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Karst Geomorphology

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KARST OF THE CAINOZOIC LIMESTONES OF THE OTWAY BASIN,  
SOUTHEASTERN AUSTRALIA

**ABSTRACT:** WHITE S., *Karst of the Cainozoic Limestones of the Otway Basin, Southeastern Australia*. (IT ISSN 0391-9838, 1998).

The Tertiary and Quaternary limestones of the Otway Basin in south western Victoria and south eastern South Australia include Miocene and Oligocene marine limestones and Pleistocene calcareous dune and beach facies. These highly variable limestones of high primary porosity and high permeability show diverse karst features both in surface expression and underground, presenting particular problems with regards to the usual concepts of speleogenesis. Although there have been some studies of karst development in the Cainozoic limestones (White 1994, Grimes 1994), these are generally of small areas (less than 100 km<sup>2</sup>) and show some interesting contrasts in features. The Otway Basin is a large karst area where there is the potential to understand the regional patterns of karst development in particular the times taken for karstification in Pleistocene calcareous dunes.

Karst development shows substantial variation across the Otway Basin and between the different limestone lithologies. The karst shows important differences in the number and type of cave present per volume of limestone, total passage length, passage orientation, passage size, and cave form. Substantial differences in other karst features are also evident such as the presence of the distinctive cenotes and other surficial features in some areas and yet their complete absence in otherwise similar sites.

Although environmental factors such as relief and climate do not vary greatly across the basin, there are significant changes in lithology, structure and underground water conditions. The variation in karst features can be explained partly by lithological variation; especially in such highly variable karst host rock. The overall regional view can add some important insights into concepts of speleogenesis.

**KEY WORDS:** Karst Geomorphology, Speleogenesis, Otway Basin, Australia.

INTRODUCTION

The Otway Basin in south western Victoria and south eastern South Australia (fig. 1) includes Miocene and Oli-

gocene marine limestones and Pleistocene calcareous dune and beach facies. Both these limestones are generally poorly lithified and their responses to karst forming processes, despite some strong similarities are not identical. The limestones vary in texture and lithology. Just as not all massive limestones are equally soluble, a similar situation exists with poorly consolidated limestones. Soluble rocks must not only be soluble but have sufficient strength to support the cavities produced by such solution.

LITHOLOGIES

The Tertiary marine limestones are generally horizontally bedded, well sorted fine to medium grained bioclastic



FIG. 1 - Location of the Otway Basin.

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carbonate sandstones of variable purity and cementation. They were deposited in shallow marine environments during the Oligocene and early Miocene and are extensive across the basin. More than one geological formation is calcareous (Kenley, 1971). Fig. 2 shows the main limits of these limestones with respect to karst; the limestone areas extending further north and east show virtually no karst development. The limestone is a relatively soft and poorly cemented rock which develops localised thin case hardening and limited calcrete capping. It is locally well jointed with generally north west joint trends in the western part of the basin and a north eastern trend in the east. The limestone is predominantly calcite with a varying presence of aragonite, and has intermittent beds of more siliceous material. The sequences of Tertiary limestones therefore show variable purity.

Overlying the Tertiary limestone in many areas of the Otway Basin are Pleistocene aeolian calcarenite dunes (aeolianite). Dating of a sequence of dunes overlying some of the coastal area indicates they were deposited and stranded over the past 800 thousand years (Huntley & alii, 1993). Particular dunes at Codrington and Bats Ridge, which have a high degree of karstification, have been dated by thermoluminescence at  $238 \pm 45$  ka to  $244 \pm 74$  ka, and  $295 \pm 35$  ka respectively.

The Pleistocene deposits are regarded as the Bridgewater Group (Orth, 1988) and are predominantly stranded dune ridges but do include some more flat bedded beach facies. They are well sorted fine to medium grained bioclastic carbonate sands of variable purity showing crossbedding, variable cementation, strong laminations and a well developed kankar or caprock.

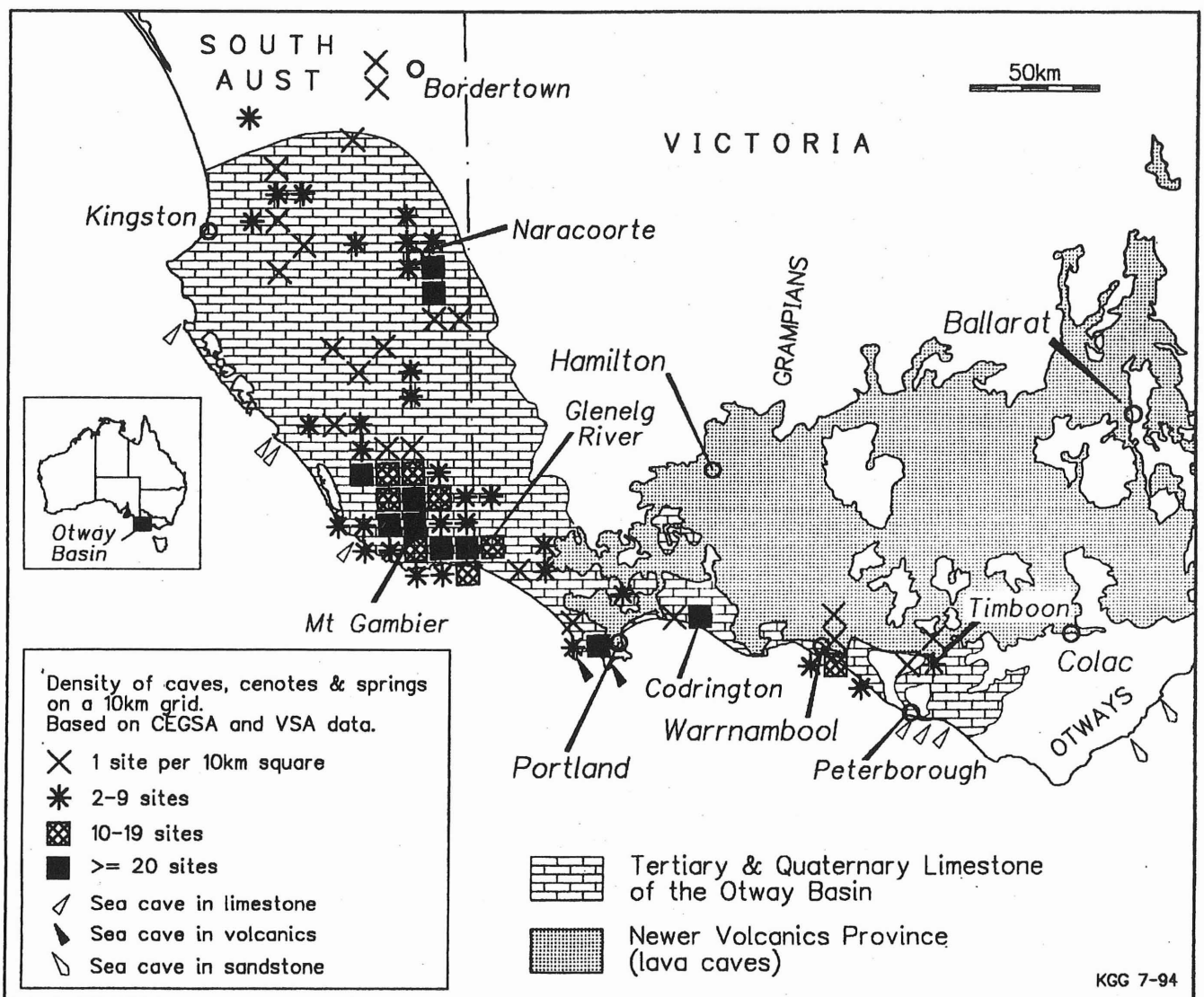


FIG. 2 - Distribution of limestone caves in the Otway Basin. (Grimes, 1996).

The Cainozoic limestones of the Otway Basin show some similarities in their variable cementation, variable purity of calcium carbonate and poor consolidation, but also show strong differences in their bedding, jointing and ability to develop a strong caprock or kankar. It is these differences which are important in the differential development of the karst.

## KARST FEATURES

Karst processes have been defined as being at their maximum in areas of strong, compact limestone possessing well defined secondary jointing and where there is sufficient rainfall for solution to occur and for underground water to develop. However karst features are well developed in the relatively poorly consolidated Cainozoic limestones in the Otway Basin in specific localised areas (fig. 2).

Karst in the Tertiary limestones is characterised by single linear joint controlled systems showing extensive horizontal development and collapse features. The Tertiary (Port Campbell) Limestone is extensive in Western Victoria but is of variable carbonate purity and has only limited karst development despite the extensive area of carbonates. The Port Campbell coast has spectacular limestone rock stacks such as The Twelve Apostles. These impressive limestone rock stacks are the best examples of the ruck sacks along the coast and show prominent basal notches. The taller stacks are 50 m high.

More extensive karst occurs in the Naracoorte and Glenelg River areas. Important Pleistocene vertebrate deposits occur in a number of caves eg. Victoria Fossil Cave (Naracoorte), McEachern Cave (Glenelg River). Other caves show impressive sand cones. Cenotes, drowned collapsed dolines, are a common feature of the Mt Gambier part of the basin where water tables are relatively high.

Karst in the Pleistocene limestones is characterised by shallow sinuous cave systems with multiple entrances, low flat, wide chambers and horizontal development, solution

pipes and roof avens and extensive cap rock (kankar) development. The dune landscape has interdune lakes and swamps which have increased the aggressivity of the surface and ground waters.

Two specific areas show the karst development in these dunes. Codrington is an area of cave development in a mid Pleistocene dune ridge predominantly composed of calcareous sand. The characteristic karst features are found in this dune which is considerably lower in altitude than the more seaward two dunes, indicating some landscape lowering (Berryman & White, 1995). Karst features also occur in more complex mid Pleistocene dune sequence at Bats Ridge. This ridge has a general alignment north east-south west, with low spurs on the northern side. These spurs are separated by swampy swales or hollows, some of which hold water in wet seasons. It is about 100 m above present sea level and has a relative relief above the surrounding plain of 38 m. There are peat swamps on both northern and southern sides of the dune (White, 1994).

The characteristic landforms associated with these Pleistocene calcarenite strandline ridges are the result of karst processes of solution and collapse. The caves are shallow with horizontal development and have formed under a hardened cap rock (kankar layer) in the calcarenite dune. This formed as the result of solution and redeposition of calcium carbonate, under sub-aerial conditions. The cementation is primarily as meniscus cement which confirms that diagenesis has occurred under sub-aerial conditions. The position of the caves within the dune can reflect a previous higher water table. These near coastal dune systems show karst development which is contemporaneous with lithification (syngenetic karst) (White 1994, Berryman & White, 1995).

The passage orientation of the karst features in the two types of limestone is distinctive. Cave passages in the dune limestones show a spread of passage directions whereas cave passages in the Tertiary limestones are more obviously directional; commonly either NE-SW or NW-SE which reflects the jointing patterns of the limestones. The examples in fig. 3 are typical.

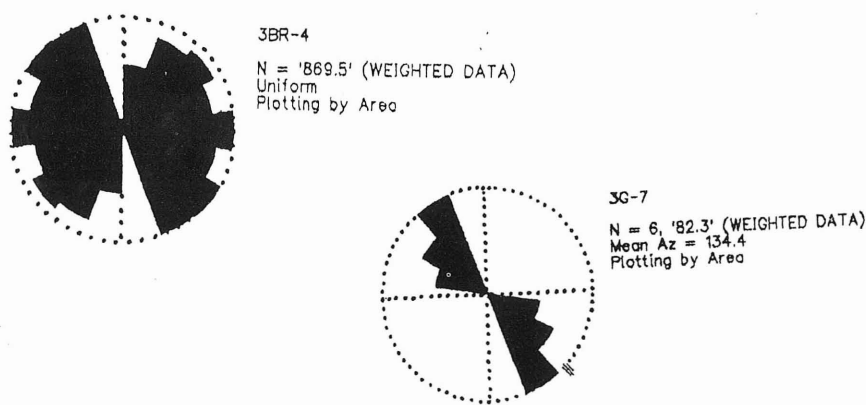


FIG. 3 - Passage Orientation Rose Diagrams.

3G-7 Tertiary Limestone

3BR-4 Pleistocene Limestone

There is very limited calcite speleothem development; often expressed as moon milk or calcite straws in both the limestone types. Phreatic preparation can be seen in the walls of the caves. Roof pendants are a feature of some caves, but the easily eroded nature of the soft limestone precludes many of these being preserved.

## CONCLUSION

The Otway Basin has large karst areas where there is the potential to understand the regional patterns of karst development, in particular that of the Pleistocene calcareous dunes. Karstification in these limestones shows substantial variation across the basin and between the different calcareous lithologies but has some overriding similarities relating to the highly porous and permeable natures of these Cainozoic limestones.

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