2. GEOLOGY AND GEOMORPHOLOGY

2.1. South-west of Western Australia

2.1.1. Coastal Limestone

The coastal limestone is believed to have formed 100,000 to 500,000 years ago. At that time, extensive glaciations caused the lowering of the sea level as much as 60 metres below present levels. The south-west of W.A. is one of the windiest sections of temperate coastline in the world. The high wind and wave energy results in a fast flux of sand-sized particles from the sea to the beaches to the active dune belts beyond. These particles are mainly calcareous and of biological origin, viz. mainly mollusc shell fragments of the calcareous red algae, and the microscopic skeletons of Foraminifera. Other particles are derived from the erosion of the basement rocks and the reworking of soils. These are mainly quartz in the Leeuwin Naturaliste Ridge, with some feldspars, garnets and heavy minerals.

This sand, over several incursions inland, blew into large dunes up to 200 metres above sea level. These dunes became stabilised by vegetation and the contemporaneous processes of soil formation, lithification and karstification began to occur. The lithification or solidification of the dunes is caused by rainwater, during the wet season, dissolving out part of the carbonate of lime which is then carried downwards to the watertable or the gneiss basement. During the dry season, reprecipitation of this carbonate of lime produced a very hard cap rock near the surface, with less well- cemented limestone below, and a leached quartz sand above. With time, the quartz sand developed into mature soils ranging from humic loams to terra rosas with ferricrete. These processes continue to the present.

One factor important to the development of caves in this area is the ease with which the northward-migrating dune belts helped by prevailing winds threw barriers of dune sand over the courses and valleys of small streams which lacked the flow of water in summer necessary to resist the encroaching sand. More perennial steams such as Turner Brook modified the dunes to form gorges of construction (Jennings, 1968).

North of Perth, even very large rivers (for example, the 160 km long Arrowsmith River) are very seasonal in their flow and could be blocked by the encroaching dunes. This has resulted in some very large streams sinking and forming large cave systems, for example, the river entering the Stockyard Gully system has been measured at 40 cusecs.

The streams whose downstream courses had been crossed by the dune belts would continue to flow through the porous dunes along their old courses, though some ponding would produce swamps. These vegetation-choked swamps would, with time play an important role in contributing to the aggressiveness of the stream waters.

When the dune belt solidified into limestone, a cavity could form above the stream. This cavity was widened and undercut by the stream until it became too wide for the roof to support the weight of limestone above. At this stage a collapse occurred producing a collapse dome or in some cases the collapse followed lines of weakness such as dune bedding or soil horizons. The weakness of the coastal limestone results in a preponderance of collapse forms, both doline and cave passage, often of considerable size. While the dune was solidifying, tree roots going deep within the sand would act as conduits for the flow of percolation water. Sand around these roots would not lithify, leaving a tube of loose sand through the solid rock. If a collapsing cave intersected such a tube, the sand plus some surface soil would fall into the cave producing a soil cone and a shaft or solution pipe. Many caves are entered by such pipes.

As the coastal limestone consists of sand grains cemented together, water can move downwards between the grains whereas with impermeable crystalline limestones this percolation is restricted to the joints. Thus, straws, stalactites, etc., can occur over the whole roof of a cave, and the preponderance of small pores favours the formation of helictites. The minimal role played by joints (if any) in downward percolation of water disfavours the formation of rimstones, as concentrated flows of such waters are rare. The sloping roofs reflecting dune bedding favour the formation of shawls of which there are many fine examples.

North of Perth stalagmites are more common and obvious. A suggestion (Dick Van der Roest, pers. comm.) is that a temperature gradient between roof and floor may be responsible in these shallow caves below a sparsely vegetated hot surface.

The common occurrence of sand grains in the caves, derived from soils and stream dissolution of calcarenite, favours the formation of oolites. The complete life history of an oolite nest from initiation to final cementation has been observed over a 20 year span in the Easter Cave dig.

Asphodelites, a peculiar flower-like splatter formation formed on cave floors by very saturated drip waters, have been described from Calgardup, Blackboy Hollow and Deepdene Caves by Bridge (1972).

Halite exudation which plays a very important role in the Nullarbor caves is of less importance in the south-west but forms undercuts in seaward facing gorges and peels the 'skin' off stalagmites in Quinninup Lake Cave.

Extensive moonmilk forms are common around entrances in coastal limestone caves. This is the combined result of the multiplicity of percolation pores and the seasonal wetting and drying of this area of the cave. In the north where the climate is more seasonal, the zone of wetting and drying is more extensive.

The rocks underlying the limestone affect drainage patterns and hence the mode of formation of caves. The Leeuwin Naturaliste limestones are underlain by Granite - gneisses and Granulites at least 660 million years old. Streams are swiftly flowing and confined more or less to their gneissic river valleys. In contrast, the limestones of the Swan Coastal Plain overlie softer Tertiary sediments and in most cases this contact is below local watertable levels. Streams are thus not confined to valleys, complicated hydrological systems past and present result from collapse diversion of cave streams.

Surface karst forms are rare, being precluded by soil cover and lithology. Linear karren are rare in poorly cemented calcarenites, but in some indurated cap rocks, small sections of rillen-karren occur, for example, Yallingup Cave entrance. Splash and rain-pitted karren are common on exposures, especially near the sea. At the slope of the younger Augusta limestone onto the older, and on remnants of similar limestone in northern Witchcliffe, areas of karst pavement with local runoff pipes occur. Extensive karst pavements occur in the Eneabba area.

2.2. Geology and Geomorphology of the Leeuwin-Naturaliste

The Leeuwin Naturaliste Ridge coastal limestones stretch for 80 kms atop a ridge of Granite-Gneiss and Granulites which show considerable local variations in relief for W.A. The cave areas in this ridge, from south to north, are Augusta, Witchcliffe, Margaret River, Cowaramup and Yallingup.

The Witchcliffe area and the three areas north of it are typified by stream cave systems whereas the Augusta area is typified by shallow nothe-phreatic maze caves. Recent extensive mapping, some geomorphological and geological interpretation and the beginnings of a hydrological investigation have given rise to a fairly complex (but tenable) hypothesis for the formation of the Augusta caves which further work shall put to the test.

Witchcliffe cave streams drain swamps. Further north, the basement has a greater relief and catchments and streams are smaller. Hence active streams are rarer and inclined fissure caves are more common.

2.3. History of the Leeuwin-Naturaliste

Between Cape Naturaliste and Cape Leeuwin lies a belt of dune limestone some 80 kms long and 7 kms wide at the maximum, intersected only in places by various streams, rivers and certain geological features such as the Boranup Sand Patch. In this area can be found more than 300 speleological features and caves.

Over a period of more than 100 years, this area has been explored and surveyed by numerous groups of early settlers and surveyors and later, in the last 30 years, by members of the Western Australian Speleological and Speleological Research Groups.

The earliest reports on exploration of caves were mentioned in a report in the newspaper The Inquirer dated 1848 by a Mr Turner of Augusta, giving a detailed description of some caves explored in the area near Augusta. One such cave could possibly be the Old Kudardup Cave which has an excellent display of historical cave graffiti on it's formation. During the 1880's and 1890's more major caves were discovered when the forest was cleared by the M.C. Davies Timber Co. and also by the Bussells who were early settlers in the district. Caves in these areas have also been found to contain the names of early settlers written on the formation.

The turn of the century saw the establishment of the Caves Board by J.W. Hackett for the purpose of managing the caves for tourism. Between 1901 and 1914 more than 14 caves were developed for tourism and recreation and several other caves were partly developed but were never opened. The first caves in the south-west to be developed with electric lighting were Yallingup cave in 1903 and later Northcote Grotto in 1905, while the caves in the Margaret River area were still being lit with magnesium lamps.

The government commissioned Marmaduke Terry in 1900 to survey all speleological features above ground between Yallingup and Augusta. This above ground survey is the basis for the W.A.S.G. Cave Lists in the south-west today. Later in 1902, Yallingup Cave was also surveyed by Terry and a proposal for a shaft to a cave in Yallingup Gorge was put forward but later this plan was abandoned.

During the years 1907 to 1909 the Caves Board promoted an extensive advertising campaign with lectures and slides and printed pamphlets of a descriptive nature. These were sent to tourist centres throughout the world advertising the caves of the south-west.

In 1910 the Caves Board was partly abolished and in 1914 it was fully integrated into the Licence and Liquor Board which was in control of the state's hotels. Many of the tourist caves became neglected and although the caretaker of the caves, Tim Connolly, appealed for money for repairs, it was denied.

For two decades from 1920 onwards, many of the installations in the tourist caves were neglected and slowly disintegrated or were damaged by vandals or bush fires.

Two events were important in this period. Lake Cave flooded in 1924. This required the contracting of mining engineers to construct a shaft to drain off the flood water so that the cave could again be opened for tourism.

In 1928 visits to the caves had reached over 2000 people per year. In 1936 a huge bushfire swept through the caves reserve, burning and destroying most of the entrance ladders to Bride's Cave forcing the closure of this cave to possible use by the public.

From the early 1930's to 1950, much caving and exploring was done by Ruddock, including the entering of the downstream section of Strong's Cave in 1938. By the 1950's only five caves were open to the public, of which three are still open today.

Cavers exploring in the Augusta area in the late 1950's discovered the majestic Jewel Cave system which has over 3 kms of passageways. This cave was developed for tourism and opened to the public in 1959 by Sir David Brand, thus closing Moondyne Cave nearby.

Around this time, the same small group of cavers, discovered major extensions in nearby Easter Cave. This small group were to form the nucleus of W.A.S.G. the formation of which, these discoveries helped promote. In 1960 members of W.A.S.G. discovered and explored Labyrinth Cave. This gave rise to increasing activity by cavers and W.A.S.G. went from strength to strength, with the discovery of Strong's Cave in 1960 and the Christmas Star extension in Crystal Cave in 1968.

In the next decade, major finds included Terry Cave, Winjans, Boya Booka, Beenup and many more. Major extensions were found in Easter Cave, including the CEGSA extension found in 1976 during the survey of this extensive system. Easter Cave now totals 7.5kms of phreatic passageway.