaic sequences through outer shelf and shelf-edge mass-flow deposits to a deeper-water turbidite sequence is recognized. Consideration is given to the palaeoecology and palaeoclimate of the trough, its volcanic association and the thickness of the sediments. The trough is interpreted as a back trough related to an early Mesozoic orogenic phase in the Antarctic Peninsula region.

A SEQUENCE of marine clastic sediments with a composite thickness of about 8,000 m. is exposed in south-eastern Alexander Island. The tectonics, post-depositional dyke intrusions, slump structures, sedimentary petrology and authigenic minerals of this succession have already been described (Horne, 1967, 1968*a*, *b*, *c*; Horne and Thomson, 1967). The present paper attempts to synthesize this and other information in an interpretation of the sedimentology and palaeogeography of the depositional trough. In an earlier paper (Horne, 1967) the name "Bellingshausen trough" was used for the trough described in this paper. This terminology is now considered unsuitable and it has been discontinued for a number of reasons, the most important being that the name "Bellingshausen" already refers to a present-day sea or marine basin.

DISTRIBUTION OF THE SEDIMENTS

Due to the dominant southerly or south-westerly dip of the sub-horizontal sediments on the coast and the plunge of the fold axes in the sediments farther west (Horne, 1967), the Cretaceous sediments of south-eastern Alexander Island appear to form a continuous sequence younging towards the south. Since the axis of the trough was orientated north–south, lithological, petrological and faunal changes in the sediments in this direction are the combined result of synchronous facies variations parallel to the sedimentary strike or trough axis and of vertical sedimentation trends through time. Because of this constant southerly "stratigraphic tilt", these variables cannot be separated, and facies patterns along the length of the trough at any point in time cannot be determined.

At Transition Glacier, a distinct but unexamined lithological discontinuity separates dark, massive, probably volcanic rocks to the north (Horne, 1967) from clearly stratified sediments to the south. At Ablation Point, the ammonites indicate an Upper Jurassic age (Howarth, 1958) and the Mollusca an Aptian age (Cox, 1953). At Belemnite Point, the belemnites are Upper Jurassic in age (Adie, 1964; Stevens, 1967). The sequence exposed between Succession Cliffs and Keystone Cliffs is considered to be Aptian in age (Cox, 1953; Howarth, 1958; Taylor, 1965, 1966*a*, *b*, 1967). From Keystone Cliffs south to Stephenson Nunatak, the sediments are less fossiliferous and less well known but they probably represent the final phase of sedimentation in the trough during the latest Aptian or even into the succeeding stages.

On structural, petrological and palaeontological grounds the strata cropping out from east to west (or normal to the trough axis) are considered to be approximate lateral equivalents, and their lithological and faunal contrasts to be synchronous facies variations. The special problem of the age of the sediments of the interior of Alexander Island, from which megafossils have not yet been obtained, is considered in detail below.

PALAEOGEOGRAPHY

A reconstruction of part of the trough during mid-Cretaceous time is attempted on the basis of the palaeogeographical significance of lithological, petrological and faunal variations and of the distribution and orientation of syn- and post-depositional structures (Figs. 1 and 2).

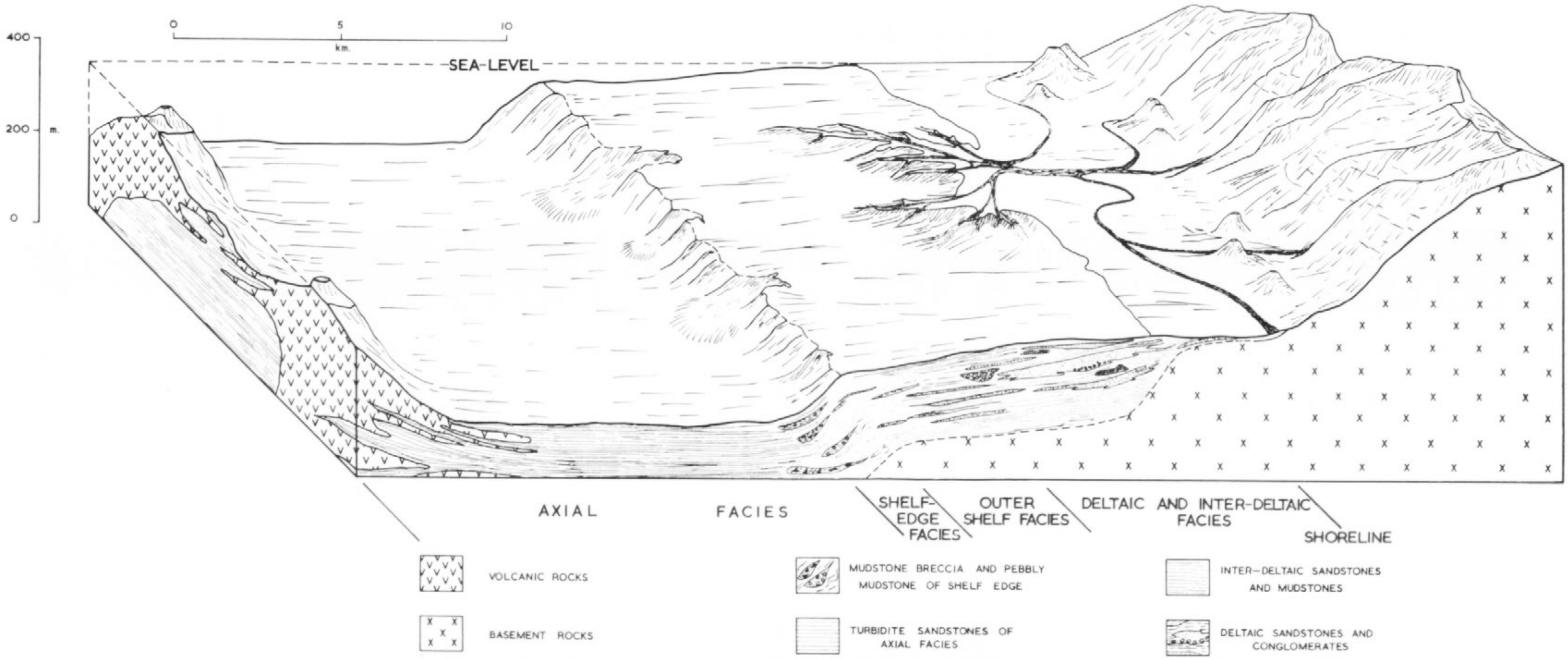


Fig. 2. A theoretical and generalized block diagram illustrating the suggested sedimentation patterns and mechanisms of the late Aptian trough in south-eastern Alexander Island.

The trough lay to the west of a geanticlinal ridge which was uplifted during a preceding orogenesis. The distribution of inshore, deltaic and inter-deltaic sediments in a zone adjacent to the east coast of Alexander Island indicates that the eastern shoreline of the trough was close to the present east coast of the island and trended roughly north–south, parallel to the cordilleran axis. The current directions and down-slope slump structures consistently indicate that both the general current trend and down-slope direction were from east to west away from this shoreline (Fig. 1). Sediments of both deltaic and inter-deltaic facies are represented in this inshore zone. To the west, beyond and between the delta fronts, more regular sedimentation occurred on a gently sloping shelf in moderate water depths. The western scarp face of this shelf is distinctly marked by a narrow zone of diamictites such as pebbly mudstones and breccias, resulting from mass flowage on this steep scarp (Horne, 1968*a*). Beyond this again and extending westwards to the limit of survey is a zone of massive sandstones and minor shaley interbeds which are considered to have been deposited from turbidity flows originating at the delta fronts on the shelf. These turbidites are interbedded with irregular masses of agglomerate. The western edge of the trough has not yet been located but it may have been defined by a chain of volcanic islands or a volcanic landmass. A figure of 30 km. is a minimum estimate of the original width of the trough.

Deltaic facies

At several levels in the sedimentary succession of south-eastern Alexander Island there are deltaic sequences, dominated by current-worked cross-laminated sandstones with minor conglomerates and thin argillites.

A sequence of rocks of this facies about 1,500 m. thick is exposed in the vicinity of Bandstone Block and Triton Point (Fig. 3a). The sandstone horizons are frequently very thick, in places texturally isotropic but in others extensively cross-laminated and showing wash-out structures (Fig. 3b). Rhythmic sedimentation is common particularly at a locality south of Neptune Glacier where a sequence of sandstone–claystone couplets about 80 m. thick is exposed (Fig. 4). Each co-set includes a relatively thick massive sandstone containing ellipsoidal calcareous concretions and a thin claystone or siltstone bed. Current structures such as flow casts (Fig. 5*a*) are common on the base of these argillaceous interbeds.

The sandstones contain large amounts of volcanic fragments and they are extensively zeolitized (Horne, 1968*b*, *c*). Conglomerates are present in two distinct environments. The inner deltaic conglomerates are composed of re-worked indigenous fragments, either rounded and imbricated (Fig. 5b) or angular and associated with wash-out structures (Fig. 3b). The conglomerates of the outer deltaic environment are composed of well-rounded, occasionally imbricated, exotic pebbles and cobbles (Fig. 5c and d).

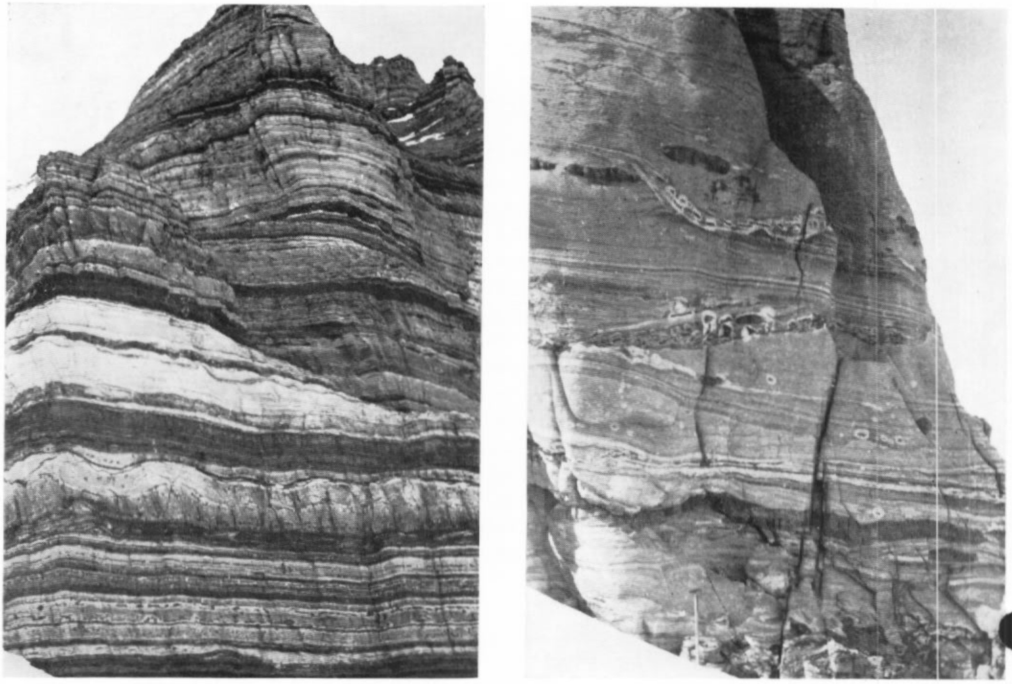
Fossils are either rare or absent in rocks of this facies but large amounts of plant material, largely macerated and carbonized, and lithified fragments and segments of fossil wood are present. Trace fossils and organically re-worked horizons are locally abundant (Figs. 9 and 10).

The youngest rocks of south-eastern Alexander Island are exposed in the isolated nunataks south of Saturn Glacier. They appear to represent the terminal paralic facies, containing thin coal seams associated with thick conglomerates (Adie, 1964).

Inter-deltaic facies

Approximately 4,000 m. of interbedded massive mudstones and coarser muddy sandstones or siltstones are exposed between Succession Cliffs and Keystone Cliffs (Fig. 6). The mudstones are poorly sorted admixtures of material of silt or clay grade with small irregular amounts of sand and including quantities of volcanic fragments and fossil material. Many of these mudstones are highly calcareous. They are dark grey or black in colour, massive and superficially isotropic in the hand specimen. No trace of bedding parting or fissility is apparent, the rock breaking under the hammer along curved sub-chonchoidal fractures (Fig. 7). They contain numerous ellipsoidal calcareous concretions.

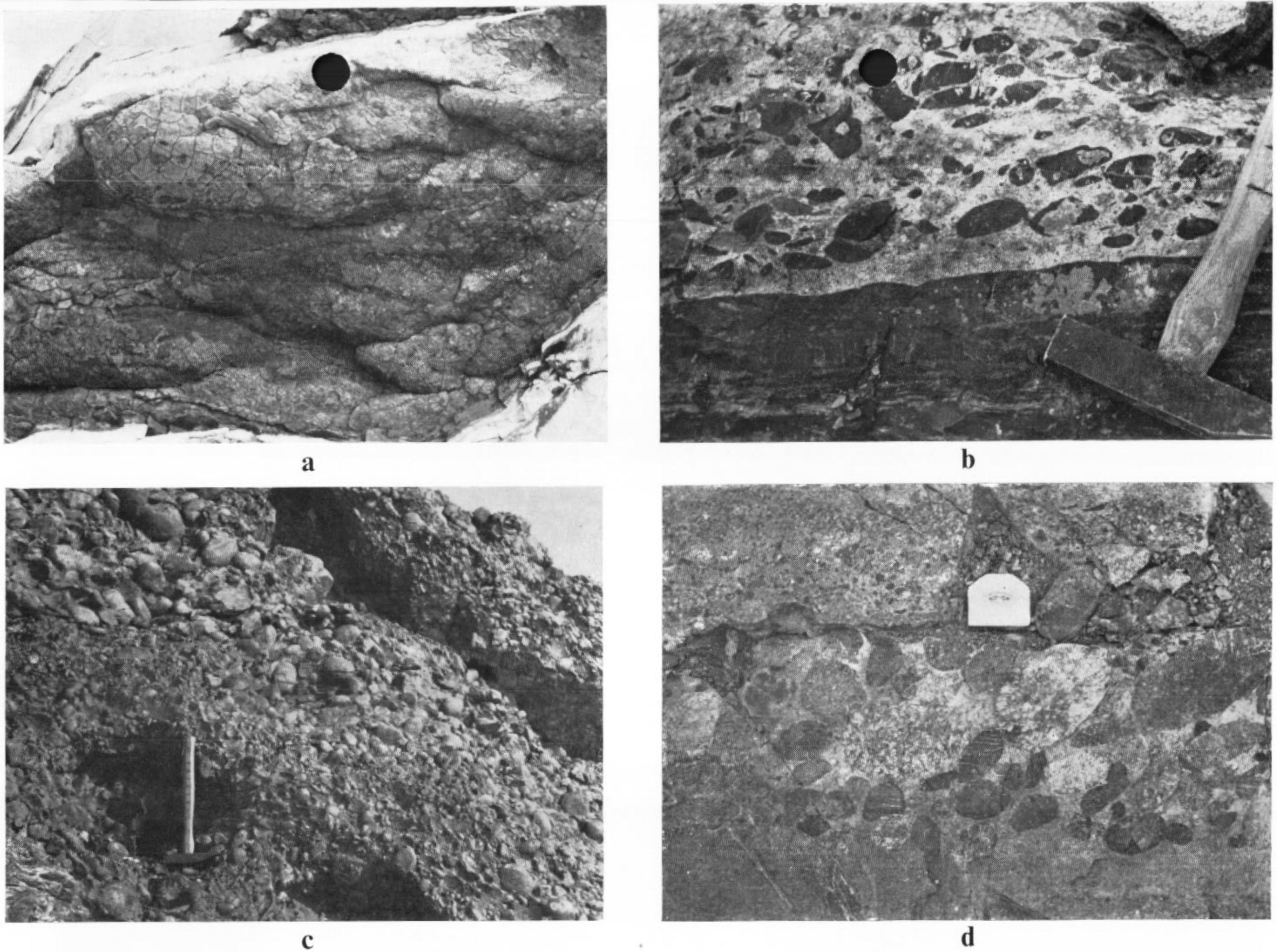
Two forms of banded mudstones are developed at certain levels in this facies sequence. The first type is built up by the repetition of thin graded units usually about 5 cm. thick. Where this grading is distinct the rock could be described as "varved", although this term has a genetic significance which is not applicable here. This structure results from deposition under



a **b**

Fig. 3. a. A sequence of deltaic sandstones and siltstones and sandy mudstones about 300 m. thick, showing gravity disruption of mudstone beds and flowage of sandstone horizons.
b. Wash-out channels in massive deltaic sandstones, the material infilling the channels being identical sandstone containing angular fragments of mudstone which are surrounded by white laumontite-rich aureoles (Horne, 1968*c*, p. 3–7). The ice-axe is 0·9 m. long.

Fig. 4. A deltaic sequence of rhythmically repeated couplets comprising a thicker, massive or weakly laminated, concretionary sandstone bed and a thin massive claystone bed. Many of the sandstone horizons show convolute lamination near the top. The succession illustrated is about 80 m. thick.



a b c d

Fig. 5. a. Large-scale flute casts on the base of one of the claystone interbeds of the sequence shown in Fig. 4.
b. An inner deltaic conglomerate of moderately rounded indigenous mudstone pebbles possessing distinct imbrication and enclosed in a matrix of coarse sandstone. The material forming the pebbles is identical to that composing the mudstone bed below. The hammer shaft is marked in 2·5 cm. units.
c. Conglomerate of well-rounded exotic pebbles of the outer deltaic environment. The hammer shaft is marked in 2·5 cm. units.
d. A conglomerate layer in a coarse sandstone with well-rounded imbricated pebbles and cobbles of plutonic material. This conglomerate was deposited, like that shown in Fig. 5c, in the outer deltaic environment. The scale is 5 cm. across.

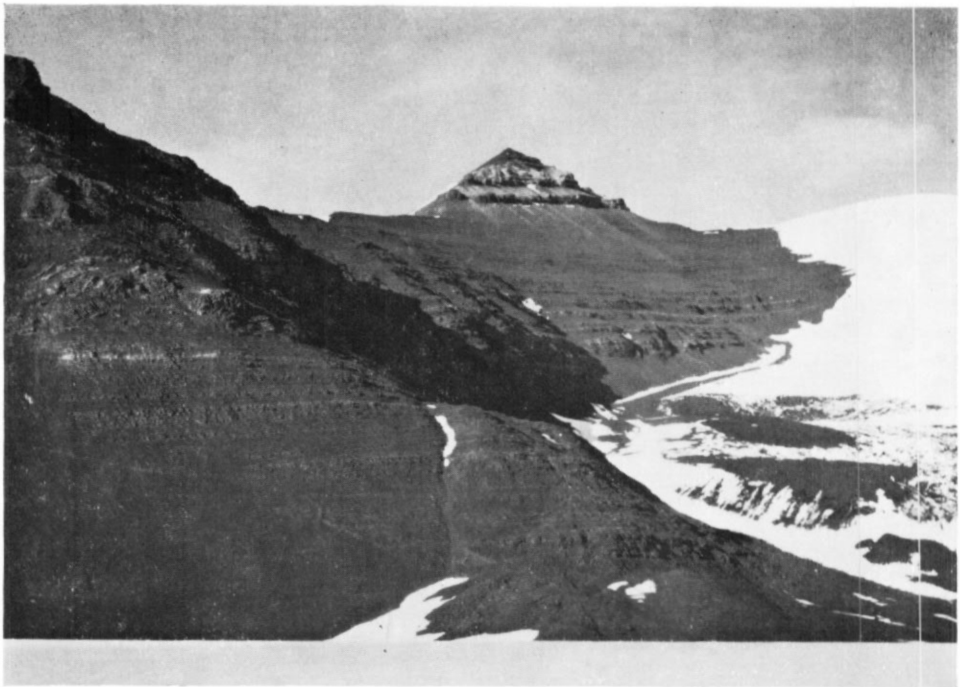


Fig. 6. A thick inter-deltaic sequence at Fossil Bluff showing the repeated interbedding of massive mudstones with coarser muddy sandstones or siltstones. (Photograph by B. J. Taylor.)

Fig. 7. A conglomerate lens representing the cross-section of a wash-out channel cut into typical massive mudstones of inter-deltaic facies. The hammer head is 16 cm. long.

non-turbulent conditions below the level of active currents, the transporting current showing regular, possibly seasonal, variation in competence. In the second type a laterally continuous band of argillaceous silt about 5 cm. thick alternates with a thin (about 1 cm.) lensoid and often discontinuous band of lighter coloured purer silt which is almost invariably cross-laminated. These lensoid bodies are generally planar convex or bi-convex. This structure has been termed "flaser bedding" by Pettijohn and Potter (1964). Pettijohn (1957, p. 366) has provided an illustration of an identical rock which he has regarded as the product of intermittent turbulence, a period of non-turbulent settling of clay-rich silt followed by turbulent irregular deposition of washed and sorted silt in the development of each bedding unit. Coleman and Gagliano (1965, p. 146) have regarded lenticular lamination of this type as the most abundant single structure of inter-distributary bays in the Mississippi delta.

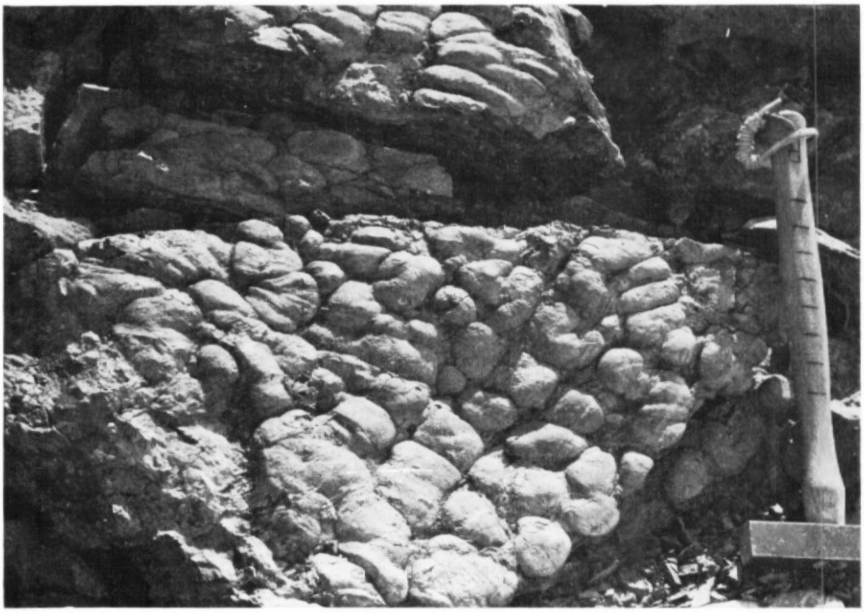
The interbedded sandstones and siltstones are massive, irregularly and locally graded, and have a variable content of muddy matrix. They are strongly arkosic, contain considerable amounts of contemporaneous volcanic material and in the main are cemented by calcium carbonate (Horne, 1968*c*). Thick conglomerates with well-rounded pebbles and cobbles are locally developed. The morphological maturity of the pebbles contrasts strikingly with the immaturity of the angular clasts in the sandstones. These conglomerates have the form and appearance of pebble banks or shoals. Small pebble lenses representing cross-sections of conglomeratic ribbon deposits infilling wash-out channels are locally developed (Fig. 7).

The mudstones and fine sandstones of this facies yield an abundant benthonic and nektonic fauna, and large amounts of plant material partly as well-preserved fronds and leaves, and partly as macerated and carbonized fragments.

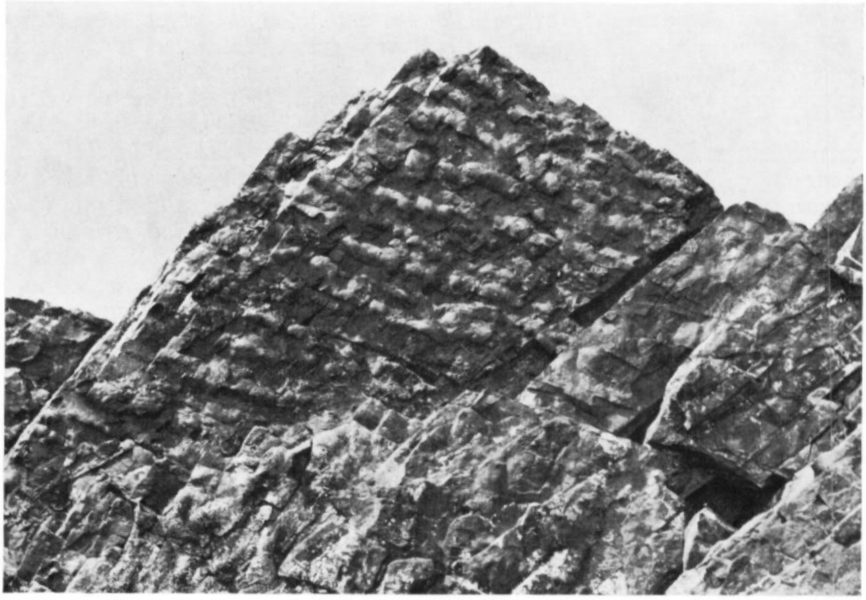
The repetitive clayey sandstone–mudstone sequences of this facies (Fig. 6) superficially resemble deep-water sandstone–shale sequences typical of pelitic flysch sediments in eugeosynclinal furrows which show repeated graded bedding, hieroglyphs, convolute lamination, absence of macro-fossils and other evidence of a deep-water environment, and are widely regarded as having been deposited by turbidity currents. Here, however, these structures are replaced by cross-lamination, wash-out structures, gravity-deformed lamination and an abundance of fossils indicating deposition in shallow to moderate water depths. Similar sequences have been recognized in New Zealand (Kingma, 1958) and in Oregon (Dott and Howard, 1962; Dott, 1964); they are typically associated with deltaic sediments in back troughs in the circum-Pacific mobile belt. The inter-deltaic facies sequences of Alexander Island appear to have been deposited partly by small-scale turbidity flows of limited extent and partly by strongly turbid river currents in flood periods in shallow to moderate water depths in the marine embayments between the deltas. This depositional model is similar to the "courants turbides de surface" discussed by Duff and others (1967, p. 35) in relation to "flysch facies in molasse". As in modern deltas, the coarser sand was trapped in the inner delta, whereas fine sand, silt and clay were carried seawards in streams of turbid water into the pro-deltaic environment (Fisk and others, 1954), and particularly by lateral distributaries on to the shelves on either side of the delta (Shepard, 1956). In the embayments, the thick lenses of texturally mature pebble conglomerates were built up in the form of pebble bars. The moderate water depths, the abundance of organic debris and intermittent sedimentation favoured a rich benthonic and nektonic fauna.

Shelf facies

The sediments of this facies accumulated on the outer areas of the marginal shelf of the trough beyond and between the delta fronts. They are characterized by more regular, laterally continuous strata than in the inshore facies. The ratio of arenaceous to argillaceous horizons approaches unity. There is little evidence of current action, and syn-depositional structures such as cross-lamination are rare. Load casts are common in this zone (Fig. 8a and b). They are generally of elongate form resulting from distortion by down-slope creep. Because of the westward slope of the shelf, intrastratal convolutions due to shearing of mobile horizons acting as lubrication zones for the down-slope sliding of the overlying strata are numerous (Horne, 1968*a*). The asymmetry of these convolutions invariably indicates that the bottom slope was towards the west. Fossils in these rocks are more limited as regards numbers of genera and individuals.



a



b

Fig. 8. a. Load casts on the base of a mudstone horizon of outer shelf facies showing rounded rectangular form. Those near the top of the photograph show deformation probably as a result of down-slope creep. The hammer shaft is marked in 2·5 cm. units.

b. Load casts from the same locality as Fig. 8a in the form of sub-parallel rounded ridges whose relief varies irregularly along their length. They are identical superficially to structures described as transverse load ripple marks by Kelling and Walton (1957, p. 490).

Shelf-edge facies

The western edge of the shelf is marked by a zone of mass-flow deposits such as pebbly mudstones and breccias of mudstone fragments set in a sand matrix (Horne, 1968*a*) resulting from mobilization, limited flowage under the action of gravity and mixing of sediment on the scarp slope.

Axial facies

To the west of this again, massive uniformly dark grey sandstones interbedded with thin black argillites crop out in the Mount Umbriel area (Fig. 1). These sandstones are thought to have been deposited from turbidity currents deriving their sediment from the marginal shelf of the trough. They contain isolated pebbles of exotic material and rounded fragments of indigenous mudstone. Graded bedding is widespread but convolute lamination and hieroglyphs were not recorded from the limited area investigated. The interbedded argillites are finer-grained, possess better sorting and a more definite bedding parting consistent with a deep-water origin. Irregular bodies of agglomerate with admixed vitric, lithic and crystal fractions are enclosed in these sediments in the Mount Umbriel area.

This progression from exotic delta-front conglomerates and sandstones, through pebbly mudstones and breccias (Horne, 1968*a*), into axial proximal turbidites provides an example of Walker's (1967) continuous facies series. A frequent objection to the theory of turbidity currents is the lack of evidence for a mechanism for their initiation and maintenance. With the establishment of large deltas on the marginal shelf of this tectonically active trough, however, delta-front slumping of rapidly accumulating unstable sediment, possibly mobilized by seismic disturbance, would initiate and feed turbidity currents flowing out and over the edge of the shelf into the deeper water beyond. Such a relationship between deltaic sedimentation and turbidites in late geosynclinal troughs and basins has also been proposed by Allen (1960) and Walker (1966).

Age of the Axial Facies

No mega-fossils have so far been obtained from the sandstones of the axial facies encountered in the ridge trending north–south through Mount Umbriel (Fig. 1). Difficulty therefore arises in determining their age and relationship to the fossiliferous (Aptian) sediments to the east. From the present study much evidence has been assembled to indicate that they are the deep-water equivalents of the inshore Cretaceous rocks. First, they are identical mineralogically to the sediments of shallow-water facies, even in such details as the proportions of feldspar species and heavy minerals. Therefore, they have an identical provenance. The volcanogenic component of the different environments is identical in composition and texture. Their lithology, textures and depositional structures are consistent with their geographical position in the trough reconstructed on the basis of other evidence, and a mechanism for their emplacement, which has been recognized in similar troughs containing deltaic and turbidite sequences (Allen, 1960; Dott, 1966; Walker, 1967), is proposed. The different facies zones are completely conformable structurally and their structural state is believed to correlate with their depositional environment (Horne, 1967).

Grikurov and others (1967) have reported similar unfossiliferous "greywacke" sandstones, interbedded with effusive and pyroclastic volcanic rocks from the western side of Lemay Range and the Lully Foothills in central Alexander Island. On the basis of their structural and lithological similarity to the Trinity Peninsula Series, which is of Upper Palaeozoic age in Trinity Peninsula, and on the evidence of rare spores they have regarded this sequence of isoclinally folded sediments and volcanic rocks as being pre-Cretaceous, probably Palaeozoic and in part Carboniferous.

The relationship between these rocks studied by Grikurov and others and those cropping out to the west of the present area (described here as the axial facies) is uncertain but they are structurally conformable and have strong lithological and petrological similarities.

Palaeoecology

The systematic palaeontology of the Cretaceous sediments of south-eastern Alexander Island (Taylor, 1965, 1966*a*, *b*, 1967; Thomson, 1970) is in course of publication. The fossil fauna and flora of the sediments is considered here only in relation to palaeogeography and palaeoclimatology.

The mudstones and sandy siltstones of the inter-deltaic facies contain many fossil indicators of the depositional environment. The presence of genera of shallow-water affinity, such as *Lingula*, *Pinna* and *Trigonia*, of stemmed crinoids, and the largely intact preservation of inshore decapod crustaceans and delicate plant fronds all point to a shallow water depth (probably less than 50 m.) and quiet, non-turbulent current regime coupled with rapid sedimentation. In the arenaceous, current-worked deltaic facies, fossils other than floral material and trace fossils of burrowing organisms described below are either absent or very scarce. In the outer shelf environment the number of benthonic species is gradually reduced towards the shelf edge which marks the western limit of mega-fossils.

This benthonic fauna, particularly the lamellibranchs, gastropods, *Lingula*, annelids and decapod crustaceans are all euryhaline organisms (Craig, 1952; Emery and others, 1957; Pearse and Gunter, 1957; Hudson, 1963; Hallam, 1965). Most of these groups can also survive, if not flourish, under intermittently highly turbid conditions. Other common shelf faunas such as corals and sponges, which require a very restricted range of salinity and turbidity, are notably absent. Also, the benthos is a predominantly mobile one capable of adjusting to periodically high rates of sedimentation. Although the fauna was capable of surviving such conditions, their growth is likely to have been restricted as a consequence. Many of the forms are of small size and they are thin-shelled. Another indication of brackish water conditions is the co-existence within the fossil assemblage of low numbers of species with high population numbers within these species. The high population densities of the favoured molluscan genera in the trough has resulted in a few cases in the development of almost monotypic shell beds of *Inoceramus* or of *Aucellina*, or mixtures of these genera.

Trace Fossils

The trace fossils of these sediments have been described by Taylor (1967). Seilacher (1967) has proposed a general bathymetric zonation of trace fossils defined by a sub-littoral or deltaic association of rhizocorallid-type burrows, an intermediate *Chondrites–Zoophycus* facies and a deep-water zone of superficial grazing traces (Pascichnia) associated with turbidites. Such a relationship between bathymetric facies and trace-fossil zones is also in evidence in Alexander Island.

Extensive bioturbation is a common feature of interbedded sandstones and mudstones of deltaic facies (Fig. 9). The burrows, which average 3 cm. wide and 5 cm. deep, are developed in thin interbeds of mudstone and are defined in masses of light-coloured sand separated by layers of dark argillaceous material (Fig. 10a and b). The mode of life of the organisms occupying the burrows was the only one compatible with an environment of rapid currents of fresh or brackish water and rapid accumulation of unstable sediment.

The inter-deltaic sequences, representing deposition in less agitated intermediate water depths, contain a varied ichnofauna dominated by *Chondrites* and *Zoophycus* of Seilacher's neritic zone (Taylor, 1967). Simpson (1957) has considered that the preservation of *Chondrites* tunnels indicates rapid sedimentation in water not greatly agitated.

Irregular trails of castings occur in great numbers on the bedding surfaces of many mudstone and siltstone sequences of the deeper-water outer-shelf environment. These casts do not appear to be associated with cross-cutting burrows and they represent the feeding trails of surface-dwelling organisms.

Flora

The inshore sediments contain abundant plant material in varying states of preservation. Many finely preserved fronds and leaves are found in the argillaceous rocks of inter-deltaic facies. In many cases, delicate leaf structures and frond shapes are retained, implying that this plant material was transported in deep wide non-turbulent but turbid rivers flowing through country that in its coastal parts, at least, was heavily vegetated. In contrast, the equally abundant plant material in the deltaic-facies sequences consists either of quite large carbonized and lithified plant stem and branch fragments, and thin coal seams.

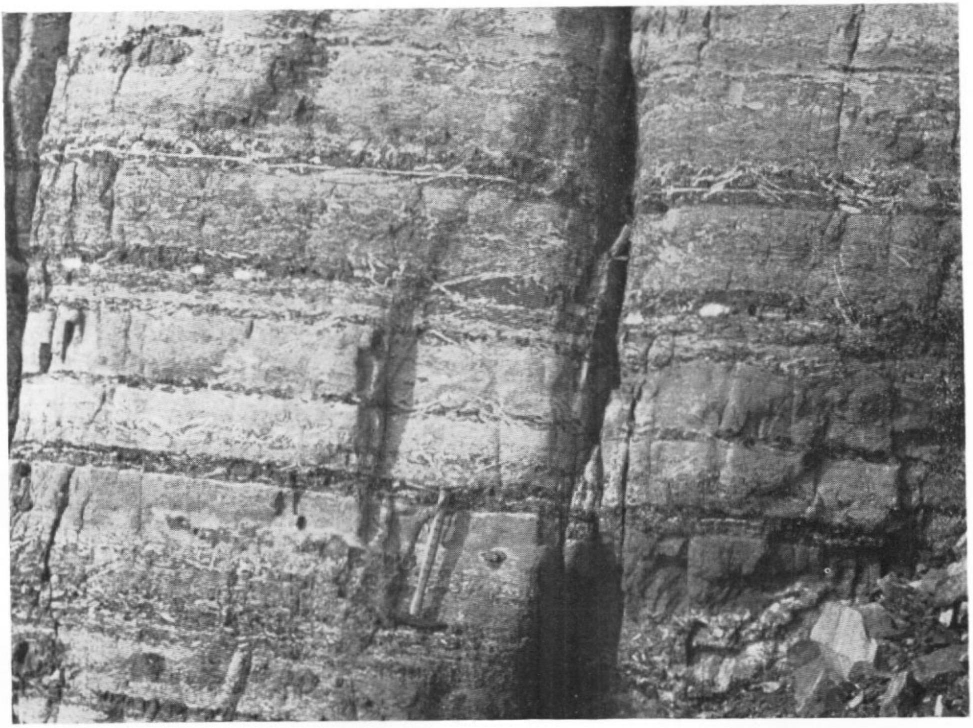


Fig. 9. Organic re-working of interbedded mudstones and sandstones. The re-worked block illustrated in Fig. 10a and b was derived from this outcrop. The hammer shaft is marked in 2·5 cm. units.

These plants comprise a typical Lower Cretaceous assemblage of cycadophytes, ferns and minor conifers. Fronds with distinctive pinnately compound leaves on a strong rachis, which appear similar to forms termed *Nilssonia*, are numerous. Other cycadean fronds have affinities to the genera *Ptilophyllum* and *Pterophyllum*. In a review of floras collectively termed cycads, Harris (1961) has observed that trees bearing leaves termed *Nilssonia* were dominant in deltaic swamps or on river banks. The occurrence of numerous leaves of *Nilssonia* type within the inter-deltaic facies of this trough supports this conclusion.

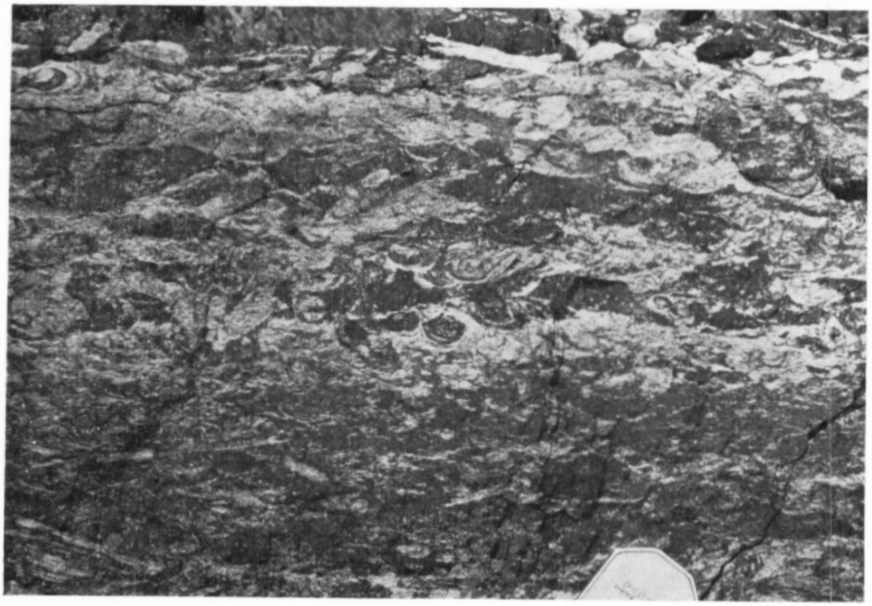
Palaeoclimate

Of those factors discussed above, the most significant indicator of palaeoclimate is the abundant vegetation of at least the lower parts of the source area adjacent to the coast. Of particular significance is the abundance of cycadophyte forms whose presence is generally interpreted as indicating at least a warm temperate if not sub-tropical climate. The fauna, on the other hand, generally shows inconclusive climatic affinity. Certain petrological observations support the hypothesis of a warm wet climate in the vicinity of the trough in mid-Cretaceous times. Very rapid derivation of sediment, ranging from sand to clay, is not characteristic of cold or heavily glaciated areas where ice mantling and absence of chemical alteration restricts denudation. However, rapid derivation of sand and silt from plutonic rocks is typical of areas with warm and periodically very wet climates. Under these conditions, a plutonic terrain with steep but not necessarily elevated topography will yield periodic influxes of large volumes of strongly arkosic, texturally immature detritus (Krynine, 1935, 1941; Horne, 1968*b*).

Thickness

The sediments of the east coast of Alexander Island between Block Mountain and Stephenson Nunatak appear to form a continuous conformable sequence younging southwards.

a



b

Fig. 10. a. The upper bedding-plane surface ("plan view") of sand-filled, laminated burrow structures in mudstone. The finer branched tunnels of *Chondrites* are visible to the right of the tape measure, which is 5 cm. across.

b. A vertical section of the same block ("elevation view") shown in Fig. 10a. The scale is 5 cm. across.

Stratigraphic repetition by faulting is considered to be limited to local overthrusting (Horne, 1967), a conclusion in agreement with preliminary palaeontological evidence (personal communication from M. R. A. Thomson). Assuming the non-repetition of strata, the composite apparent thickness for this sequence calculated on the basis of both measured and estimated dips and outcrop widths measured by tellurometer is 8,000 m. This figure is an aggregate one and does not mean that a vertical thickness of sediment of this magnitude was ever present in any part of the trough, since it disregards the possibility of progressive, either continuous or discontinuous, migration of sedimentation.

Differential uplift leading to migration of sedimentation is to be expected in troughs, such as that considered here, which are established in association with tectonically active orogens. It is thought that the present southerly younging of the rock groups of eastern Alexander Island (Horne, 1967) is a reflection of progressive preferential uplift in northern Alexander Island as sedimentation proceeded during Upper Jurassic and Lower Cretaceous times. This would have resulted in the migration of the main area of subsidence and deposition southwards parallel to the trough axis.

Migration of sedimentation through time has been emphasized by Dott (1964) in his discussion of deltaic sedimentation in Cretaceous and Tertiary troughs in California and Oregon. He has observed that in similar troughs in southern Chile "regional offlap occurred in late Cretaceous and early Tertiary time along the geosynclinal axis from north to south as well as eastwards. This carried the deltaic and littoral sedimentation gradually southward through this time interval." Brown and Thayer (1963) have described a composite 12,190 m. Upper Triassic and Lower Jurassic succession comprising five distinct, slightly unconformable units from the Aldrich Mountains, Oregon. They have demonstrated that "the basin of deposition apparently shifted southeastwards as folding and sedimentation progressed together". Vance (1968) has observed that the Palaeozoic strata of north-west Washington have a composite thickness of 1,000 m. but that individual sections are much thinner owing to "stratigraphic discordance between the major units". Coombs and others (1959) have suggested that in the New Zealand geosynclinal troughs "the locus of most rapid sedimentation may have migrated repeatedly". These few examples are chosen to illustrate that throughout the circum-Pacific mobile belt the Mesozoic succession is interrupted by numerous discontinuities or unconformities of varying magnitude and regional extent. It seems probable, therefore, that further field work will reveal similar discontinuities in the Alexander Island Mesozoic succession.

Volcanic Association

The petrology, derivation and distribution of the volcanic material associated with the sediments of this trough have already been described (Horne, 1968*b*). The syn-depositional volcanism was of intermediate (andesitic) character and the volcanic fragments in the sediments appear to have been derived largely by erosion of tuffs and lavas accumulating in the source area and partly by direct introduction of pyroclastic material in the form of ash clouds (Horne, 1968*b*, *c*).

Aubouin (1965) has recognized a late geosynclinal phase of igneous activity of essentially intermediate character largely restricted to the internal zones and including a predominantly granodioritic suite of plutonic rocks associated with the orthogeosynclinal orogenesis and andesitic volcanism related to the subsidence of the internal back troughs (Aubouin's epieugeosynclines). This suite of igneous rocks he has regarded as a result of palingenesis of sialic crust and hydridization with simatic (basaltic) material. In his review of Jurassic volcanism in the composite Fraser belt of western North America, Dickinson (1962) similarly concluded that these andesitic magmas were formed by sialic crustal contamination of a primary basaltic magma or by partial fusion of the lower sialic crust.

Regional Relationships

Although the general stratigraphy of Alexander Island has not been fully established, the accumulation of clastic sediments in the depositional trough of eastern Alexander Island appears to have commenced in mid-Jurassic times and to have persisted into Upper Aptian times at least. A great volume of sediment was derived from the east from a source area whose elevation must have been maintained during this period. The present regional metamorphic and igneous complex of the southern Antarctic Peninsula is believed to represent the degraded remnant of this source geanticline (Horne, 1968*b*). Regional metamorphic rocks and plutonic rocks of granitic-granodioritic composition were therefore exposed in this area during Upper Jurassic and Lower Cretaceous times.

This conclusion further augments the increasing evidence for an important pre-mid-Cretaceous phase of metamorphism, intrusion and orogenesis in the Antarctic Peninsula area. At Mount Flora, Hope Bay, in the extreme north of the peninsula, an unconformity separates flat-lying sediments containing plants which have been assigned an uppermost Middle Jurassic age (Adie, 1964) and overlying lavas from the underlying Trinity Peninsula Series, which is a thick, complexly folded, deep-water sandstone–shale sequence of Upper Palaeozoic age. The phase of deformation and metamorphism indicated by this unconformity may also be represented in the South Orkney Islands where the 199–176 m. yr. (Upper Triassic–Lower Jurassic) (Miller, 1960) and 235–205 m. yr. (Triassic) (Grikurov and others, 1967) ages for the metamorphic complex are believed to date the metamorphism of this complex and the deformation of a sandstone–shale sequence similar to the Trinity Peninsula Series. Recent radiometric dating of rocks from the Antarctic Peninsula has confirmed the presence of numerous plutonic intrusions which cooled in the period 180–160 m. yr. B.P. (Rex, 1967). The intrusion of these plutonic rocks, ranging from gabbro to granite but mainly granodioritic in composition, post-dates the regional metamorphism of a sedimentary and volcanic sequence now represented by schists, gneisses and amphibolites. An amphibolite and gneiss from this complex give ages of about 240 m. yr. and another gneiss an age of 140 m. yr. The metamorphic complex of the Marguerite Bay area has yielded dates ranging from 140 to 95 m. yr., interpreted by Grikurov and others (1966) as indicating the partial modification of an older metamorphic complex by an extensive phase of plutonic intrusion in the period 100–50 m. yr. B.P. To the west-south-west of Alexander Island, in the Jones Mountains, a plutonic complex, yielding an age of 199 m. yr. (latest Triassic), and a felsitic volcanic sequence are cut by dykes with an isotopic age of 104 m. yr. (mid-Cretaceous) (Craddock and others, 1964). This volcanic group is considered to be roughly contemporaneous with the mid-Cretaceous dykes. In the Clark Mountains, in the extreme west of the western Antarctic mobile belt, a regionally metamorphosed sandstone–shale sequence is intruded by adamellite with an isotopic age of 140 m. yr. (Boudette and others, 1966).

The collated evidence from the Antarctic Peninsula and Marie Byrd Land reveals an important phase of deformation, metamorphism, intrusion and orogeny in the interval 200–160 m. yr. B.P. (late Triassic to mid-Jurassic). If the plutonic complex of the southern Antarctic Peninsula (Palmer Land) acted as the source for the Alexander Island sediments, its metamorphism and intrusion are pre-mid-Cretaceous and probably pre-Upper Jurassic, and it may be equivalent to the early Mesozoic complex of other parts of the Antarctic Peninsula. In northern Palmer Land it is overlain unconformably by a sequence of gently dipping terrestrial red conglomerates, coarse sandstones, and finally tuffs and lavas with an andesitic composition like those of the Alexander Island trough. It is suggested that these non-marine terrestrial flood deposits and volcanic rocks were laid down amongst deeply eroded mountains (personal communication from K. D. Holmes) in the source area of Palmer Land during the later stages of the erosive and volcanic phase which produced the detrital and pyroclastic marine sediments of Alexander Island.

The mid-Jurassic to mid-Cretaceous trough of south-eastern Alexander Island was established in an internal position with respect to the tectonic and metamorphic axis of the preceding early Mesozoic orogenic belt as an elongated marine trough which exhibits all the characteristics of a back trough (Aubouin's *arrière-fosse*). It contains a thick succession of marine clastic sediments of mineralogical and textural immaturity, showing complex and rapid variations of grain-size, texture and facies, associated with abundant syngenetic volcanic material of intermediate composition. Parts of the succession are highly fossiliferous.

Aubouin (1965) has observed that due to orogenic polarity such back troughs are established earlier than the equivalent fore basins. This evolutionary pattern is exhibited in the Antarctic Peninsula by the mid-Jurassic to mid-Cretaceous back trough of Alexander Island and the

Upper Cretaceous (Lower to Middle Campanian) fore basin of the James Ross Island area.

Grikurov and others (1967) have described from the Colbert Mountains in the west of Alexander Island a thick sequence of flat-lying apparently little deformed lavas and tuffs yielding an isotopic age of 70 m. yr. This may indicate a minimum age for the deformation of the sediments in the trough which therefore would appear to have followed closely upon the termination of sedimentation in mid-Cretaceous times. This is in agreement with the suggestion that sedimentation and uplift may have progressed together (p. 73) and the evidence of tectonic structures involving incompletely lithified sediments (Horne, 1967).

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