THE GEOMORPHOLOGY OF THE CAPE HAMELIN COASTAL LIMESTONES AND SAND DUNES, WA

T.D. Bain, 1962:
Western Australian Speleological Group, Journal. **1962:** pp.18-28.

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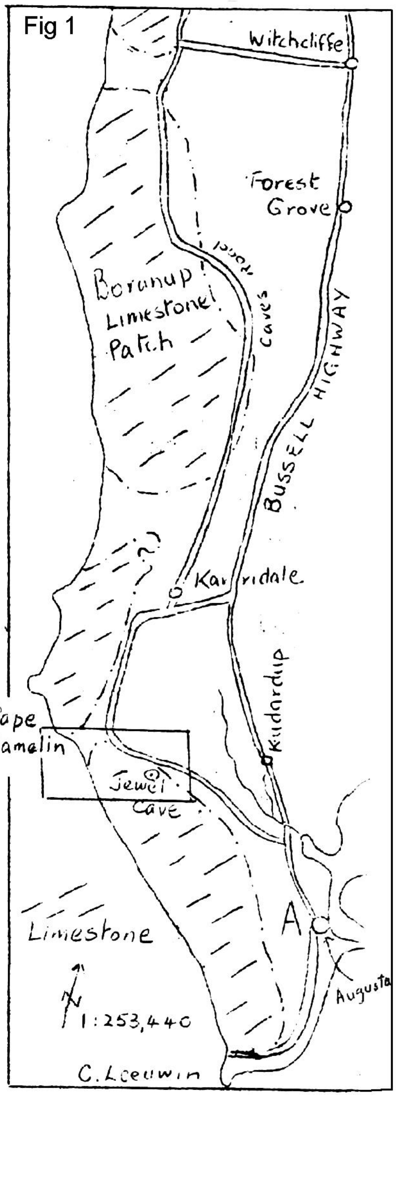
Introduction

The area under study lies immediately inland from Cape Hamelin and includes Deepdene, the Augusta jewel Cave and the Cape Hamelin Sand Patch. (See Fig. 1)

Climate:

Lying as it does, in the exceptionally humid Mediterranean type climate, the district receives a high annual rainfall in the long winter season and experiences a short summer drought. The Southwest as a whole receives an annual average of about 33 inches of rain. Representative figures being: Cape Naturaliste 33"; Margaret River 46"; Karridale 48"; Kudardup 47"; Augusta 37"; and Cape Leeuwin 39". The southern edge of the Naturaliste-Leeuwin Ridge receives above average rains. Run-off is thus comparatively greater than in other sections of the coastal plain, there being, (a) more precipitation, and (b) less evaporation due to milder temperatures. During the winter, the region receives as. much as a seven inch water surplus.



Pronounced seasonal rainfall changes (both Leeuwin and Karridale receive 80% of their total annual average rainfall in the 6 months, April-September) are accompanied by wide variations in soil water regimes (Smith, 1951). The amount of run-off reaches its peak in winter and the shallow soil water tables reach to the surface in many areas, particularly in the low, swampy ground east of the coastal limestone belt. In summer, however, these shallow water tables all but disappear.

Soils:

The soils of the district vary from brown soils formed on recent exposures of Pre-Cambrian granites to soils associated with Pleistocene dunes. The dominant soil of the latter consists of two associations (Smith, 1951).

(a) ***The Leeuwin Association*** soils consist of deep, calcareous sands occupying the undulating slopes of the

New Dunes. These New Dunes retain their sharp crests and steep slopes in their original vigorous form while Limestone is characterised by less vigour of topographic form and by a greater maturity in soil profile. Occasionally may be found outcrops of consolidated limestone in the top soil. These outcrops have been laid bare when wind action has scoured the New Dunes. The dominant vegetation of the Leeuwin Association soils is heath scrub with peppermints (*Agonis flexuosa*) and blackboys (*Zanthorroea preissi*).

(b) ***The Deepdene Association*** soils consist mainly of deep brown sands overlying coastal limestone on the leeward slopes of the New Dunes. The vegetation is heavy secondary growth and karri (*Eucalyptus diversicolor*).

Fossil soil profiles have been found both along the coast and in caves. Fairbridge and Teichert (1953) report the presence of fossil soils at Hamelin Bay where they average 1-3 feet in thickness. They report a fine-grained soil lacking stratification and with a soft, "earthy" feel. These fossil soils alternated with dune formation during the Pleistocene. Numerous bands of fossil soils (either rendzinas or terra rossa) are also found in quite a number of caves in the South-west. Unfortunately, these occurrences have not been scientifically investigated and surveyed with a view to establishing a correlation with Quaternary climates and limestone formation.

Geology and Landforms

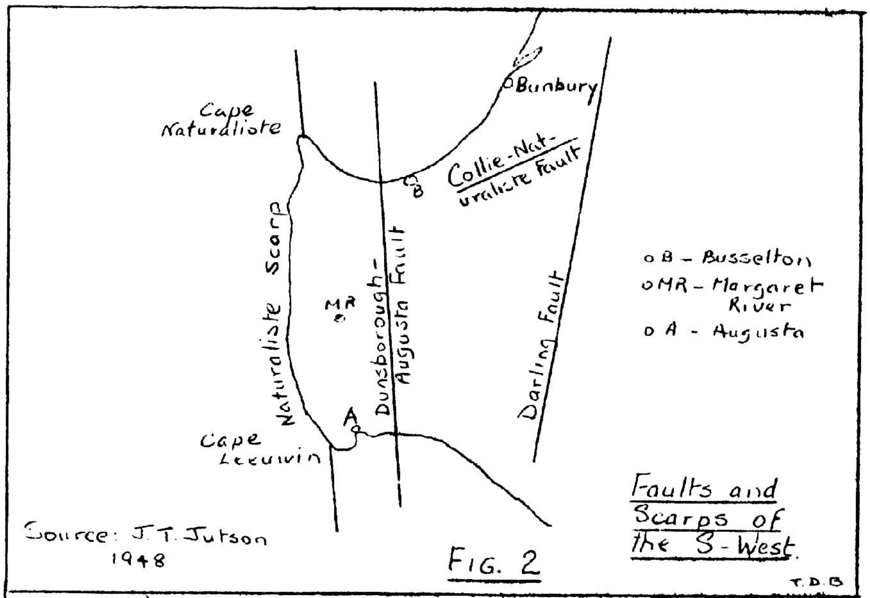
The Cape Hamelin region lies at the southern end of the Naturaliste-Leeuwin horst which is bounded on the west by Saint-Smith's step fault, and on the east by the rift valley between the Dunsborough-Augusta Scarp and the Darling Fault scarp (See Fig. 2). The ridge is made up of hard, crystalline Pre-Cambrian granites, granite-gneiss and allied rocks and is overlain on the west by the Limestone and New Dunes of the Pleistocene. These dunes have been blown over the basement rocks to heights of over 700 feet and consist of consolidated limestone underlying the geologically more recent sand drifts. In places the basement complex is overlain by patches of lateritic soils.

The coastal limestone, part of the Geraldton-Albany belt is not continuous; it is broken in parts by perennial streams such as Margaret River, Turner Brook and Cowaramup Brook. Turner Brook lies within the area under discussion. It is a perennial stream that flows due south to reach the sea one and a half miles south-east of Cape Hamelin. Having its source in the low swampy undulating granite and laterite, it flows past the limestone cliffs at Deepdene to meander through the dunes before entering the sea. The dunes become more pronounced and have a NNW-SSE longitudinal axis and an almost W-E movement axial trend.

The topography of the Cape Hamelin region reveals three distinct landscapes. These are the New Dunes, the Coastal limestone and the granite. The last of these occupies but a small section so we will concentrate on the morphology of the New Dunes and coastal limestone.

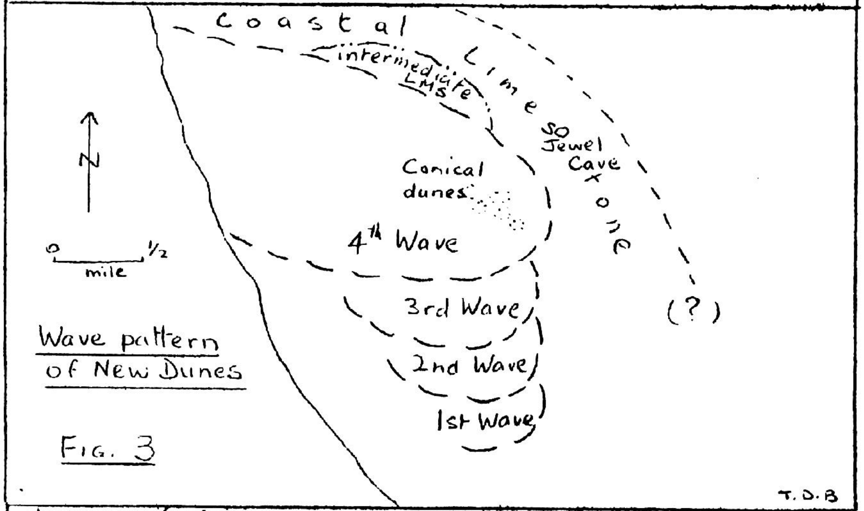
The New Dunes:

The Cape Hamelin Sand patch extends from Cape Hamelin and covers an area of about 6 square miles. Rising to over 400 feet, the New Dunes retain their sharp crests and steep slopes. They are practically fixed by vegetation but not entirely so close to the shoreline. On the gentler slopes (particularly near the crests) scrubby plants have got a firm hold with roots going down 18-30 inches and already beginning to form a substantial topsoil. On the steeper slopes and in certain wind channels the dunes are still bare.



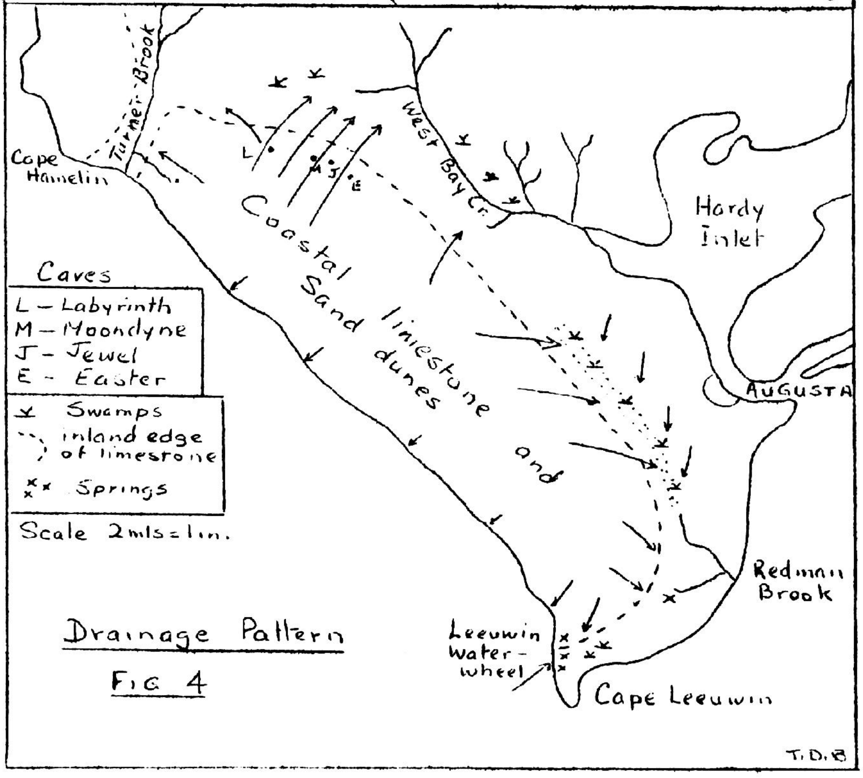
Faults and Scarps of the S-West

FIG. 2



Wave pattern of New Dunes

FIG. 3



Drainage Pattern

FIG 4

Three or four "waves" may be distinguished in the Sand Patch. They may be seen to overlap each other, particularly in the south-eastern section of the patch (See Fig. 3). This could indicate several maxima of dune formation of differing intensity. The foredunes lie parallel to the coast and would appear to have a SW-NE axial trend. Too much emphasis cannot be laid on prevailing wind directions deduced from dune alignment because the South-west of Western Australia lies in the variable wind belt. Vegetation has fixed the foredunes to a certain extent though they still appear capable of some movement. Further inland, the dunes have been firmly fixed with a parkland vegetation consisting mainly of grassy heath, blackboys and peppermints.

The coastal limestone:

This belt consists of the oldest Pleistocene deposits which were laid down during the Wurm glacials and inter-glacials. The chief characteristics of the aeolianite are less vigour of topographic form, a greater maturity in soil profile, numerous hard, jagged, amazingly sharp limestone outcrops which are extensively eroded under high rainfall conditions, very heavy vegetation - mainly karri and secondary undergrowth, and the presence of numerous caves and depressions with a semblance of karst topography.

It has been estimated (Bastian 1960) that the water table is between 100 and 150 feet from the surface in the vicinity of the Jewel Cave. Within our area, the aeolianite is gently undulating and varies no more than 50-80 feet in height between highest and lowest surface levels. Few known caves reach the water table; Jewel (134 ft), Moondyne (100 ft), Easter (135 ft) and The Labyrinth (90 ft) have developed as far as the water table. Other caves do not (or have not been found to) reach the water table.

The limestone is extremely hard in the "caprock" zone and presents a smooth, greyish appearance when newly cut. Its granular origin is then clearly seen. Many of the caves have huge surface collapses and these present striking morphological features (especially in bush walking after dark!). Some of these collapses are of considerable size. Skull Cave is up to 20 feet across at its widest, while Bride's Cave and Lake Cave in the Witchcliffe region are far larger.

A. Montgomery (1903) believed that the distinct stratification of the coastal limestone was too regular to be the result of wind action. He considered that it was laid down in large, shallow lagoons and offers as evidence of their marine origin, the presence of heavy shells and coarse conglomerate too heavy to have been moved by the wind. However, the presence of drift-bedding makes the aeolian origin of the lime and sandstones quite apparent. Cross-bedding has been caused by temporary shifts in the prevailing wind. Montgomery argues that marine deposition would result in hardening and subsequent uplift. Bastian, in a paper published elsewhere in this Journal, believes that cave formation is synonymous with the consolidation of sand into limestone and that this occurred above sea level as the dune underground streams must have flowed towards base level.

Simpson, Fairbridge, Teichert, Woodward and Blatchford all recognise the aeolian character of the coastal limestone and see them as hardened dunes.

The calcareous matter consists of considerable amounts of shell fragments and foraminiferal tests plus minor clastic detritus. This has become cemented together with calcium carbonate by the permeating action of meteoric water. The coastal limestone is believed to have been formed during the late Pleistocene. Dunes may be built up either during emergence or submergence. If the sea level falls and the coast emerges, the dunes would tend to be left behind while if the sea rises to submerge the coast they would be driven forward to the maximum limit of the sea's advance. The emergence of a coast would result in a succession of dune ridges each in turn being the foredune.

In my opinion the Cape Hameln Sand Patch (and others like it) has been brought about by emerging shoreline conditions. When glaciation caused repeated lowering of sea level to as much as 200 feet below present sea level, large expances of calcareous sands on the sea bed were blown by onshore winds into belts of dunes. The fine sand seems to have reached to as much as 700 feet above present sea level. It may be noted here that conditions need not have been particularly arid as it is not so much the aridity as the absence of vegetation which induces dunes. During glaciation the enlargement of the Antarctic Ice Cap would have driven the westerly wind belt equatorwards with the result that the South-west would have come under its influence all the year round, instead of only in winter as at present. This would have increased rainfall and consequently induced a greater growth of vegetation.

Given the right physiographical, geological and climatic conditions, we can now interpret a cycle of dune formation. Starting with the exposure of the sea bed, we have the formation of calcareous dunes under the influence of prevailing winds. These become fixed, followed by the development of soils. Partial or total destruction of vegetation would result in a renewal of dune movement. Ultimately, a gradual consolidation into coastal limestone occurred. Note that summer dessication would hasten capillary action so forming caprpck which will seal of the rest of the dune. However, if a rain-all-the-year-round climate is postulated, as during a glacial maxima, then consolidation would be hastened as capillary action would be reduced.

Caves

The first point to note about caves in coastal limestone is that they have not been formed by the enlargement of joints and fissures for these are absent from aeolianite. Massive limestone is extremely impervious to water; water movements are essentially through secondary porosity - joints and fissures. The caprock on parts of our coastal limestone is very massive, yet shafts are known to breach it and lead to extensive systems of caves (e.g. The Labyrinth). One can therelore postulate cave formation either <u>before</u> caprock formation, or <u>after</u> through some agency other than jointing, or even <u>simultaneously</u> with caprock formation. This last idea is currently being developed by Bastian and others.

A second point to note is the comparatively large sizes of our caves. Our coastal limestone is tentatively labelled the "Third Aeolianite" with an absolute chronology of 40,000 years (Fairbridge & Teichert, 1953). Two earlier aeolianites are recognised in the vicinity of Perth with an aboslute chronology of 130,000 years. The South-west coastal limestones rest on the Cowaramup Conglomerate (in places) which an turn rests on Pre-Cambrian rocks. Earlier aeolianites may thus lie buried inland or out on the continental shelf. Thus, being young in geological time, our south-west caves contain the anomoly of large caverns. In many caves the sand of walls and roofs is barely coherent and large handfuls can be scratched out. It is this phenomenal growth of caverns plus the large amounts of sand which indicate that the caves have been formed in consolidating dunes. The mechanism of simultaneous consolidation and dissolution under conditions of controlled precipitation has been worked out by Lex Bastian in his article on Cave Origins which appears elsewhere in this Journal.

A third point to note is that there are no examples of streams entering any of the holes and depressions on the limestone. The engulfing sand dunes would have overr ridden the

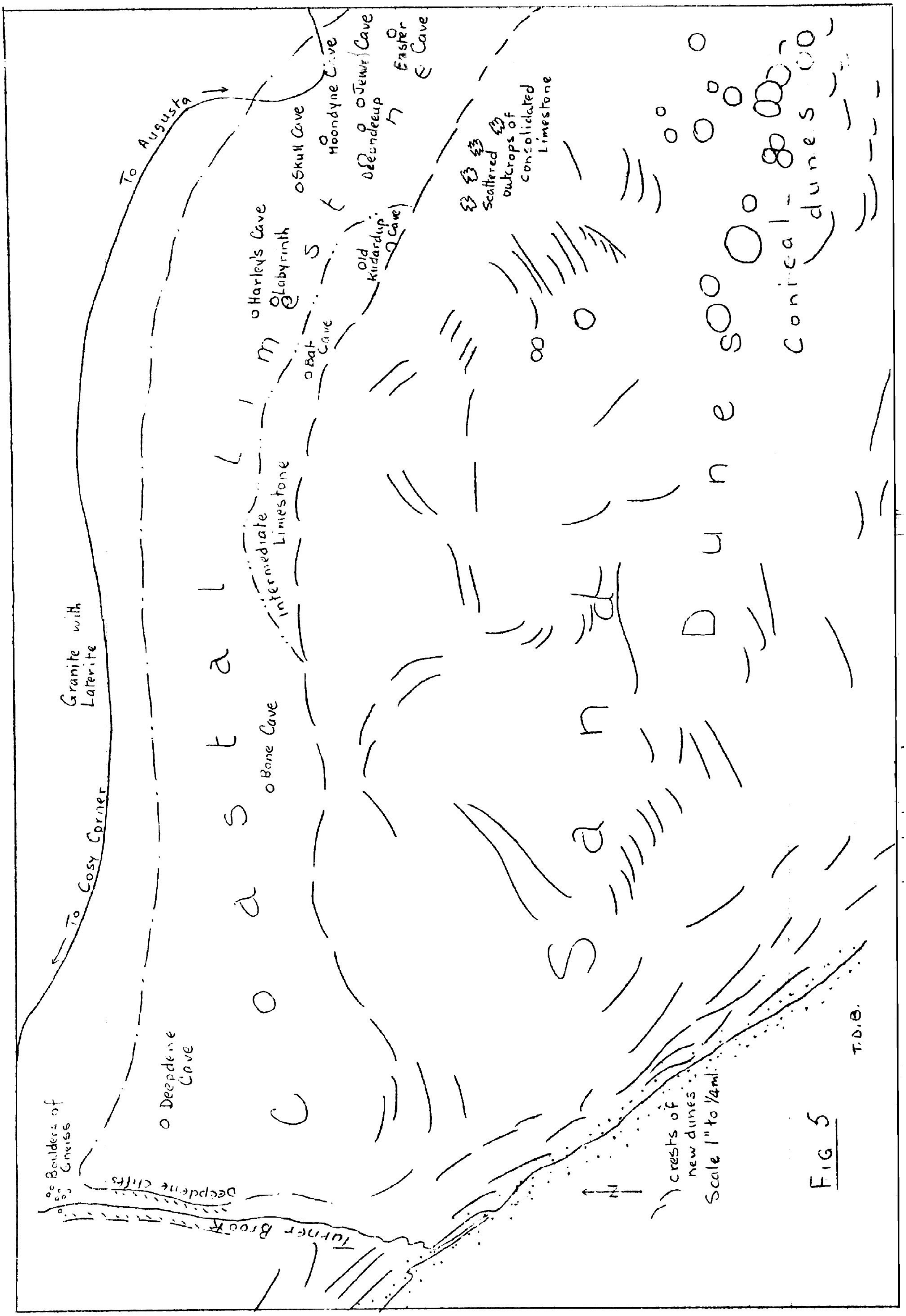

To Augusta
Skull Cave
Moondyne Cave
Jewel Cave
Easter Cave
Deeundeeup
Harley's Cave
Labyrinth
Old Kudardup Cave
Bat Cave
Scattered outcrops of consolidated Limestone
Conical dunes
Coastal Limestone
Intermediate Limestone
Sand Dunes
Granite with Laterite
Bone Cave
To Cosy Corner
Deepdene Cave
Boulders of Gneiss
Deepdene cliffs
Turner Brook
N
crests of new dunes
Scale 1" to 1/4 ml
T.D.B.

Fig 5

existing drainage pattern of the initial topography. Perennial streams would have kept their beds clear of sand, but only strong seasonal streams would have been able to maintain some sort of course throught the dunes along their old valleys. This exhuming of old valleys appears to have been done by both the Mammoth Cave stream and Rudduck's Swamp Cave stream. Both these caves occur at the north- eastern edge of the Boranup limestone patch. The initial arainage pattern in the Jewel Cave region appears to have been outwards from a ridge running from near Cape Hamelin towards Cape Leauwin. This ridge is overlain by limestone and sand dunes, the Jewel Cave and others lying on the north-east flank but on a slope draining towards the north-east (towards the swamps of West Bay Creek).

A glance at Fig. 4 will show how the drainage pattern of the Jewell ave, Moondyne Cave, Easter Cave and The Labyrinth is towards the north-east. The Labyrinth has a north-west trend as well. Few streams enter the sea between Hamelin and Leeuwin, the most noticeable being the stream which supplies the Leeuwin Waterwheel. This stream, and a few others in the vicinity, emerge at the junction of the limestone and granite.

Established caves here collect drainage to themselves. Some caves contain the water table, which is either stagnant or moving very slowly. It is to be assumed that the water table is higher under the New Dunes and that there will be slow movement towards the lower coastal limestone. None of the four caves with water table lakes have flowing vadose streams. Yet, it is clear from an examination of cave walls and roofs and formations, that there has been considerable variation in water table height. This fluctuation apart from being seasonal could also be part of a cycle of many years and consequently could have an important bearing on cave origins.

Within the Cape Hamelin region, the caves are concentrated in a narrow fringe from near Deepdene Cliffs to Easter Cave almost 2½ miles away (See Fig. 5). The exposed limestone is very limited in extent being only half a mile in width between the New Dunes and the granite. In the vicinity of Bat Cave and the Old Kudardup Cave may be recognised an intermediate limestone which is exposed to high rainfall erosion. The hilly nature of this limestone is contrasted by the gently undulating main limestone in which are found the majority of the caves. Both Bat Cave and the Old Kudardup Cave are situated right up against the New Dunes which fall onto the limestone at angles of up to 30˚. Both are fairly deep, Bat Cave Showing a small surface collapse but with a predominantly vertical development. The Old Kudardup Cave contains an immense chamber with a sandy floor.

The extremely thick vegetation of the limestone belt makes the finding and establishing of caves difficult. Known deep and extensive caves in this belt are Jewel, Moondyne, Easter, Deeondeeup and Labyrinth all of which occur in an area of 1000 by 100 yards. The systems that have been developed are very complex and have been found to be interconnected in some cases. None of them shows linear development in the manner of Strong's Cave or Rudduck's Swamp Cave and this indicates extensive water table development. Skull Cave does not reach depth and is probably blocked off from the water table. The entrances to Jewel, Easter, Deeondeeup and The Labyrinth are all narrow shafts ranging up to 40 ft in length. Caprock is evident in them. These four, together with Moondyne, reveal extensive development of secondary decoration, this being a feature of many caves in the high rainfall regions. Strong's, Crystal, Nannup in the Karridale region and Lake, Mammoth and Calgardup in the Witchcliffe region are further instances of this correlation.

The lack of fossils, except for the occasional one, is a feature of the major caves with their small entrances. Skull Cave ana Harley's Cave, in both of which David Cook has done considerable work, are veritable graveyards of animals because they have large entrances which make it difficult for trapped animals to escape.

A spectacular feature of this region are the Deepdene Cliffs which rise to over 200 feet. They form a gorge through which Turner Brook has cut. The collapsed cavern theory is, in my opinion, untenable. For one thing the west wall is nowhere as precipitous or as regular as the east. Turner Brook appears to have been strong enough to have kept its bed reasonably clear of sand. At the north end of the gorge it runs over gneiss. The dunes could have been built up on either side of the stream which cut laterally into the hardening dunes, continually undermining them. Mass wastage would have contributed. Alternatively, the river could have cut downwards through a period of slow local uplift. Jennings (1957) describes how "major streams in King Island, Tas., have successfully maintained their flow through encroaching dune belts perhaps because of their steady regimes; this combines with the building up of the dunes to produce narrow, steep-walled valleys through the coastal dune belt as much as two miles long and more than 200 feet in depth". I leave the question to another day.

TERENCE BAIN

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