HOLIDAY GEOLOGY

Pinnacles Desert, Australia

In the Nambung National Park of Western Australia, the Pinnacles Desert is noted for its spectacular karst landscape in the form of many thousands of limestone pinnacles. It lies 15 km south of Cervantes, a small coastal settlement 260 km north of Perth. The Pinnacles Desert is easily accessible by car along a circular track about 3 km long that provides many opportunities to stop and wander among these rare landforms. It is also possible to reconstruct something of the history of burial, karstification, reburial and re-exposure of the limestone pinnacles. As an additional stop in the area, modern stromatolites can be seen around the margins of Lake Thetis, a small saline lake a few kilometres inland of Cervantes near the turn-off to the Pinnacles Desert.

The pinnacles are the karsted remains of the late Pleistocene Tamala Limestone. This is up to 150m thick, though it has been locally reduced by karstic dissolution. The limestone is a calcarenite, composed of sand-sized grains of shells, algae and bryozoans, deposited in a near shore setting and as aeolian dunes (Lowry, 1974; Playford *et al*., 1976; Cockbain, 1990, McNamara 2002). Modern aeolian carbonate dunes along the coast towards Perth show how the Tamala Limestone was deposited.

The pinnacles are limestone pillars up to 3 m in height. They occur in elliptical groups several hundred metres across separated by areas of bare sand in which pinnacles are absent or scarce, and the groups generally, but not always, occur on topographic highs (Fig. 1). Individual pinnacles have three main shapes:

• Simple conical pinnacles with broad equant, sub-circular bases up to 1 m in diameter that taper upwards to a point. The lower parts of these pinnacles are greyish while the upper parts are brownish, with the colour change occurring at the same level within a group of pinnacles (Fig. 2).

• Composite pinnacles are similar in height to the conical pinnacles but have elongate bases up to several metres long, above which the composite pinnacles taper abruptly to one or two smaller slimmer terminations. The brown to grey colour change commonly coincides with the top of the broad lower part of the composite pinnacles.

• Split pinnacles are similar in size to the composite pinnacles, but are split by a vertical fissure that is infilled by calcrete (Fig. 3).

The pinnacles are formed of three materials. Most are made of well-lithified limestone. Some are formed of poorly cemented, cross-bedded calcarenite (Fig. 4); these are less common, perhaps because they are easily eroded. Many are coated by laminar calcrete and rhizocretions (Fig. 5).

Calcrete forms in semi-arid soils by the precipitation of calcite around roots and root mats often moulding themselves to any lithified surface within the soil, such as clasts or the bedrock. Some pinnacles have surfaces entirely of calcrete, but it is not possible to tell if this is a coating of calcrete or if these pinnacles are composed entirely of calcrete.

Outliers within the Pinnacles Desert show that the pinnacles were later buried by a succession of sandstone, probably also aeolian, with calcrete horizons interbedded with cross bedded calcarenite.

All these features point to a complex history of the pinnacles, starting with the deposition of the Tamala Limestone as aeolian carbonate dunes. These were cemented soon after deposition to form a lithified limestone; however, cementation was not complete, and some parts of the carbonate dunes were poorly lithified. The many closely spaced pinnacles formed when the bedrock underwent karstic dissolution, probably beneath a soil. Dissolution took place along vertical solution pipes, probably associated with the vertical root systems. In well-cemented limestone, the pinnacles represent pillars of lithified limestone left behind between the dissolution pipes. However, the formation of calcrete along fissures and within the

Figure 1. *Two groups of pinnacles located on topographic highs that are surrounded by areas of bare sand with few pinnacles. Topographic highs may correspond with buried aeolian ridges of the Tamala Limestone.*

Figure 2. *A group of simple and composite pinnacles made up of lithified limestone. The transition from the lower grey (light) onto the upper brown (dark) parts of the pinnacles takes place at about the same level within the group.*

limestone also contributes to lithification, known as case hardening (Jennings, 1985). Thus, in poorly lithified areas, the carbonate grains surrounding the solution pipes would have been eroded leaving pinnacles made of calcrete (e.g. Playford *et al*., 1976).

The presence of both karst and calcrete features, notably in the composite pinnacles, points to alternating periods of wet and arid climate during the development of the pinnacles. The broad bases of the composite pinnacles formed during the first episode of sub-soil karstic dissolution, and were then partly re-exposed and modified by a second phase of karstic dissolution; the brown to grey colour change may represent the level of exhumation. Split pinnacles are adjacent pinnacles that were 'welded' together by calcrete infilling their intervening fissure, and also imply a second phase of karstic dissolution. After this, the pinnacles were buried by aeolian quartz and carbonate sands - which have since been largely eroded, so that the Tamala Limestone with its karst pinnacles is exposed once again.

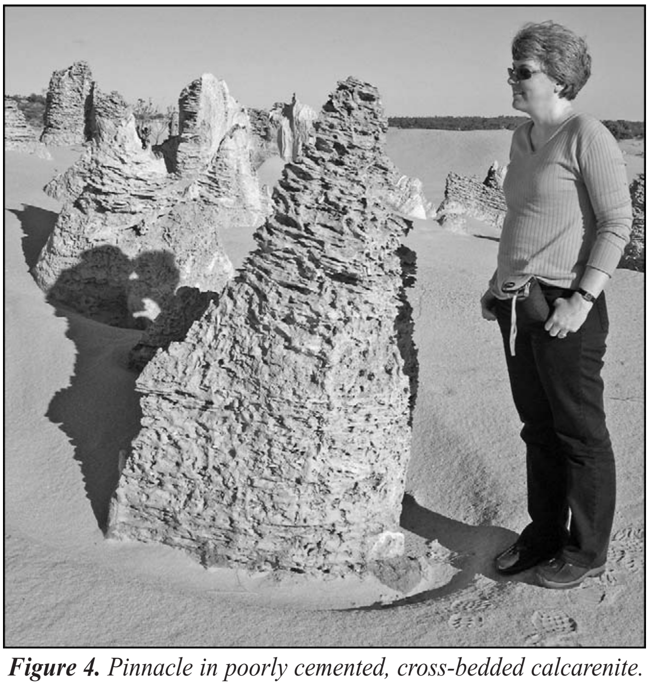

Figure 4. *Pinnacle in poorly cemented, cross-bedded calcarenite.*

Figure 3. *Split pinnacle (1 m across) cut by a vertical fissure filled by calcrete between two original pinnacles.*

When the Pinnacles Desert is seen from the air, groups of pinnacles appear to coincide with a number of sub-parallel sinuous ridges that cross the area. These ridges may represent the original crests of aeolian carbonate dunes in the Tamala Limestone that are now covered by vegetation. The distribution of pinnacles may thus reflect the original thickness variations of the limestone, with groups of pinnacles occurring over former dune ridges where it is thick, whereas pinnacles are absent between these ridges where the limestone is thin or absent.

References

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Figure 5. *Pinnacle partly coated by tubular rhizocretions formed by calcite precipitation around a root when the pinnacle was buried by soil. The pinnacle is 750 mm across.*