Management of Karst in Pleistocene Aeolianite

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Abstract

Solutional features including substantial caves are found in the very extensive areas of Pleistocene aeolianite dunes along the southern coast of Australia. This paper will review the interesting features of the karst and discuss the issues of management. The management of such soft limestones includes their land tenure and land use issues, the nature of the karst and the interpretation of such features. The rock is very friable and easily collapses; many caves have large amounts of very delicate calcite formation including huge areas of moonmilk; and many sites are close to areas of population and so can easily suffer from overuse. The interpretation of dune karst has suffered from the lack of understanding by many managers of syngenetic karst and some spectacular misinterpretation examples will be examined. The paper will concentrate on the dune karst of the Otway Basin in Victoria and South Australia in particular Bats Ridge and Codrington where intensive karst occurs in mid-Pleistocene dunes.

Introduction

Karstification is a complex process controlled by the nature of the lithology, tectonic structure and climatic conditions. In particular, lithological variation of porosity, chemical composition, and strength can be extremely high. Whereas massive, well-jointed, and relatively chemically pure limestones are traditionally perceived as having the best karst development, the extensive but relatively poorly consolidated Pleistocene dunes in southern Australia have developed extensive karst systems and can offer interesting insights into speleogenesis as well as insights into management of less well consolidated limestone systems

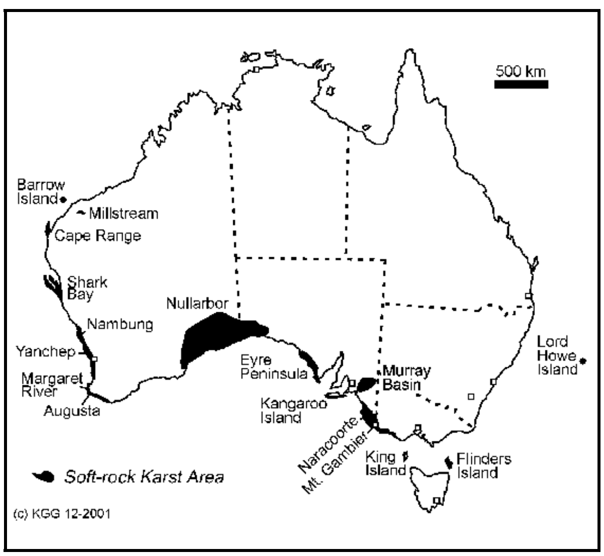

Figure 1. *Australian Karst Types: soft rock karst includes Oligo- Miocene marine and Pleistocene aeolianite (Grimes, 2001)*

Australia has extensive areas of dune limestone karst, described locally as soft rock karst, along the southern and southwestern coasts, sometimes extending inland for up to 100 kilometers. (Figure 1). Some areas such as the Nullarbor and Mount Gambier areas have Oligo-Miocene cool water marine carbonates underlying the Pleistocene aeolianites, but the "Soft-rock" Karst areas shown on Figure 1 indicate the distribution of the aeolianite karst in Australia. In cases such as Otway Basin, the aeolianite karst extends across the two Tertiary karst provinces.

Characteristics of Karst in Pleistocene Aeolianite

The particular issues of karst processes in young and relatively unconsolidated limestone such as chalk, coral, and dune calcarenite was highlighted in the 1960s by Jennings (1968) who discussed speleogenetic problems in rela-

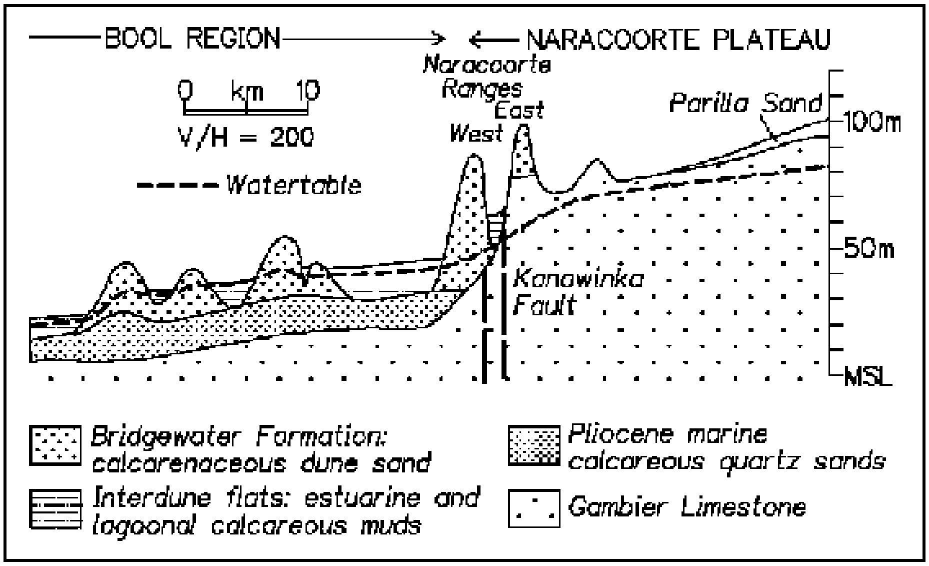

Figure 2. *Lithological relationships of the Pleisotcene dune ridges in the Ottway Basin (Grimes 2001)*

Figure 3. *Caprock in entrance at Milliways Cave (CD 28) Codrington.*

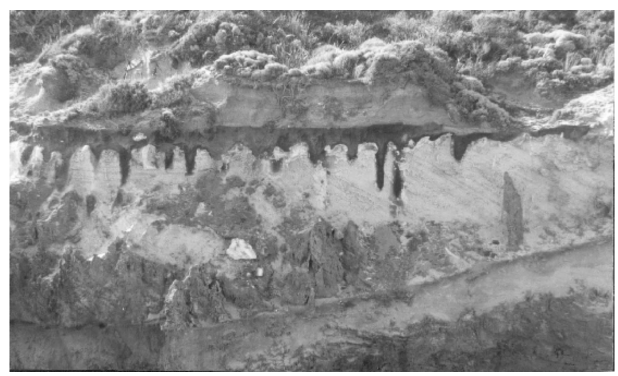

Figure 4. *Solution pipes filled with soil buried under younger dune. Features such as these are common.*

tion to the Pleistocene dune limestones of southern Australia and developed the syngenetic scheme of karst evolution. White (1989, 1994) has further developed this scheme. Carew and Mylroie (1988) have developed a similar scheme in the Pleistocene limestones of the Bahamas.

Karst development on coastal aeolianite ridges is dependent on several interrelated conditions: the purity of the limestone, its porosity, its ability to support a cavity and the availability of aggressive water capable of solution. The higher the proportion of carbonate, the more likely the karst features will develop. The aeolian calcarenites are well sorted fine to medium grained bioclastic carbonate dune ridge and beach facies of highly variable purity and cementation. Lithological relationships are shown in Figure 2. The development of underground karst features is dependent on the ability of the limestone to support a cavity. Insufficient strength in the limestone will result in solutional cavities collapsing before they are very large.

The simultaneous nature of the lithification processes, which convert the unconsolidated carbonate dunes into aeolian calcarenite rock, and the development of solutional karst features in the dunes, characterizes such karst areas. The dunes were deposited during the mid Pleistocene and the caves dissolved at times of higher water tables, not long afterwards. The lithification process involving solution by CO_2 enriched percolating water and redeposition of calcium carbonate, results in the formation of a hardened kankar/caprock layer in the dunes (Jennings, 1968; White, 1994).

It is the formation of this caprock of sufficient compressive and tensile strength to support cavities, which in turn is dependent on the interrelated factors of limestone purity, water chemistry conditions, and watertable position that has resulted in the rapid formation of karst features. Groundwater flows towards the coast with swampy areas between the calcareous dunes resulting in localized flow in the aeolianite areas. The karst is characterized therefore by shallow, sinuous, and maze cave systems

Figure 5. *Moonmilk development on cave walls, Bats Ridge.*

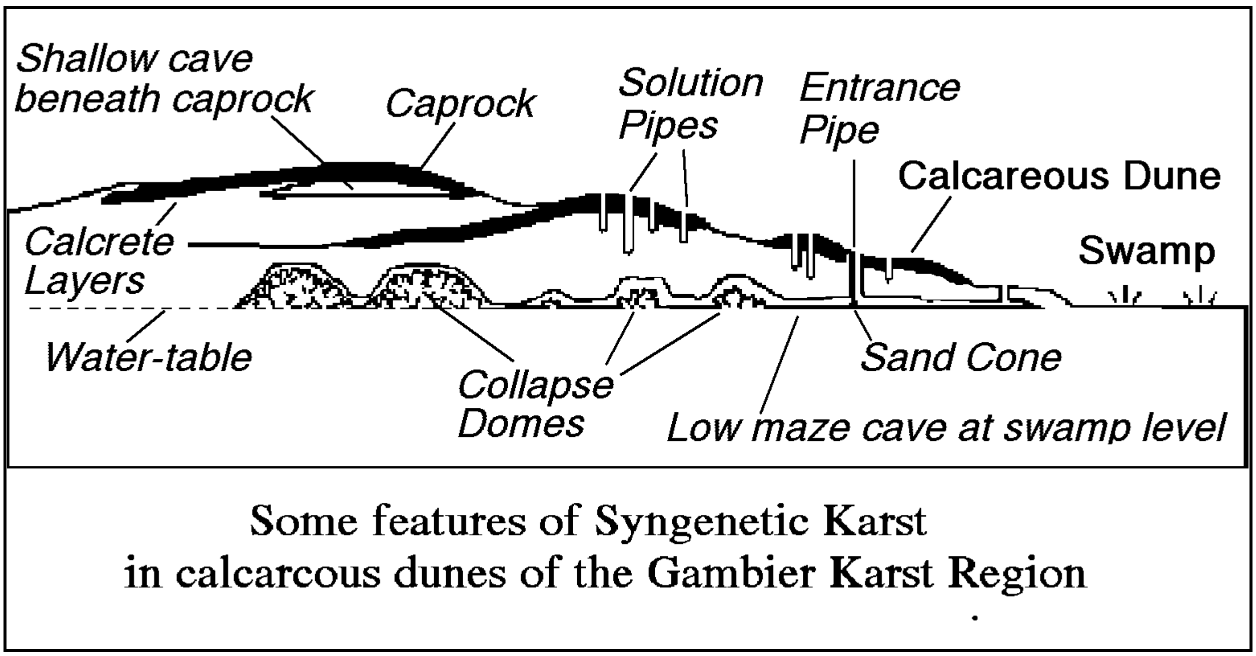

Figure 6. *Features and characteristics of aeolianite syngenetic karst (Grimes 2000)*

with multiple entrance. Low, flat, wide chambers and extensive horizontal development is common. Although collapse is very common, the cap rock (kankar) is an integral component of the cave development. Such a caprock feature is shown in Figure 3. Solution pipes are common (Figure 4).

The interdune lakes and swamps are modified by solution. In some areas such as southwest Western Australia extensive and complex speleothem development occurs, but in other areas this is less.

Extensive areas of moonmilk development are ubiquitous throughout the aeolianite karst (Figure 5). A diagrammatic characterization of the karst is shown in Figure 6.

So, What's the Problem?

Problems of management of such a relatively unconsolidated rock type can be grouped into three areas: problems associated with physical conditions, land use issues, and inappropriate and inaccurate interpretation. Primarily there are basic physical problems, which need to be addressed in management. The host rock is relatively soft and poorly consolidated and is prone to collapse. This problem is often only partially understood as being a natural if awkward process by cave area managers, but is even much less understood by the construction industry. From senior engineers to backhoe operators, the limited ability of dune limestone to support construction without collapse is usually ignored. The areas with such limestone have many examples of ground collapse, sometimes with very serious consequences such as the tragedy in Western Australia where school children sheltering under a small overhang were killed when it collapsed. A recent development of large windmills on a dune area gave insufficient attention to such risk management. Given that, to a large extent, sophisticated engineering solutions are available for many of such problems faced in Australia, the poor understanding of the issues by the industry is an ongoing problem.

Similarly, unsuccessful attempts to fill in solution pipes show poor understanding of the processes involved. Some places have fenced some soil pipe areas with better success, although careful assessment of the area to be fenced is required.

The caves are often small and many caves host extensive and delicate speleothems. In particular, the walls and ceilings of most caves have extensive moonmilk development. These can be easily damaged by overuse, although limited regeneration of moonmilk does appear to occur. Nevertheless, some better care by both managers and cavers is necessary in the more heavily visited areas.

Caves and karst can be compromised in a variety of ways both directly and indirectly and the usual range of issues including destruction, damage, or inappropriate use occurs for aeolianite as well as other karst areas. These threats involve quarrying; road and other construction works; rubbish dumping, especially in dolines and cave entrances; liquid waste disposal; land clearance; blocking up of caves and dolines; vandalism; and disturbance of cave dwelling biota. None of these are more prevalent in aeolianite areas than other karst areas although there are some particular local problems for some of these. The issues of pollution are not rare in karst areas but for Australia the dune karst areas are the main karst areas with any substantial population. The only state capital built on a substantial area of limestone is Perth, which has important areas of dune aeolianite. The issues of management are often related to inappropriate development and land uses and the inability of planning and development authorities to ensure suitable remediation or modification of development to more appropriate activities or places.

The final management problem is the seriously poor interpretation in many (most) of the areas controlled by the various park and reserve management agencies. Despite some outstanding examples of excellent interpretive material (such as at Naracoorte in South Australia), there are a large number of cases where out of date, incorrect information continues to be presented to the public. This is particularly the case with respect to the earth science component of interpretive material. The same level of inaccuracy in the biological sciences is not tolerated. In the case study below, not only is it tolerated but perpetuated as new signs have been produced perpetuating the incorrect information.

The "Petrified Forest" Cape Bridgewater/Cape Duquesne Victoria in southwestern Victoria near Portland, is a well visited tourist location with spectacular coastline landscape containing karst features. Pleistocene Bridgewater Group aeolianites (dune limestones) overlie the late Pliocene/early Pleistocene volcanics. The aeolianites developed solution pipes/ soil pipes as found in many other areas in the region. The limestone is now in a period of erosion, resulting in the exposure of some spectacular exhumed solution pipes, some of which are partially infilled. The Victorian Geological Survey produced a memoir on the Geology of Portland which described the features and interpreted them as a petrified forest (Boutakoff, 1963). By the mid 1980s there was literature (for example Trounson, 1985) disproving this interpretation. The Victorian Geological Survey geologists in general were not particularly interested in the material but certainly knew that Boutakoff was wrong in his interpretation. However, the signs that went up at about this time and subsequent upgrades, including during 2001, continue to perpetuate the myth.

The "Petrified Forest" is a large number of solution pipes, which were formed in one stabilised calcareous dune. The area was then subsequently buried and the pipes filled in. The filling is often "harder" or more cemented than the surrounding dunes because of the balance between solution and redeposition of $CaCO_3$ in the conditions, especially where there is casing on the tube. Subsequent erosion, currently still occurring, is exhuming these features. They are the same sort of features as found at The Pinnacles (Nambung, Western Australia) and on King Island. Small cemented roots or rhizomorphs are present but are not an indication of large trees as no evidence of a tap root exists. They are extremely common in the dunes along the southern Australian coast and indicate interesting concretionary processes in more recent and present conditions.

The challenge now is to how to get the erroneous material out of the signs and interpretive material. The signs were recently upgraded as signs but with the old interpretation and no attempt was made as far as I can ascertain to upgrade the interpretive material. The cost of such inaccurate information being presented to an increasingly educated public is serious, as the reputation of the management authority becomes compromised. Certainly, the understanding of what is presented there is so poor that there is concern that the management do not understand the processes involved.

Conclusion

Conservation challenges in poorly consolidated karst host rock presents a range of challenges for management. This is especially a challenge for the construction industry, which needs use knowledge of aeolianite karst to minimise risk from collapse. However there is also a major challenge for public land managers to improve their interpretation of such landscapes to an increasingly educated public.

Acknowledgments

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