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A RECONNAISSANCE GEOLOGY AND GEOMORPHOLOGY OF TASMAN PENINSULA

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(with two text-figures and one plate)

On Tasman Peninsula, southeastern Tasmania, almost horizontal Permian marine and Triassic non-marine rocks were intruded by Jurassic dolerite, faulted and overlain by Tertiary basalt. Marine processes operating on the Jurassic and older rocks have produced a cliffed coastline with many erosional features widely noted for their grandeur and rarity. These features form a self-renewing economic asset.

Key Words: Tasman Peninsula, Tasmania, Permian, dolerite, erosional coastline, submarine topography.
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INTRODUCTION

Tasman Peninsula is known for its spectacular coastal scenery — high cliffs and the great dolerite columns which form these cliffs in places. These columns were the first geological features noted on the peninsula. Matthew Flinders, who saw the columns in 1798, reported (1801, pp.2–3) that the columns at Cape Pillar, Tasman Island and Cape "Basaltes" (Raoul) were "not strictly basaltes", recognising that they were not the same in form as those of the Giants' Causeway in County Antrim, Ireland, and in Auvergne, France, the subject of great interest in Europe at the time, as evidence of volcanic activity. Péron (1807, p.261) recorded that scientists with Nicholas Baudin's expedition of 1802 had noted basaltic prisms and needles at Cape Raoul, Cape Pillar, Tasman Island and The Lanterns, and the expedition artists depicted the columns, some of them shown as leaning (Lesueur and Petit in Péron 1807, Pl. III, fig.2). Péron (*loc. cit.*) wrote of Cape Hauy, named by the French explorers after a famous contemporary French crystallographer, that it "appears as an organ reposing on the surface of the sea" (trans. MRB). He further wrote (p.248), "Thus even in that extremity of the Eastern World, the earth had its revolutions and its catastrophes; there as everywhere else, it has been ravaged by volcanoes raised under the sea" (trans. MRB).

Coal was discovered near Plunkett Point by surveyors Woodward and Hughes in 1833 (GO 33/16/264-5; TSA) and the seam visited by Captain O'Hara Booth on May 23, 1833 (Heard 1981, p.158). Dr John Lhotsky reported to Sir John Franklin on this coal and the coal mining methods in 1837 (CSO 5/72/1584; TSA). His thorough report was supported by a coloured map (CSO 5/11/147; TSA) showing some outcrops of different rock types. This map, although not complete as claimed in the *Australian Dictionary of Biography* (Vol. 2, p.114), was the earliest attempt at a geological map of any part of Tasmania. The coal was mined from 1834 to 1877. It did not have a good reputation because of its high ash content (e.g. de la Beche 1851).

The Tessellated Pavement was known as early as 1836 when O'Hara Booth examined it (Heard 1981, p.204). In 1841 it was visited, probably during the winter, by Robert M'Cormick, surgeon on HMS *Erebus* then in Hobart between visits to Antarctica. A party including David Burns, journalist, made a visit in January 1842 and Burns noted the Pavement later in that year (1842, p.285). Other visitors, probably in 1842, were P.E. von Strzelecki (1845, p.97) and J.B. Jukes (1847). The regularity of the jointing attracted attention and was explained by M'Cormick (1847, p.400) as due to electromagnetic forces acting on the particles of the sedimentary rock as it consolidated. Johnston (1888) included lithographs of the

Tessellated Pavement (opp. p.121), Tasmans Arch (opp. p.124) and The Blowhole (opp. pp.122 and 126) in his book *A Systematic Account of the Geology of Tasmania*. Subsequently the Pavement has been figured in overseas publications such as Holmes' *Principles of Physical Geology* (1944, pl. 14A) and Bloom's *Geomorphology* (1978, p.447) and mentioned and figured by Carey (1957, p.229, fig.1) in *Dolerite — A Symposium* and by Branagan (1983) who described it as "a classic". A similar pavement just west of Clydes Island was figured by David & Browne (1950, vol. II, pl. 76A) in their *Geology of the Commonwealth of Australia*. Twelvetrees (1902, p.25) and Hills *et al.* (1922) attributed the jointing to contraction during cooling after heating by a subjacent body of intrusive dolerite.

Fossils from the Permian rocks of the peninsula attracted early attention (O'Hara Booth in 1836 (in Heard 1981, p.204) and Lempriere 1839 ms. (in Lempriere 1839, p.71)). G.B. Sowerby described two brachiopods from Eaglehawk Neck given to Charles Darwin by Surveyor-General George Frankland (Darwin 1844, p.177). Lhotsky collected fossil brachiopods and bivalves from Curiosity Beach and a bryozoan from Eaglehawk Neck, now in the British Museum of Natural History (BMNH). Strzelecki collected from Point Puer and Eaglehawk Neck and a bivalve from the Point was described by J. Morris (Strzelecki 1845). M'Cormick's report (1847) includes a note by Dr Jeanneret, surgeon at Port Arthur, of fossils at Point Puer and the BMNH has an extensive collection of Permian fossils from the area made by Dr Jeanneret and a few in the M'Cormick Collection. J.B. Jukes (1847, p.385) listed bryozoans, brachiopods, gastropods and bivalves from Eaglehawk Neck, The Blowhole and Point Puer, many of which are now in the BMNH. Frederick M'Coy described (1847) a brachiopod from Eaglehawk Neck and two bivalves from Port Arthur sent to him by the Rev. W.B. Clarke. Johnston (1888, pl.XI) figured a bivalve "*Sanguinolites undatus*" from Eaglehawk Neck.

No systematic large-scale geological mapping of the whole peninsula has been published. Hills *et al.* (1922) included a geological map of the northern part of the peninsula, a map shown to be wrong in places by Brill & Hale (1954). Gill (1955) provided a map of a small part of the peninsula near Safety Cove. The northwestern part of the peninsula is included in a recent systematic regional map at 1:50 000 (Gulline 1982, 1984).

Conservation and restoration activities at Port Arthur have led to studies of the geology of the peninsula, especially in areas close to Port Arthur, by officers of the Geological Survey of Tasmania (Cromer 1976a, b, Cromer *et al.* 1979) and compilation by Cromer in 1976 of a geological map (Cromer *et al.* 1979). This map forms, with some ground and aerial surveys by the authors, the basis of the accompanying reconnaissance map (fig.1).

After some observations and collecting by visitors in the 1830s and 1840s little work was done on the geology and geomorphology of the peninsula until the 1950s or even the 1970s. Geological interest in the area has been greatest when Port Arthur was a penal settlement and again when conservation and restoration were set in train. This paper is offered as a compilation and summary with some new observations, but only at a reconnaissance level.

In the following text where geographic co-ordinates are quoted they refer to the EN 100 000 metre square in grid-zone 55G. The area falls within the Storm Bay (8411) and Prosser (8412) 1:100 000 sheets, Department of Lands, Parks and Wildlife.

GEOLOGY

Pre-Permian Rocks

The oldest rocks known in the area are quartzites and metapelites reported at 362.4 m below sea level in a hole drilled just north of Lufra Hotel (760382), and correlated with the Siluro-Devonian Mathinna Beds (Gulline & Clarke 1984). The core from the drill hole shows these rocks to be intruded by granitic rocks. Granitic rocks crop out beneath the sedimentary rocks of the Parmeener Supergroup near Cape Surville further north, and, as isolated occurrences, on Cheverton Rock and the Hippolyte Rocks. The granitic rocks are thought to be Devonian by analogy with those further north at Maria Island.

Parmeener Supergroup — Permian and Triassic

Although a complete section through the lower part of this supergroup occurs in cliff sections along the east coast of Forestier Peninsula (Gulline 1984) and in the drill hole at Eaglehawk Neck, only the upper part of the Upper Marine Sequence and the Upper Freshwater Sequence crop out on Tasman Peninsula.

Upper Marine Sequence — Permian

Malbina Formation

This formation, which consists predominantly of siltstone with some sandstone beds, crops out along the east coast from Clydes Island to Waterfall Bay

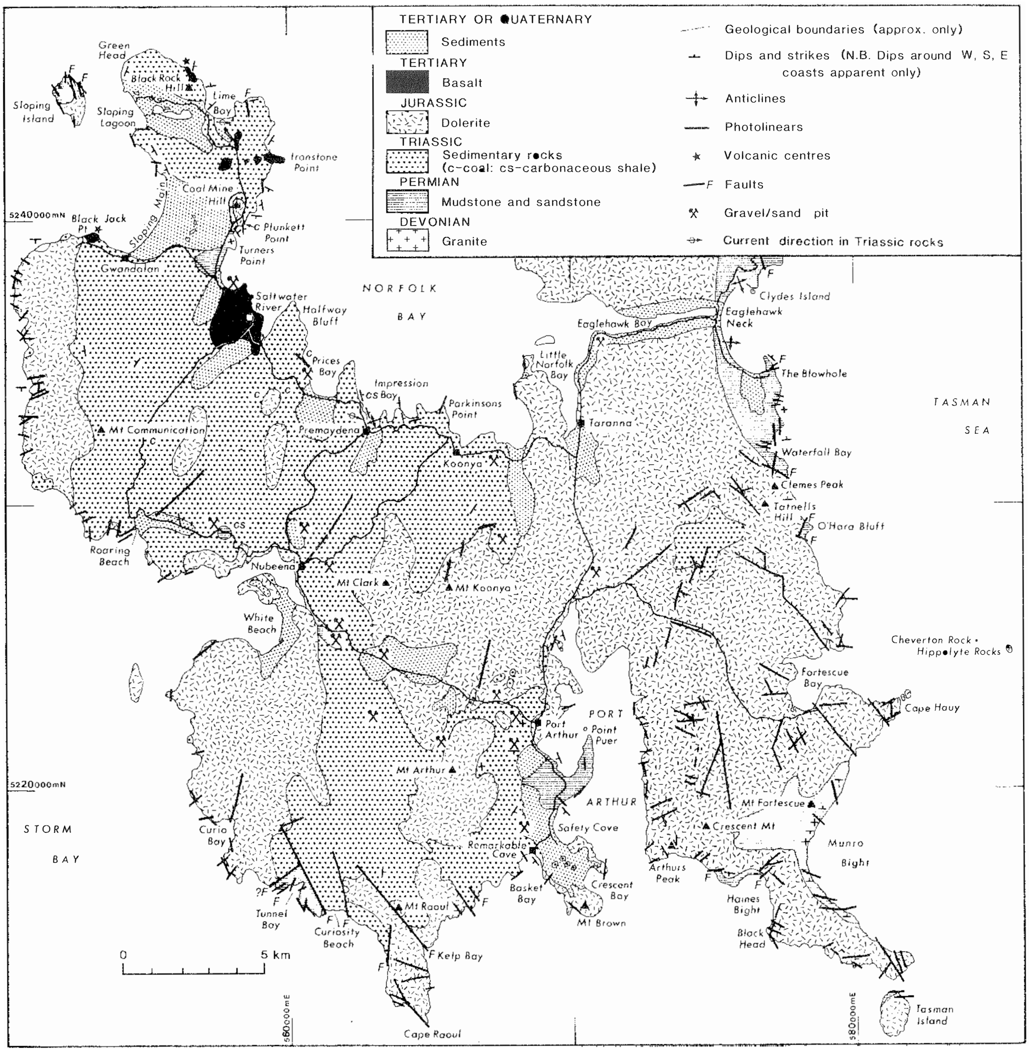

FIG. 1 — Reconnaissance geological map of Tasman Peninsula — mainly after Cromer et al. *1979 but with amendments and additions.*

and possibly beyond. The Tessellated Pavement, Fossil Island, The Blowhole, Tasmans Arch and the Devils Kitchen are either composed of or are cut in this formation. Jukes (1847) and Johnston (1888, pp.125–126) described this unit and Voisey (1938, p.317) assigned it correctly to the Malbina Formation (then "Woodbridge Glacial Formation").

The oldest part of the Malbina Formation known in the area is exposed on the elevated shore platform north of Clydes Island where interbedded fissile and non-fissile siltstones crop out with erratics up to 1 m long and sparse marine fossils. These are overlain on an erosional surface by a thin (1–1.5 m) bioturbated sandstone. This corresponds to Member C of the Malbina Formation (Banks & Read 1962) and also outcrops on the point (760377) immediately north of the Tessellated Pavement, in the gulches north and south of The Blowhole, at The Blowhole and in the cliffs from The Blowhole to Waterfall Bay. At the Tessellated Pavement it contains pebbles of granitic rocks (including porphyry; Jukes 1847, p.248), quartz, quartzite, schist, and at The Blowhole fossiliferous Devonian sandstone (such as occurs in the Florence Sandstone of western Tasmania). Above this sandstone, Member D is represented by alternating fissile and non-fissile, sparsely to richly fossiliferous siltstones with erratics as seen at the Tessellated Pavement and near The Blowhole. At the Tessellated Pavement *Spirifer vespertilio* G. Sowerby (= ?*Sulciplica transversa* Waterhouse) and *Fusispirifer avicula* (Morris) occur and this may have been the collecting site of the fossils described by Sowerby (in Darwin 1844). In the cliffs north of Clydes Island, in quarries on the Arthur Highway north of Lufra Hotel, on Fossil Island and probably along the cliff top at The Blowhole and between The Blowhole and the Devils Kitchen, the siltstones are very fossiliferous and include small pods of limestone. The fossils include bryozoans especially *Stenopora crinita* Lonsdale, brachiopods such as *Echinalosia ovalis* (Maxwell), *Terrakea brachythaera* (Morris), *Tomiopsis* spp., *Fusispirifer avicula* (Morris), bivalves such as *Myonia corrugata* Fletcher, *Vacunella curvata* (Morris) (Runnegar 1967) gastropods such as *Peruvispira* sp. and *Platyschisma rotundatum* Morris and crinoids such as *Tribrachyocrinus* sp. In the richness in fossils and composition of the fossil fauna this siltstone correlates well with Malbina Member E. The Malbina Formation is Artinskian and is postulated to have been deposited in a shallow sea beneath drifting ice (Banks & Clarke 1987).

Fern Tree Mudstone

The basal unit of this formation, the Risdon Sandstone, may be represented by a thin sandstone exposed in cliffs of mudstone in Munro Bight and by a fossiliferous sandstone from Curiosity Beach (specimen in BMNH). From Flat Rock (close to Curiosity Beach) a silicified tree trunk in sandstone has been noted (H.J. Read, pers. comm.).

Fern Tree Mudstone occurs at Point Puer, Tunnel Bay, Turners Point and on Sloping Island (Brill & Hale 1954) and possibly in Munro Bight, at sea level on the northwestern face of Tasman Island, between Mount Fortescue and Crescent Mount, near Haines Bight and on Stormlea Road near its junction with the Nubeena Road (618250).

The formation consists mainly of fissile and non-fissile siltstone, in alternations of the order of 0.5 m thick. Dropstones are present in all outcrops examined — on the shore platform a few metres north of Safety Cove concentrations of pebbles of varied composition occur as more or less circular patches half a metre or so across and at Tunnel Bay as blocks up to 0.8 m long. Pyrite occurs as a joint filling at Tunnel Bay and was reported from Point Puer (Jeanneret in M'Cormick 1847). Body fossils, mainly as impressions, are rare but pieces of wood, sponges, brachiopods such as *Terrakea brachythaera* (Morris) and spiriferids and bivalves such as *Merismopteria macroptera* (Morris), *Myonia carinata* (Morris) and *Megadesmus ovalis* (Sowerby) have been reported (Morris in Strzelecki 1845, Jukes 1847 and M'Coy 1847, Brill & Hale 1954, Pickett in Woodmansee 1983, p.158, figs. 69, 70). Silicified *Terrakea* have been known, probably from decomposed carbonate concretions, from Point Puer since noted by Jeanneret (in M'Cormick 1847) and Jukes (1847). The formation also shows intense bioturbation in places (e.g. Point Puer).

The Fern Tree Formation is Middle Permian and is thought to have been deposited in a brackish lagoon marginal to the sea and intermittently ice-covered (Banks & Clarke 1987).

Upper Freshwater Sequence — Late Permian to Triassic

Much of the peninsula west of the Arthur Highway has sandstone as the surface rock and this rock is well exposed in cliffs along the Norfolk Bay coast.

Cross-bedded quartz sandstones with carbonaceous siltstones on the road between Nubeena and Roaring Beach 4.15 km from Nubeena at 577291 may be Late Permian. In the bay south of Premaydena

Point (at about 627333) carbonaceous siltstone is interbedded with sandstone with many burrows, both vertical and horizontal. One set of ripples in the sandstone shows currents to 130°. This sequence may also be Late Permian but, as at Nubeena, evidence for age is not clear.

Pale to yellow, quartz-rich, cross-bedded sandstone associated with clay-pellet conglomerates and grey siltstones are widespread but, as noted by Brill & Hale (1954, p.281) no detailed section is available. On the shoreline of Impression Bay, north of Premaydena, at about 624339 quartz sandstone, carbonaceous siltstone and red siltstone occur. The carbonaceous siltstone contains *Cylostrobus sydneyensis* Helby and Martin, *C.* cf. *grandis* H. & M., *Hoegia* cf. *papillata* and *Pterrorachis barrealensis* Frenguelli (J.A. Townrow, *in litt.*). These plants indicate an Early Triassic age (*D. zuberi* Oppel Zone of Retallack 1977). From a thin carbonaceous siltstone unit on the western shore of Lime Bay (71175517) scattered bones of the amphibian *Blinasaurus townrowi* Cosgriff have been collected. This rock is associated with brown sandstone and reddish-brown shale. The amphibian indicates that this bed is very early Triassic in age (Cosgriff 1974).

Coal associated with "feldspathic sandstone" (= lithic arenite) has been reported from near Plunkett Point where it was mined, near the Hurdle Bridge over Saltwater River (587357) where an attempt was made to mine it, on the western side of Prices Bay (606356), west of Prices Bay at about 600340 and both east and west of Mount Communication at about 558317 and 534323. Little is known of these occurrences although Jukes (1847, p.248) noted the thickness (up to 2.4 m) of the coal, the associated sedimentary rocks and dolerite and the presence of fossil plants including *Cladophlebis australis* Morris and *Phoenicopsis* sp.

Dolerite (Jurassic)

As noted earlier dolerite is common on the peninsula and has produced spectacular coastal scenery. Only close to Remarkable Cave has the dolerite been studied. There the top of the dolerite sheet heated the overlying Triassic sandstone enough to cause plasticity in the sandstone as seen in the sides of the gulch immediately east of Remarkable Cave and even to melt it and produce rheomorphic injections of molten sandstone into the dolerite (Powell 1967, Ch.8). On most other known contacts on the peninsula the metamorphic effects are minor but Cromer (1976a, p.4) drew attention to metamorphic effects 10 m from a contact just west of Port Arthur (675225).

Jukes (1847, p.247) used the abutment of horizontal and apparently unaltered sandstone against perpendicular cliffs of dolerite just to the east of the mouth of Port Arthur as evidence that the dolerite was older than the sandstone. The locality seems likely to be the bluff just west of Haines Bight. This and other similar evidence gave rise to the erroneous view that some of the dolerite was older than the Permian rocks, a view not finally overturned until about 1900. The contact at Haines Bight is very steep but may well be a fault.

In broad terms, the dolerite is intrusive into Malbina and Fern Tree Formations in the eastern part of the peninsula and between the Fern Tree Formation and Triassic sandstones or into the Triassic rocks west of the meridian of Port Arthur. The intrusions are either irregular or are faulted as shown by the pockets of sandstone surrounded by dolerite along the coastline west and north of Curio Bay.

Basalt (Tertiary)

Tertiary basalt is shown on the geological map (Hobart 1:250 000) at a number of places bordering Norfolk Bay including, incorrectly, Plunkett Point which is dolerite (see Brill & Hale 1954, p.280; Gulline 1984). Volcanic centres occur just west of Lime Bay, at Ironstone Point and at Black Jack Point (Brill & Hale 1954, p.283). The only basalt to have been studied is that from Black Jack Point, an alkali olivine basalt (Everard, p.36 in Gulline 1984).

Quaternary Deposits

Dolerite cobbles and pebbles loosely cemented by iron oxide occur in the bay west of Black Jack Point (Brill & Hale 1954, p.283). Discoidal cobbles of dolerite in and on a sand with ferruginous cement at Roaring Beach dip seaward and represent a fossil beach. They are associated with buried dunes that are strongly podzolised and have thick iron pans. A fossil iron-cemented boulder beach also occurs at Remarkable Cave (Colhoun 1977).

Modern boulder and cobble beaches are widespread around the cliffed east, south and west coasts and along the shores of Eaglehawk Bay. The boulders and cobbles are mainly dolerite but Permian mudstone and hornfels also form cobble beaches where such rocks crop out nearby.

Sand deposits occur both as dunes and as beaches. Dunes can be recognised at Eaglehawk Neck, near Remarkable Cave, at Roaring Beach and southeast of Sloping Lagoon, and windblown sands cover the dolerite between Eaglehawk Neck and Taranna, in places in dune form. The degree of podzolisation of sand dunes varies from strong, e.g. east end of Roaring Beach, Masons Point, basal dune at Remarkable Cave, to weak at Eaglehawk Neck, Safety Cove and elsewhere. The degree of podzolisation is primarily related to the age of formation of the sand body, the deep podzols being much older than the shallow podzols.

Sandy beaches occur at Eaglehawk Neck, Fortescue Bay, Safety Cove, White Beach and Roaring Beach. They are more extensively developed along the Norfolk Bay coastline. Alluvial deposits occur in the valleys close to the coast of Norfolk Bay and lagoonal deposits behind Sloping Main and elsewhere. Neither have been studied.

The only Quaternary deposits to have been systematically studied are those in the gulch adjacent to and behind Remarkable Cave. There a basal, iron-cemented, boulder beach interpreted as being of Last Interglacial Age is overlain by slope and valley fill deposits which contain charcoal fragments and organic-rich layers. These deposits are all older than 37 000 radiocarbon years BP. At the back of Remarkable Cave an iron-cemented boulder bed is overlain by slope deposits. All of these deposits predate the formation of Remarkable Cave (Colhoun 1977). Pollen in the slope and valley deposits suggest that the vegetation of the area during most of the early part of the Last Glacial stage was similar to that in the area today.

Geological Structure

The basement rock of the Forestier Peninsula is granite intruded into metamorphosed quartzwacke turbidite and slate (Gulline 1984, Gulline & Clarke 1984). The surface of these rocks beneath the Parmeener Supergroup is irregular, the upper beds of the Lower Marine Sequence and even of the Lower Freshwater Sequence resting on a polished granite surface two or three metres above sea level at Deep Glen Bay. In contrast the basal beds just over 200 m stratigraphically lower in the section rest on basement at about 360 m below sea level in the drillhole north of Eaglehawk Neck about 5 km to the southwest which gives an average slope of the surface of about 30 m/km if several faults of small throw are ignored. It is likely that the maximum slope is greater. Granite rises above sea level at the Hippolyte Rocks and Cheverton Rock and the nearby dolerite, at Cape Hauy, rises through Upper Marine Sequence mudstones. Thus basement west of Cheverton Rock may be faulted down or slope down rapidly to the west.

Most dips in the Permian beds are low, less than 5°, and variable in direction. Low amplitude, long wavelength folds can be inferred just north of the Tessellated Pavement and in Pirates Bay, south of the Neck, and they can be seen in the cliffs at Waterfall Bay and Munro Bight.

The Triassic rocks are gently folded (Brill & Hale 1954, p.284). Folds may be seen in cliffs at 642332 and 625333 where an anticline plunges gently towards 260°. Known dips and the distribution of the formations (fig.1) are insufficient to allow the general structure to tbe deduced.

Although joints are common in the Permian and Triassic rocks, only close to the Tessellated Pavement have they been intensively studied. The Pavement shows varied joint patterns. In general, the joints form sets of planar and parallel cracks along which there has been no movement. They occur as steeply dipping fractures in the flat-lying sedimentary rocks. In places very fine markings (plume structure) are displayed on the joint surfaces.

Several sets of joints may occur within a sedimentary bed, and result in attractive and interesting geometrical patterns. The joints are best developed in the coarser-grained pebbly sandstone beds, but may be poorly formed in the finer-grained pebbly mudstone layers. The joints, however, are normally unaffected by grain-size within a bed since they transect pebbles as well as the fine-grained matrix usually without deviation (see also Hills *et al.* 1922, p.119). They have developed approximately perpendicular to bedding, which varies in dip from 2° SW to 3° ENE. The spacing between the parallel joints of a set is unrelated to the grain-size of the beds in which they occur, and it varies from about 100 mm to some 750 mm and in a few places greater.

At least two joint sets occur in all the sedimentary layers. A NW directed set varies in strike from bed to bed from 326° to 342° (average 330°) whereas a NE directed set varies from 68° to 80° (average 75°). The dihedral angle bounded by the joint sets facing the SE varies from 92° to 72° (average 76°), but the bisectrix, which is the acute bisectrix for nearly all the beds, is remarkably constant in a direction of some 295°. There is no apparent relationship between the grain-size of the beds and the variations in the strikes of the joint sets or dihedral angle. Of the two sets the NE directed one is the best developed, for the joints are usually continuous and regularly spaced whereas joints of the NW directed set are sometimes non-planar and discontinuous in the finer grained beds.

In some beds, which may be fine- or coarse-grained, a third set occurs varying in strike between 360° and 25° (average 15°). Members of this third set can be shown to have developed later for they commonly terminate at the joints of the earlier two sets. In one bed, a silty mudstone with sparse pebbles, a further set with 310° strike shows a late development with joints terminating against the joints of the earlier two sets. Joints of all sets transect laminae within beds, to which they are orthogonal, but usually terminate abruptly at surfaces which mark notable changes of grain-size or composition. At some localities the joints of a set in one layer may continue into minor *en echelon* hackle joints of notably different strike at a bedding surface, and the hackle joints may be shared with joints of a set of similar trend in an adjacent layer.

The variation of the strikes of the earlier two sets of joints from bed to bed and the constancy of the SE directed bisectrix of their dihedral angle indicate that the fractures did not follow directions determined by a depositional fabric. The joint sets have been developed symmetrically about an approximately 295° direction. Their formation can be accounted for as a response to a tangential maximum stress acting along their bisectrix, with a direction at right angles being a tangential minimum stress and gravity the median stress. Such a stress system may well have developed in post-Permian times, and as a precursor to conditions where, with decreasing tangential crustal stresses, gravity eventually became the maximum stress direction, and regional normal faulting resulted along an approximately NNE strike parallel to the later joint set of similar trend. The fourth set of joints at 310° strike occurring in one bed may well be due to later adjustments of the region settling to more normal stress conditions after the stresses to which it had been subjected. Uncommonly joints later become minor faults along which lateral movement has taken place, possibly during times of adjustments. A reversal of dip just north of the Tessellated Pavement may indicate an anticline trending about 300° and plunging SE.

Within the joint-bounded areas of all beds fine cracking (elephant-skin weathering) may occur at the surface, penetrating to a depth of some 30–60 mm. The fine cracks are orthogonal to the bounding joints, against which they terminate, but become irregular in direction in the central area forming a polygonal structure. These structures are formed later than the joints and are related to the present-day exposed rock surfaces.

A number of small steep faults have been recognised (fig.1). They commonly trend ENE downthrowing to the north, and are steep. These parallel steep sinistral shear faults have developed along some joints at the Tessellated Pavement. Another common direction is between NNW and NNE and it is interesting to note that this general direction corresponds with that of a set of dextral shear faults developed along some joints at the Pavement. The major topographic low from Little Norfolk Bay to Port Arthur may indicate a fault zone. If so the downthrow is likely to be to the west, Permian being predominant to the east and Triassic to the west.

Air-photo linears (fig.1) show some preference for trend to 20° (strongest), 325°, 339°, 356° and 290° (weakest), and in places are parallel to known faults or are faults.

The form of the Jurassic dolerite body or bodies is not entirely known. In many places the outcrop to contour relationships of dolerite contacts suggest that they are shallowly dipping to horizontal, probably being concordant, e.g. around Mount Arthur. The dolerite under the Triassic near Remarkable Cave has an almost concordant contact and is probably a sill or sheet. On the other hand steep contacts are known to occur in a number of places, e.g. a quarry 0.8 km south of the Neck (dip steeply west, over Malbina Formation), just south of O'Hara Bluff (dip steeply, against Malbina or Fern Tree Formation), on the northwestern face of Tasman Island just above sea level (dip about 60° to SE over ?Fern Tree Mudstone), and two km NE of Kelp Bay (dip about 45° to NE under Triassic). In many places on the peninsula outcrop to contour relationships suggest steep contacts but these have not been adequately mapped. Narrow dolerite dykes have been reported cutting Triassic rocks south and east of Green Head (Brill & Hale 1954, pp.280–283), in the bay west of Parkinsons Point, and cutting dolerite at Mount Brown and north of Crescent Bay (Gill 1955, p.20; Cromer *et al.* 1979, map). The trend of the dykes varies from NE through ENE to E. The dolerite at the coal mine near Plunkett Point may be partly a dyke (Brill & Hale 1954, p.283; Bacon 1985).

The columnar cliffs of dolerite owe their form to more or less planar fractures which may individually extend through tens or even hundreds of metres vertically and tens of metres to well over a kilometre horizontally and are spaced from less than a metre to well over two metres apart (e.g. Caine 1983, p.14). Commonly there are two sets almost at right angles but there may be other sets as well. In places major joint sets seem to change direction gradually over some kilometres and produce a series of concentric arcs with a radius of curvature of several kilometres (Caine 1983, fig. 2.5c; Forsyth 1984, p.126). Cooling joints some metres apart may be present in the centre of a dolerite body but only close to contacts are cooling fractures obvious and there they are closely (0.01 to about 0.2 m) spaced perpendicular to the contact with much more widely spaced joints parallel to the contact. Horizontal joints are spaced at from 4 m (Caine 1983, p.15) down to 0.1 m. In addition there are oblique joints dipping at 65° (Caine *loc. cit.*) in places and about 45° in others, e.g. Tasman Island (Sanders 1968), Mt Wellington.

Low-level aeromagnetic traverses over the peninsula close to the eastern and southern coasts (Aeromagnetic Survey 1967) show a series of narrow magnetic highs and lows elongated NNW north of Fortescue Bay at Mount Fortescue, Arthurs Peak and Basket Bay. A magnetically flatter area lies west of Fortescue Bay and low areas occur west of Haines Bight (outcrop of Permian mudstone) and a narrow one just east of Black Head trending NNE. North of Fortescue Bay four narrow horsts of dolerite or four feeder dykes may explain the magnetic pattern. Further south a NNW trending feeder dyke under Mount Fortescue may be succeeded further west (Black Head to upper Denmans Creek, 755200) by another feeder. The steep-sided magnetic ridge from Arthur Head to just east of Stinking Bay (718248) suggests a further feeder and a similar but narrower meridional ridge through Maingon Blowhole (702169) suggests yet another. The topography is unlikely to explain the variations in magnetic intensity. The low-level aeromagnetic intensity map indicates that dolerite thins rapidly or disappears off the east coast and off the south coast as far west as Cape Raoul. The magnetic intensities and the outcrops of Devonian granite at the Sisters, north of Eaglehawk Neck, and at Hippolyte Rocks, suggest that pre-Permian rocks underlie the sea floor just off the east and south coasts. The -800 m (-2440 ft) and -900 m (-2750 ft) contours on magnetic basement are remarkably straight and meridional from immediately east of Tasman Island to beyond the latitude of Cape Frederick Henry on Forestier Peninsula suggesting fault control. The geology suggests downthrow to the west.

High-level aeromagnetic mapping (Finney & Shelley 1966) reveals a very narrow, very steep meridional ridge of high magnetic intensity from Halfway Bluff (623350) to Cape Raoul. This ridge may be a dolerite dyke in the pre-Permian basement. The ridge is matched by a low running from just west of Nubeena to just west of Saltwater River coal mine.

A reconnaissance gravity survey (Johnson 1972) shows a high in the Bouguer anomaly map trending NNE from just west of Cape Raoul on to the Forestier Peninsula. The near coincidence of the gravity anomaly and the magnetic intensity ridge support the concept of a dolerite dyke through the basement.

In an 18-year period ending in December 1978 one earthquake, a minor shallow one, was recorded as centred on the peninsula (Shirley 1980) although a few more were recorded as originating offshore.

On a broader scale, interpretation of the gravity field in Tasmania suggests that the Earth's crust is 23 to 24 km thick below Tasman Peninsula (Leaman *et al.* 1980). Further, the granite basement is thought to descend rather sharply from less than one kilometre in depth in the eastern part of the peninsula, to four kilometres just west of Nubeena and reach nine kilometres under Frederick Henry Bay. The presence of granite at the surface of Cheverton Rock and The Sisters, and at -350 m (approx.) just north of Eaglehawk Neck has already been noted. The average slope of the granite surface to the west under the peninsula is therefore 1:3.4 and could be as steep as 1:2.4 west of Premaydena. A proved component of slope of the basement surface of 1:30 from the northeast to Eaglehawk Neck has been noted earlier.

GEOMORPHOLOGY

Introduction

The geomorphology of the peninsula shows the importance of the combined influence of variations in rock type and in geological structure. East of a line through Little Norfolk Bay and Mount Brown the rock is predominantly Jurassic dolerite with minor sedimentary rocks and the topography is high. Along the line is a low area, underlain mainly by dolerite. To the west the area south of Nubeena is mainly dolerite with some sediment. In this area the relief is variable with high dolerite hills and intervening sandstone valleys. North of Nubeena and south of Gwandalan there is more sandstone than dolerite exposed at the surface. The topography is generally lower and stream density higher than elsewhere on the peninsula. Finally the area north of Gwandalan is predominantly underlain by Triassic sandstone. Here the relief is low, the surface is sandy and stream density is very low.

The main geomorphological processes are stream and coastal erosion, with minor deposition only. Mass movement and the wind play minor roles although wind transport and deposition of sand have played important roles in the past and are locally important now. Remnants of old erosional surfaces and evidence of both higher and lower stands of former sea level are present on the peninsula and beneath the waters surrounding it.

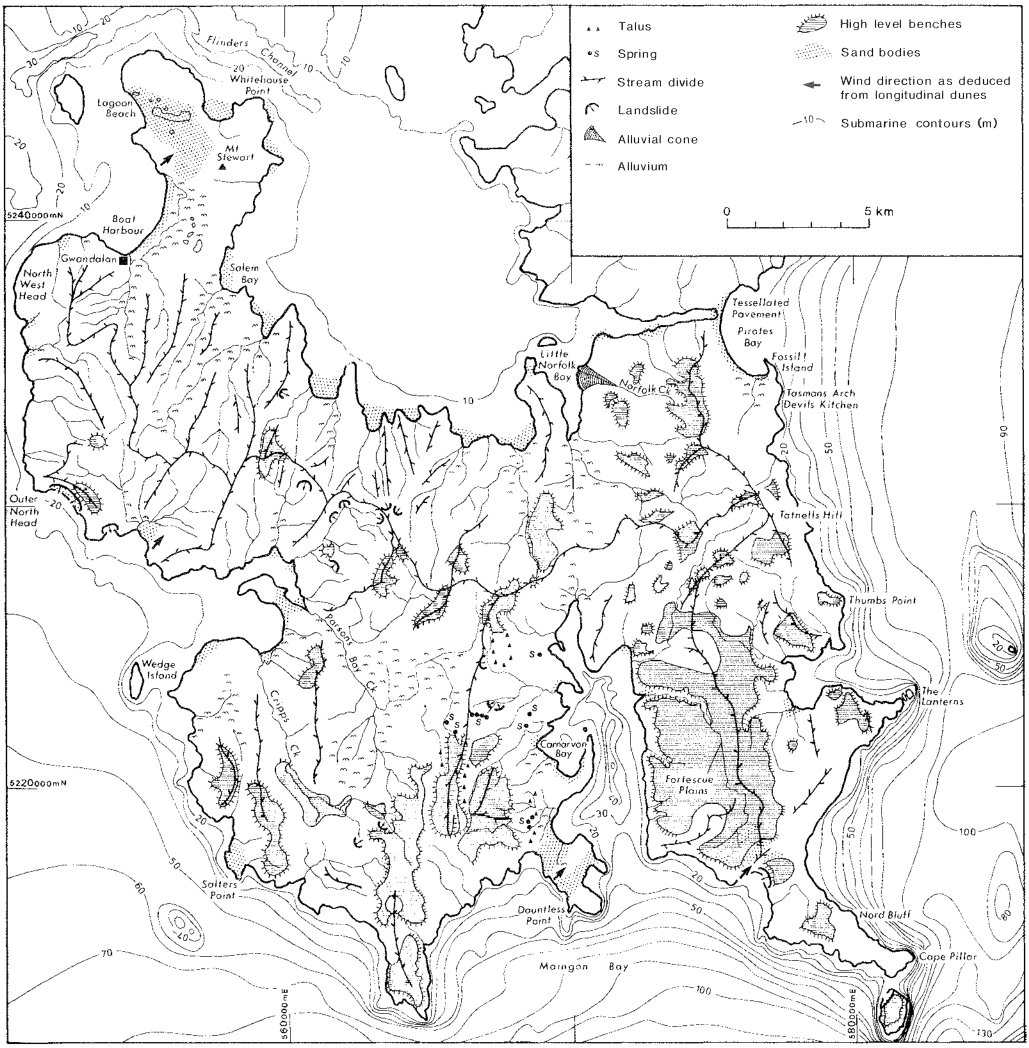

FIG. 2 — Reconnaissance geomorphological map of Tasman Peninsula.

Soils

Only a small-scale soil map of Tasman Peninsula has been prepared (Nicolls & Dimmock 1965, map 6) which shows three soil types. The soils include grey-brown podzolic soils on dolerite, yellow podzolic soils on sandstone and groundwater podzols and podzols on the sands of the far northwestern part of the peninsula, at Eaglehawk Neck and near Masons Point.

Mass-movement Forms

Scree fans occur towards the bases of steep dolerite slopes at many places along the cliffed coastlines. Examples may be seen east of Mount Fortescue, just north of Nord Bluff and on the northwestern coast of Tasman Island. As noted previously, early painters showed the tilted dolerite columns of Cape Pillar.

Landslip scars and slump masses have been noted by Cromer *et al.* (1979) and others, and identified on aerial photographs (fig.2). The slips have occurred due to failure of steep seacliffs in dolerite and Permian mudstone. Slips are less common in dolerite and Triassic sandstone and siltstone inland.

Streams

Springs have been reported in a number of places close to Port Arthur (Cromer 1976a) commonly just below dolerite on Triassic sedimentary rock contacts and below talus (e.g. Safety Cove area). They are likely to be much more widespread than shown on the map (fig.2).

None of the streams on the peninsula is long, the longest and most complex being Parsons Bay Creek, the main stem of which is close to 11 km long with an average slope of just under 30 m/km. Parsons Bay Creek is a fourth order stream. This degree of branching is relatively simple. Most of the streams on the eastern and exposed southern coastlines are short and steep.

Stream density and pattern depend on the geology. On the part of the peninsula east of the line of Little Norfolk Bay and Port Arthur, stream density is low (44 intersections/100 km of grid line) and the streams tend to show a rectangular, trellised pattern controlled by master joints or shears in the underlying dolerite and minor sandstone. On the south central part of the peninsula, south of a line through Nubeena, stream density is higher (67 intersections) and the pattern varies from rectangular where controlled by master joints or shears, to dendritic where the bedrock is predominantly sandstone. In the north-central section the stream density is greatest (83 intersections) and shows, especially northwest of Nubeena, a preferred orientation, NNE–SSW, probably controlled by minor faults in the sandstone. The peninsula north of Salem Bay, mainly covered by wind-blown sand, has few streams (24 intersections). Stream density is greatest on the Triassic rocks, less on dolerite and least on wind-blown sand. The main divides (fig.2) run broadly north–south and east–west, partly on dolerite, partly on sandstone.

Most of the valleys have narrow floors with little development of flats adjacent to the streams. A few valleys have developed wide flats (fig. 2) adjacent to Norfolk Bay. Even where valley flats are developed they do not widen progressively downstream but have constrictions. The most notable example is Parsons Bay Creek with a main valley flat that terminates downstream at about 100 m a.s.l. (e.g. Benjafields Marsh) and narrow, short, discontinuous valley flats that terminate at 40 m and at 20 m. Cripps Creek also has a wide upland valley terminating at about 80 m a.s.l. On the geological information available the constrictions in the valley of Parsons Bay Creek could be Triassic sandstone beds and that in Cripps Creek a dolerite contact with sandstone upstream. One creek seems to have developed an alluvial cone, Norfolk Creek, with the cone forming Norfolk Point.

Inland Cliffs

Inland cliffs are rare and are low in height. They are mostly in Triassic sandstone and commonly have long, low caves developed at their bases. The caves are probably due to seepage along the interfaces of permeable and impermeable beds.

Upland Benches and Plateaux

One impression gained on viewing the Peninsula from the lookout point on the Arthur Highway is of a flat-topped ridge that drops from about 560 m a.s.l. at Tatnells Hill to about 440 m a.s.l. south of Cashs Lookout. This is an outlier of the Higher Coastal Surface of Davies (1959). It is noteworthy that Mount Fortescue, Mount Raoul, Mount Arthur and Mount Koonya all peak at 460–480 m and all are dolerite-capped.

The most extensive upland flat, clearly visible from the Safety Cove Road, is that of Fortescue Plains and their continuation south to Crescent Mount and beyond. Denmans Creek and several short coastal streams draining this flat steepen abruptly at about 120 m a.s.l. This flat is cut mainly in dolerite but also includes Permian sedimentary rocks. It may represent part of the Lower Coastal Surface of Davies (1959).

On many of the hills and ridges benches are present. The heights of the edges of such benches seem to be concentrated at about 100 ± 20 m, 200 ± 20 m and about 300 m a.s.l. The heights do not appear to vary systematically with geographic position nor to be related broadly to rock type. A series of 11 projected E–W sections across the peninsula at 2 km intervals (from 15N to 35N) showed concentrations around the heights noted above and also at 20 m a.s.l. It emphasised the low from Little Norfolk Bay to Port Arthur. The 20 m level may well be related to the Last Interglacial high sea level. The significance of these observations must remain unclear pending detailed study.

The Coastline

The eastern, southern and western coasts are spectacularly cliffed — part of the attraction and grandeur of the peninsula; the northern coast is much more gentle. The northern coast is partly erosional, partly depositional, the other coasts are very predominantly erosional. In general terms Tasman Peninsula forms part of a well-developed ria-type coastline.

Erosional Coastline

Wave attack on dolerite, mudstone and sandstone, which are cut at relatively close intervals by steeply-dipping joints, has produced steep high cliffs with outlying rock stacks, e.g. The Lanterns, and islands, e.g. Tasman Island, Wedge Island. Wave erosion by hydraulic action and abrasion along closely-spaced joints at a high angle to the coast has produced geos such as Devils Kitchen and the gulch next to Remarkable Cave, arches such as Tasmans Arch and at Tunnel Bay, and blowholes such as The Blowhole and Maingon Blowhole (692169). Development of The Blowhole was facilitated by the landward slope behind the cliffs (illustrated in David & Browne 1950, Vol. I, pl. 33A) related to a drowned river of which Blowhole Creek is the remnant.

Cliffs in dolerite differ from those in sedimentary rocks in lacking horizontal or gently sloping platforms at or close to sea level, features common at the base of cliffs in sandstone or mudstone. Sanders (1968) noted wave-washed planar joint surfaces sloping seaward at 45° in dolerite on the eastern side of Tasman Island and remarked that horizontal platforms do not occur on dolerite on the sheltered northwestern side of that island although they do on mudstone. The dolerite cliffs commonly continue smoothly to about -20 m, except for minor ledges dipping at about 45° (Sanders 1968), below which a slope of large angular blocks occurs (Sanders 1968, P. Last, pers. comm.). In contrast, areas of sedimentary rock commonly not only have an intertidal shore platform but submarine benches separated by steep cliffs of varying height (Sanders 1968, P. Last, pers. comm.). These differences probably reflect differences in susceptibility to marine erosion and suggest that the dolerite is so little susceptible to marine erosion that the coastal cliffs in that rock are essentially drowned escarpments developed during glacial low sea levels. Erosion since the sea reached its present level some 6000 years ago has barely affected the dolerite.

A feature noticeable in the cliff of Permian rocks along the eastern coast is the development of sea caves, cut in bedrock and sometimes floored by a veneer of rubble, at heights of a few metres to many metres above sea level. It seems likely that some of these developed at higher stands of sea level.

As noted above, shore platforms occur in the intertidal zone where sedimentary rocks are exposed, e.g. Pirates Bay, west of Haines Bight, Safety Cove, Norfolk Bay. Only between the Tessellated Pavement and Clydes Island have these been studied in detail (Sanders 1968 and authors). In this area there is a zone of wave-quarried joint blocks, some barely displaced, at the seaward edge of the platforms. To landward there follows a zone in which the joints are eroded by abrasion to depths of 30 to 50 mm more than the intervening rock, producing the appearance of closely packed loaves of bread (plate 1). A little further inland irregular depressions begin to appear in the surface of the joint blocks in zones parallel to and 10 to 30 mm from the joints. Progressively inland, these depressions coalesce to form grooves parallel to the joints with the top of the block overhanging the grooves and showing honeycomb weathering. The grooves widen as the top of the block narrows and lowers and finally the block develops a central depression (pan) defined by low ridges (rims) immediately adjacent to the joints.

Both the joint pattern and the rims around the pans were attributed by Hills *et al.* (1922, p.119) to the effects of a dolerite intrusion. However, the joint pattern is not that to be expected from contraction after heating. The rims, thought by Hills *et al.* to be due to hardening of the rock adjacent to the joint by limonite derived from iron-laden hot solutions derived from the host dolerite, are in places iron-rich (limonitic) but in others have little or no iron in them.

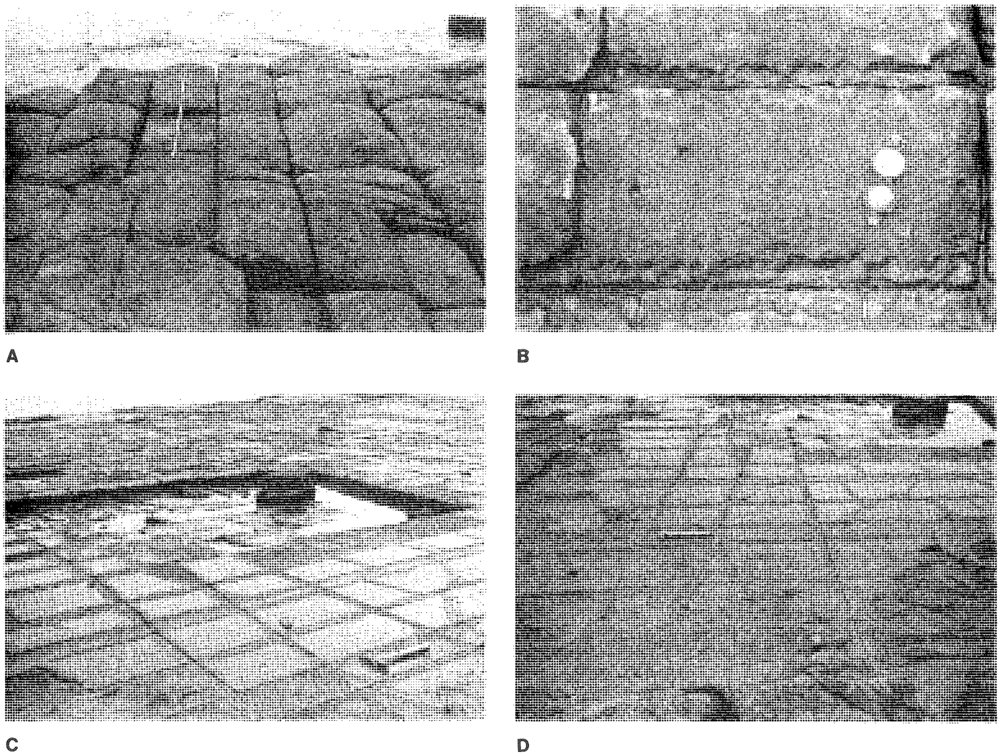

PLATE 1

(A) The seaward edge of the shore platform at the Tessellated Pavement showing quarried blocks and "loaf of bread" zone. (B) A joint block at the Tessellated Pavement showing the submarginal depression and honeycomb weathering due to salt crystallisation. (C) Part of the Tessellated Pavement showing the "pan" zone; the joint block has a central depression and raised rims. (D) A general view of the Tessellated Pavement showing the jointing.

All that is needed to produce the effects seen is penetration of saltwater into the joint blocks at high tide, both from above and from the joints, and evaporation of the salt water in the pores between the grains in the blocks at low tide leading to crystallisation of salt and the exertion on the grains in the rock of pressure by the growing salt crystals. The effects of crystallisation will be greatest at or near the limits of saltwater penetration into each block because evaporation will be most common there. The rock must have a permeability such that saltwater can penetrate into the joint block but not completely permeate it. Negligible permeability (e.g. dolerite) will preclude effective crystallisation, high permeability (e.g. some Triassic sandstones) will result in planation of the joint blocks without the production of rims. That the joints blocks at the Tessellated Pavement are somewhat permeable is shown by the presence of iron staining to depths of 10 to 30 mm from the joints in places. Biological, and possibly biochemical, processes have aided and accentuated the effects of salt crystallisation. This is essentially the process of water-level weathering of Wentworth (1938) and water-layer weathering of others (e.g. Hills 1971).

Depositional Coastline

Sandy beaches backing rippled shallow sand flats occur in many bays along the Norfolk Bay coast, the sand probably derived from the intervening sandstone headlands. They are less common elsewhere but occur at Pirates and Eaglehawk Bays, Fortescue Bay, Crescent Bay, Safety Cove, White Beach and Roaring Beach, mostly in areas protected by headlands or shallows from the predominant south-easterly swell. The source for the sand in these beaches is either sandstone or windblown sand in the catchment areas of streams debouching close to the beaches (e.g. Fortescue Bay) or sandstone outcrops along shorelines to seaward (e.g. White Beach) or upwind now or in the past (e.g. Eaglehawk Bay, Crescent Bay and Safety Cove). The source of the sand in the beach rimming Pirates Bay is not clear. Although thin beds of Permian sandstone crop out in cliffs around the Bay, they seem insufficient to supply the volume of sand needed. If granite crops out on the seafloor to the east, it may have been exposed at lower stands of sea level, and broken down to sand which was then transported west by marine or aeolian action. Yet another possible source is sand derived from sandstone outcrops along the southern side of what is now Norfolk Bay or the exposed floor of Norfolk Bay at a lower stand of sea level when during a glacial phase the climate was distinctly colder and drier and vegetation cover less. Such sand could then be blown east by wind funnelled along the depression now occupied by Eaglehawk Bay and deposited east of the divide at Eaglehawk Neck. The sand cover at the Neck is generally thin, down to about 2.5 m below sea level, but there is a narrow channel in bedrock beneath the sand down to -7.6 m (R.J. Lewis, pers. comm.).

Cobble beaches occur on exposed coasts e.g. Tunnel Bay, south of Northwest Head, between Fossil Island and The Blowhole, and in the gulch just south of The Blowhole. Cobbles occur as just submerged or just emerged shoals and spits, e.g. from the northern end of Wedge Island, north of Green Head and on the south side of Boat Harbour (Brill & Hale 1954, p.282).

Behind Safety Cove the flat interfluves rising to about 20 m a.s.l. represent the extensive floor of a bay of Last Interglacial age. The slopes west of the old bay floor have scree down to about 20 m. The old bay floor was dissected by streams during times of lowered sea level during the Last Glaciation. A swampy area and lagoon are now impounded in front of the Last Interglacial remnants by a Holocene frontal dune.

Submarine Topography

The most notable feature on the bathymetric map is the steepness of the sea floor adjacent to the coast, especially the east and south coasts. Over much of the length of these coasts the 20 m isobath lies less than 250 m offshore (slope 1:12.5) and almost everywhere less than 750 m (1:37.5). In most parts of the east and south coasts the slope is about 1 in 40 from 0 m to -80 m. Along the east coast the slope decreases markedly in water deeper than 80 m with average seafloor slopes of 1:500 in the north to 1:220 in the south, before sloping more steeply down to 150 m and then descending at rates as high as 1:8 to 300 m. Along the southern coast the breaks of slope are at 80 m and then at 130 m. Breaks of slope at -80 m and -130 m are probably within the range of glacially lowered sea levels. North and west of Cape Raoul the break of slope rises from the -60 m level off Cape Raoul to -20 m off North West Head. North of this Head slopes immediately offshore become flatter. A wide floor less than 10 m below sea level underlies the bay west of Sloping Main. Below the 10 m isobath the floor descends rapidly to -20 m before flattening out again. Norfolk Bay, on the other hand, has a wide flat floor (mainly mud) lying between -10 and -15 m, below which it slopes gently northwest down to -20 m.

Three areas of anomalous sea-floor morphology are revealed on bathymetric maps. North of Sloping Island and Green Head the dominant feature is Flinders Channel, a somewhat meandering depression with its head at -20 m east of Whitehouse Point, which reaches a depth of at least -42 m north of Sloping Island and terminates at -30 m just west of Sloping Island. It seems likely that this channel is a drowned river valley developed at a low stand of sea level and subsequently filled in its lower reaches by sediment driven northeasterly up Storm Bay by the predominant swell. A shallow bank sloping more gently to the southwest than to the northeast lies southwest of the end of Flinders Channel. A second depression is Port Arthur which reaches depths of 50 m but has a sill at -30 m. It seems likely that this too is a drowned river valley developed at a low sea-level stand and subsequently partly barred by sand driven northwestwards from Maingon Bay or Storm Bay under the influence of the dominant swell waves and/or sand driven by wind across the peninsula south of Safety Cove. Stream flow into Port Arthur is and seemingly has been too low to move the sand seaward. The bar at the mouth of Port Arthur is distinctly steeper to the north than to the south, supporting the idea of derivation from Maingon Bay. Another striking feature is a northeasterly trending depression in the seafloor about 12 km long and up to 2 km wide, dropping from about -150 m to below -200 m with the deepest point about 5 km ESE of Tasman Island. Neither seismic (Amoco Australia 1971) nor aeromagnetic traverses (Aeromagnetic Survey 1967) provide any obvious evidence of structural control of the depression. It may represent a submarine canyon developed just off the glacial age low sea-level mouth of a combined Derwent–Coal River system and it is noticeable that the 150 m isobath defines two low areas converging on a notch in the shelf edge at about 43°11'S. This canyon may later have been filled near the shelf edge by sediment moved down the -150 m channel from the north near the present shelf edge.

The general trend of submarine contours down to the break of slope is meridional off the east coast, latitudinal from Tasman Island to Cape Raoul, northwesterly to Outer North Head and northerly beyond that. A meridional trend is exhibited by (i) Wedge Island, (ii) the spur terminating in Cape Raoul, (iii) Dauntless Point and the submarine ridge descending from it on which Black Rock rests, (iv) the elongation of the submarine depression in Port Arthur, (v) Tasman Island and the submarine ridge of which it is the upward projection, (vi) a ridge rising from about -110 m to <80 m below sea level just northeast of Cape Pillar and (vii) the western margin of the bank below the Hippolyte Rocks which is steep (1:10), linear and meridional. It is possible that a meridional fault separates Hippolyte Rocks from The Lanterns and continues south to pass just east of Tasman Island. A distinct meridional notch cuts the shelf edge on the southerly projection of such a fault, just east of 148°E.

Evidence has been cited earlier which suggests both higher (up to +20 m) and lower (down to -80 m or even -130 m) stands of sea level in the past. Even the small feature, the Tessellated Pavement has a relic shore platform, probably of Interglacial age, immediately at the foot of the cliffs and about 1.4 m above the back of the modern platform. The seaward edge of the relic platform is being eroded (a high-tide cliff) and the modern cliff so produced is notched in places.

Aeolian Forms

Coastal foredunes occur at Eaglehawk Neck and along the southwestern side of Pirates Bay, at Crescent Bay, Safety Cove, Carnarvon Bay, Whites Beach, Roaring Beach, Sloping Main and Lagoon Beach. Lagoons have been impounded behind these (except those at Crescent Bay) and are now in varying stages of filling. The filled lagoons are being used for agricultural purposes in several instances. The dunes at the Arthur Highway–Blowhole Road junction and those at the eastern end of Roaring Beach show very deeply developed soil profiles and are of Pleistocene age.

Longitudinal dunes, including blowout dunes, occur in several places and seem generally to record northeasterly to northnortheasterly winds at some time in the recent geological past. A fine set of these occurs just east of Remarkable Cave and rests on Triassic sandstone and dolerite at about 20 m a.s.l. Several NNE trending dunes also occur on the ridge west of Mount Stewart. Derivation of these from sandy soils developed locally on Triassic sandstone is readily envisaged. High dunes trend NE behind Roaring Beach and can be readily derived from Roaring Beach. Dune forms are also present on the plateau southeast of Crescent Mountain at about 240 m a.s.l.

Aeolian sheet sands with dune forms occur on the hill slopes behind Salters Point and at and east of Mason Point on Eaglehawk Bay. Those along the shoreline at Eaglehawk Bay were produced from the sandy floor of Norfolk Bay during the Last Glacial low sea level.

A pit on the east side of the road from Safety Cove to Remarkable Cave shows multiple dunes stacked one above the other. The lowest sand dune has developed a very deep podzol, the next highest a thinner podzol, and the higher dune members have moved in the recent past.

A crescentic feature (concave to the west) occurs on the top of Cape Raoul at 200 m a.s.l. In form and air-photo texture it resembles a lunette but its composition has not been checked on the ground. It impounds a shallow lagoon behind it to the west and the lagoon and "dune" together give the impression of a lunette formed by westerly winds. It seems likely that some of the features associated with the westerly winds may be Last Glacial in age, while those with the northeasterly to northnortheasterly winds appear to be mainly post-Glacial in age and are in some cases still active.

THE NON-BIOGENIC NATURAL RESOURCES

The resources of the peninsula, in the production of which biological processes play little or no part, fall into two categories — mineral products and landforms.

Mineral Products

The mineral products of the peninsula include sand, clay, aggregate (metal), sandstone and coal; all commodities with low cost per unit of mass.

Small volumes of quartz sand derived from disintegration of Triassic sandstone or from accumulations of wind-blown sand are won in several places. Reserves of such material are at best moderate (Threader in Cromer *et al.* 1979).

Clay has been used in the past for brick-making and localised deposits are used as a source of craft materials. Threader (1976) commented on some of the deposits close to Port Arthur. Small accumulations of the clay mineral, dickite, occur as a result of weathering of Triassic siltstone near a dolerite contact (657219; east of Radnor Road; Cromer 1976a, p.3).

Aggregate is probably the most common mineral product. Dolerite and mudstone are used for this purpose — several quarries being in closely jointed dolerite close to igneous contacts with sandstone. Two large (>50 000, <200 000 m^3) deposits of dolerite gravel are frequently worked at Thorntons Hill (605292) and Newmans Creek (675286) (Threader in Cromer *et al.* 1979).

Sandstone used in construction of buildings at Port Arthur was probably derived from at least three quarries (those shown just west of Port Arthur, close to Palmers Lookout Road and behind Safety Cove; fig. 1). The sandstone in the northernmost of these, Plummers Quarry, has a high smectite and mixed layer clay content and does not withstand weathering satisfactorily (Sharples 1984). Stone from the Palmers Lookout Road quarry is better but has a low stone strength and is not suitable as a building stone. The sandstone from Safety Cove has a lower deleterious clay content than that from Plummers Quarry but has a low to very low dry point load strength. Sandstones for restoration work at Port Arthur are derived from beyond the peninsula.

Although coal outcrops attracted early attention to the area and Strzelecki (1842, p.193) provided a chemical analysis, the coal is too thin, too impure, and too restricted in area to be considered as an economic resource (Bacon 1983). Strzelecki (1842, p.193) noted the resemblance of the coal to anthracite and Hills *et al.* (1922, p.121) noted that the coal has been metamorphosed by dolerite.

More important probably than any of the above mineral products in the development or use of the peninsula is water. The groundwater resources are the subject of a separate paper in this volume (Matthews, pp. 25–31).

Landforms

Spectacular or unusual marine landforms in close proximity to one another provide a significant part of the tourist attraction of the peninsula. Similar forms to the Tessellated Pavement occur in southern New South Wales but the high dolerite columns are unique to Tasmania.

The landforms result from interaction between rocks with a few crucial properties and marine processes. They are spectacular because of the relief and diverse although close to one another. The relief, diversity and proximity result from the geological history.

The physical properties are permeability (in the case of the siltstones of the Tessellated Pavement), near-horizontal bedding and linear fractures in rocks of medium to high strength. Near-horizontal bedding provides the uniformity of rock-type needed for development of the Tessellated Pavement, controls the shape of the roof of The Blowhole and Tasmans Arch as well as the top limb of the silhouette which makes Remarkable Cave remarkable and gives visual interest to the vertical walls of Tasmans Arch and the Devils Kitchen. Linear fractures play a part in one or more of three ways. The high cliffs of dolerite, the numerous dolerite stacks around the coast, e.g. off Thumbs Point and The Lanterns, and stacks and islands of Permian rock, e.g. Clydes Island and Fossil Island, have developed as a result of erosion along elongate zones of closely-spaced vertical joints, or along vertical zones of shattered rock. Zones of closely-spaced vertical joints have also controlled the position of The Blowhole, Tasmans Arch, the Devils Kitchen and Remarkable Cave. The regularity of spacing of joints in joint sets, the linearity of some of those sets and the orderly geometric relationship of one joint set to others is the main source of wonder and curiosity at the Tessellated Pavement and adds interest to other shore platforms.

The relief of the land which allows the production of cliffs hundreds of metres high results from the presence of physically strong dolerite and Permian mudstone, uplift of the area (as well as much of Tasmania) over the last few tens of millions of years as well as a sea level which is lower than it would be were there no ice at the Poles. Some of the features, e.g. Tasmans Arch and the Devils Kitchen, may owe some of their height to initiation at higher stands of sea level during previous interglacial stages.

The proximity of the spectacular landforms, one to another, results from intrusion of dolerite into Permian and Triassic rocks some 165 million years ago, probably with contemporaneous faulting, and from later faulting.

The main marine processes operative in producing the landforms are abrasion and hydraulic pressure. These lead to notching and then undercutting of vertically jointed rocks producing steep cliffs, flanked in the case of Permian and to a lesser extent

Triassic rocks, by shore platforms. On the shore platforms salt crystallisation and biological activity produce the microtopography.

While suitable rocks are interacting with marine processes, existing spectacular and interesting landforms will persist or new ones develop. No immediate or short-term danger to these landforms is envisaged. Slow changes in sea level will have long-term effects.

One process, however, currently operative on the land surface, can be seen as a potential threat in the absence of planning. Wind has and is moving considerable quantities of sand and an abundant potential supply of sand exists, especially on the peninsula west of a line from Little Norfolk Bay to Port Arthur. Triassic sandstone crops out along the coast and is being eroded by wave action to produce sand. Some of this sand is washed up on to beaches where it becomes available for wind transport. Away from the sea, the sandstone produces a sandy soil, some of which finds its way into streams and so to the sea. Blowout of coastal dunes poses no immediate problem but removal of vegetational cover inland in the western part of the peninsula on any extensive scale could provide a source of sand for wind erosion, transport and deposition elsewhere on the peninsula.

SUMMARY AND CONCLUSIONS

After an observation by Matthew Flinders in 1798 on the dolerite columns which are such a spectacular feature of Tasman Peninsula, geological observations have been sporadic. The main concentrations of observations have been from about 1830 to 1845 when Port Arthur was a penal settlement and again in the last twenty years when the buildings at Port Arthur have been undergoing conservation and restoration. The Tessellated Pavement, a shore platform with remarkably regular joint patterns, has attracted international interest because of the jointing and the marine processes leading to its sculpturing.

The peninsula consists of flat-lying Permian and Triassic rocks resting in places on a granite-injected basement and intruded by dykes, sheets and sills of Jurassic dolerite with concomitant faulting. High-level aeromagnetic and reconnaissance gravity surveys suggest a meridional dolerite feeder beneath the central part of the peninsula. Post-Jurassic faulting is likely to have occurred and there were basaltic eruptions in the western part of the peninsula in the Tertiary.

The main geomorphic processes affecting the area are erosion and deposition by short, relatively simple stream systems, many of them also steep. Relief is up to about 500 m. Marine processes, erosion along exposed coasts and deposition along the protected north coast, are important in producing the main features of scenic interest, shore platforms, blowholes, tunnels, arches, stacks and high, steep cliffs. Aeolian deposition of sand has been important in the past but is of minor significance now. Care should be taken to minimise aeolian transport and deposition of sand in the future.

Although there has been some coal mining on the peninsula it ceased more than 100 years ago and is unlikely to recur. Other mineral products — sand, gravel, clay, sandstone — are of minor significance now and are unlikely to be a source of significant employment or income in the foreseeable future. The marine landforms noted above provide a tourist attraction and will probably be self-renewing far into the future. They are likely to be more important as income-producers than the mineral products. They should be a continuing source of aesthetic stimulation and satisfaction — a valuable complement to the human artefacts.

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