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# The karst of the De Hoop Nature Reserve, Western Cape, South Africa

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**Abstract:** The De Hoop Vlei Reserve and adjacent areas, only 150km east of Cape Town, support an important coastal karst, which is developed on Tertiary dune limestones. A high density of enclosed hollows with some dry valleys constitute the surface karst. Shallow caves are localised. The complexity of enclosed hollow plan-form increases with altitude and therefore with the age of the limestone surface. A pitting index is given as a measure of difference between areas of differing karst age. There is also evidence for syngenetic karst development of both valleys and hollows.

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## INTRODUCTION

Some of the most spectacular surface karst and caves in South Africa are accorded conservation status by virtue of falling within the De Hoop Nature Reserve. This reserve, set up originally to preserve and breed endangered animals, is located on the coast of the Western Province, east of Cape Agulhas (34° 50'S: 20° 00'E), some 150km east of Cape Town (33° 55'S: 18° 28'E) (Fig.1). De Hoop Vlei, an important RAMSA bird locality, divides the karst area (Butcher, 1983). Most of the reserve lies east of the Vlei but, as a large area outside the Reserve on the west is held by the Defence Force, it has *de facto* conservation status. This karst area is developed on Cenozoic Bredasdorp Group limestones (formerly known as the Coastal Limestones).

## GEOLOGY

To help understand the karst geomorphology mention must be made of the structural context. The Reserve lies within the Cape Mountain belt. Cape Supergroup Peninsula Formation quartzites and sandstones form the mountain ranges, and Bokkeveld shales (also Cape Supergroup) underlie the intervening valleys and plains. North of Cape Town the alignment is north-south whereas eastwards the alignment swings west-east. The Reserve lies south of the orogenic node where the alignment changes (Fig.2). The change in direction can be recognised in the Bredasdorp Range, in the planed and buried ridges that crop out at Struis Bay and Arniston (34° 35'S: 20° 14'E) and in the Potberg, which rises to a maximum altitude of 370m, jutting into the ocean at Cape Infanta (34° 29'S: 21° 51'E) (Fig.2).

The resistant Cape fold ranges have assisted preservation of the limestone between the Bredasdorp and Potberg ranges. Following the break-up of Gondwana (the southern hemisphere supercontinent) a series of fault troughs developed along the coast extending off-shore, in which sediments of Cretaceous and later age have been preserved (Dingle *et al.,* 1983). The Reserve overlies the inner margin of one such half-graben (Fig.3). Two major Tertiary tectonic uplifts account for the present altitude of the limestone. Faulting that resulted is most easily recognised in the Peninsula Formation quartzites, but has also been important in directing dissolution within the limestone. The basic geology of the Reserve is shown on Figure 3.

Cenozoic near-shore limestones occur sporadically along the South African coast from Saldanha (33° 03'S: 17° 51'E) in the west, to northern KwaZulu-Natal in the east. The southern Cape outcrop between Cape Agulhas (34° 50'S: 20° 02'E) and Mossel Bay (34° 11'S; 22° 08'E), of which the De Hoop area forms a part, and that of the Eastern Cape between Woody Cape and Great Fish River (33° 29'S: 27° 16'E) have the highest density and diversity of karst. The limestones

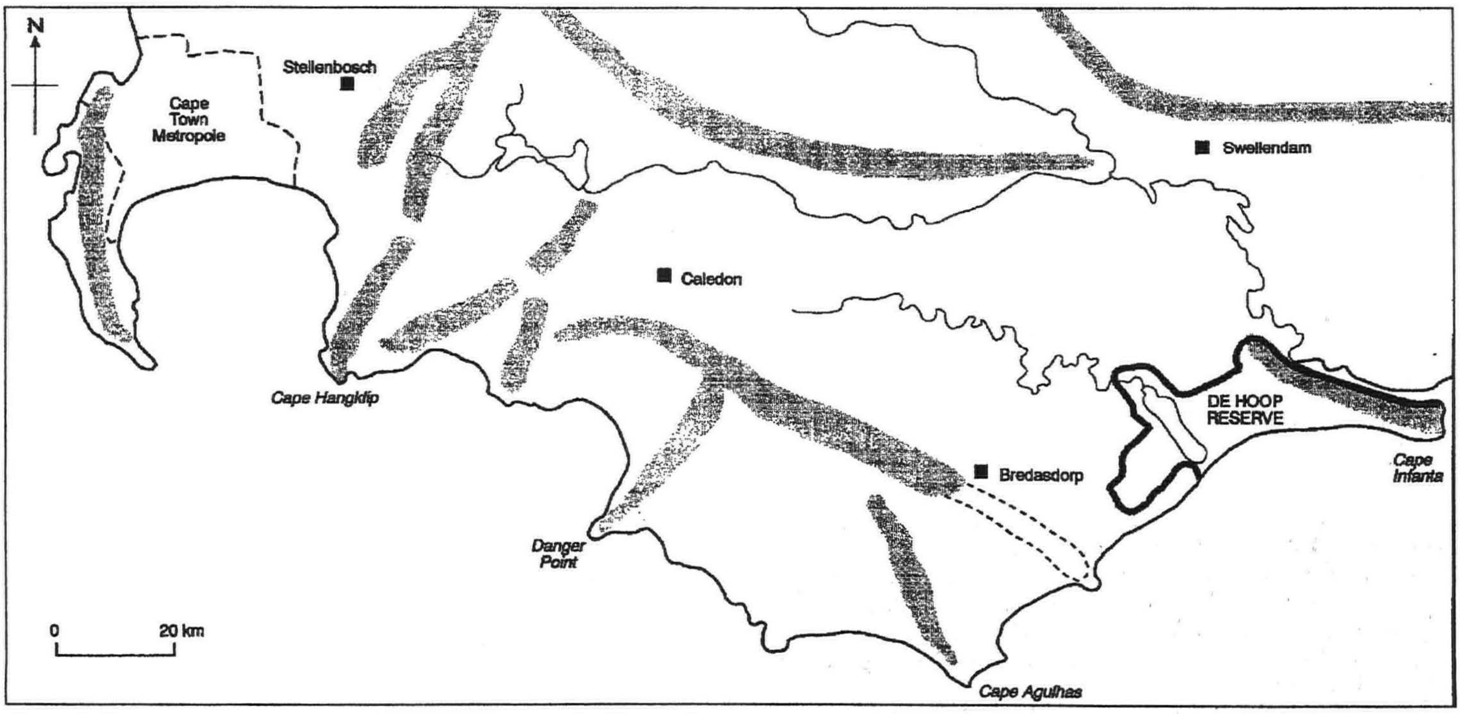


*Figure 1: The location of the De Hoop Nature Reserve within the Western Cape fold belt. Note the change of trend in the ranges from north–south in the west to dominantly west–east.*

| Formation | Description | Age |
|---|---|---|
| Strandveld | Unconsolidated wind-blown dunes | Holocene |
| Waenhuiskrans | Semi-consolidated aeolianite | Pleistocene |
| Klein Brak | Shelly quartzose sand and conglomerate | Pleistocene |
| Wankoe | Consolidated aeolianite | Pliocene |
| De Hoopvlei | Shelly quartzose sand and oyster-bearing conglomerate | Pliocene |

*Table 1: Subdivision of Bredasdorp Group (after Malan, 1990)*

that crop out in the Reserve and host its karst are Cenozoic in age and can be subdivided into 2 groups. Both groups of limestones in the Reserve have a basal marine component overlain by a much thicker aeolianite of beach and dune origin (Malan & Viljoen, 1990) (Table 1). These extend throughout the southern Cape (Table 1). The marine De Hoopvlei Formation consists of shelly quartzose sand with oyster-bearing conglomerate, and is overlain by consolidated aeolianite of the Wankoe Formation. These formations are believed to be Pliocene in age (Malan 1990). The moderately lithified Wankoe Formation is undoubtedly the main karst host rock.

Early Pleistocene deposits comprise the marine quartzose sands and conglomerate of the Klein Brak Formation and an overlying beach and dune aeolianite, the Waenhuiskrans Formation. These formations occur closer to the coast and is less well consolidated than the older limestones. Over most of the De Hoop Reserve, the Wankoe limestones actually underlie the Waenhuiskrans deposits. Mobile sand dunes of the Strandveld Group are the youngest stratigraphical element in the area, and they are well developed along the coast (Fig.2).

## KARST

The main topographical components of the De Hoop Reserve and adjacent areas constitute belts sub-parallel to the coast (Fig.2). Section A–B illustrates the topography of the Reserve immediately east of the Vlei (Fig.4). The section also illustrates the area (developed on Cape Supergroup Bokkeveld shales) north of the Reserve, which has rolling topography with scattered tabular hills rising to almost 300m (Fig.4a). The tabular hills, capped by silcrete overlying white saprolite, represent remnants of the Tertiary African Surface. With destruction of the caprock, rolling topography develops.

The remnant African land surface is separated from the limestone outcrop by a narrow valley. The settlement of Wydgeleë is sited in this border depression, drained by the intermittent Potberg River. Farther east this depression has broadened into a rand polje. Adjacent to Bredasdorp and east of the Breë River, the border depression has opened into plains. Residual lumps of conglomerate indicate that the border depression and the plains were formerly covered by limestone. The nearshore limestone then abutted directly on the African land surface.

The Die Duine (hard dunes) ridge, averaging 180 to 200m altitude, reaches a maximum altitude of 274m near the Potberg Range, but is lower to the west. It rises steeply from the border depression. Die Duine has well-developed surface karst but few known caves. The steep 10° to 12° slopes on either side are scarred by rocky gorge-like dry valleys, which run out onto a low angle basal foot slope that supports little or no karst.

From the base of the footslope to the coast the terrain is level and stepped. It is the product of marine planation when sea level stood progressively at 90m, 60m, 30 to 40m and just below 20m elevation above present sea level. This karst is dominated by enclosed hollows of progressively smaller dimensions and more regular outline with lower altitude.

Much of the seaward margin of the 20m surface is concealed by Strandveld Formation dunes, which separate the planed area from the shore, and cut off De Hoop Vlei from the sea. De Hoop Vlei is incised almost to sea level, so is bordered by rock cliffs inland. Dry valleys feed from Die Duine, with springs emerging near the Vlei. The Sout River drains from the African Surface into the De Hoop Vlei and maintains the water level (Butcher, 1983). The intermittent Potberg River is a main eastern tributary. In times of drought the Vlei can become dry.

The eastern section (C–D) across Potberg shows that there only Die Duine and the 90m and 60m benches are present (Fig.4b). Marine erosion has truncated the seaward extension of the limestone, which now abuts the coast in cliffs. In these cliffs a number of vadose caves have developed above the contact with Cape Supergroup rocks.

The De Hoop karst has high karst density and moderate diversity. The permeability of the limestone ensures that all water goes underground, leaving dry valleys on the surface and springs that emerge at the base of kloofs. All limestone landscapes are dry environments. The aridity is enhanced here by the low annual rainfall, only 350mm per annum, falling chiefly in winter. Being near the sea the environment is windy and this also increases evaporation.

This karst, like that of the coastal karst areas farther east, is dominated by enclosed hollows ranging through shallow pan dolines, deep funnel-shape dolines and cenotes, to uvalas and poljes. Dry valleys and caves are also important. Adjacent to the Potberg Range, the border depression has broadened into a rand polje almost 5km long and 2_km wide. Its depth is shallow, only 19m lower than the valley floor. It is located along the sandstone / limestone contact at the intersection of two faults (Fig.3). The development of a polje at this site can be explained in terms of increased acid run-off from the sandstone ridge, with accentuated water penetration along the faults. However, another polje, Ou Werf, west of the Reserve on the summit of Die Duine, cannot be explained in those terms (Fig.2). The summit plateau surface is case-hardened, calcretised limestone with traces of micro-karren features. Poorly defined former valleys are interrupted by rocky uvalas of oval plan, 500m – 100m in length and up to 500m wide. The largest of these is Ou Werf. All have been left abandoned by a progressive drop in water table following sea level regression.

On Dronkvlei, most caves are adjacent to large irregular uvalas (apparently let down from the 30 to 40m surface, but with floor altitude at 15 to 20m) and several of the entrances resemble cenotes. Such specific doline forms are characteristic of development in areas with a high water table, with pronounced conduit flow along joints in porous, relatively easily dissolved limestones (Marker, 1976). Cenotes are rare in South Africa and the development of Onmeetbare Diepgat has been facilitated by its location on the fault that bounds the buried Cretaceous outcrop.

Detailed mapping from air photographs of the negative relief of the karst shows considerable variation with altitude (Russell, 1989) (Figs 5a and 5b). On the basis of this variability, Russell (1989) felt able to subdivide the karst area into distinct regions, each with its own characteristics (Tables 2 and 3). She also determined a pitting index, which

| | |
|---|---|
| 1 | Border depression / karst plain |
| 2 | Summit plateau of Die Duine bevelled at 180 to 200m, deep rocky dolines and uvalas aligned along former valleys |
| 3 | 12-13° slopes from Die Duine incised by steep dry valleys in which springs emerge at vlei level |
| 4 | 15-20m surface with small circular pans only |
| 5 | Marine benches at 30 – 40m and 60m with more complex surface karst |
| 6 | 90m marine bench |
| 7 | Syngenetic karst developed on Waenhuiskrans Formation |
| 8 | No karst development, as limestone is thin or absent |

*Table 2: Karst types of the De Hoop area*

distinguished clearly between the higher karst areas on the basis of age (Table 4).

In summary, Die Duine at 180m to 200m summit altitude has a rock surface, case-hardened by calcrete, almost comprising a form of pavement. Into this surface deep, rock-rimmed uvalas are aligned preferentially along disrupted east to west shallow dry valleys. The steep slopes are cut by dry gorges which, to the south, run out onto a low angle rock foot-slope that merges with the highest of the marine planation levels. This slope carries no karst.

The marine planed benches at 90m, 60m and 30m support similar shallow uvalas of irregular outline. Their present plan form is attributed to complex coalescence of adjacent hollows. Only narrow ridges of the original surface remain (Fig.5). Variable depths of sand infill these hollows and occur as patches elsewhere. The concentration of caves in the vicinity of Dronkvlei and the localised cenotes are associated with the 30m surface where it is underlain by the fault basin. The 15m to 20m planed surface close to the vlei and inland of the coast is characterised only by shallow circular pan dolines (Fig.5b).

The different characteristics of the karst at different altitudes were attributed to the variables acting on the karst over time (Russell, 1989). These variables are discussed as follows:

**Geology and lithology**

As the Wankoe limestone is relatively uniform, being a lithified silicious beach aeolianite, the only major geological differences are in the thickness of limestone above an impermeable substrate or the piezometric surface. Where only thin limestone remains, as on the 15m to 20m bench, vertical infiltration is inhibited and lateral widening occurs. Only shallow pan dolines can develop. Where limestone thickness is greater, deep hollows can form. The less lithified Waenhuiskrans Formation supports only relatively simple karst forms. Blown sand and less lithified limestone govern the gradient of individual landforms as well as their maximum size.

| Surface altitude | Limestone thickness | Hollow depth |
|---|---|---|
| 200+ | <200 | <120 |
| 200+ | <100 | 98 |
| 90 - 100 | >80 | <10 |
| 30 - 50 | >50 | <10 |
| 20 | 10 - 20 | 4 |

*Table 3: Limestone thickness and depression depth (after Russell, 1989)*

**Syngenetic karst**

This Tertiary limestone retains topographic form from its dune origin. This has controlled the location of dolines. Both the Waenhuiskrans Formation and the Wankoe limestone host a South African example of syngenetic karst development. Hollow initiation was constrained by the dune topography and is aligned along inter-dune corridors. Ultimately the dune ridges become debased and only the alignment of depressions indicates the syngenetic nature of the karst (Marker, 1993). Jennings (1968) argued (for Tertiary coastal limestones in Australia) that syngenetic development implied simultaneous karst development and lithification of the dune sands. Lithification begins by case-hardening, with the formation of calcrete in the zone of aeration, and this preserved the dune topography. Karst develops on the case-hardened surface, even above unconsolidated sands. The De Hoop Vlei karst is hosted by Tertiary limestone. It also lies adjacent to the present coast and the different topographic belts are located parallel to the coast. The alignment of karst hollows on the harder Wankoe Formation, particularly on Die Duine where the shallow dry valleys are also parallel to the coast, indicates that it too was syngenetic in origin. This supposition is confirmed in the karst east of Cape Infanta, where the evidence is clearer.

**Eustatic sea level changes**

A series of transgressive / regressive marine events during the Tertiary and Quaternary periods affected the Cape coast. The Tertiary transgressions cut broad wave platforms in the Cape Supergroup and Cretaceous sediments, on which the limestone was deposited. The

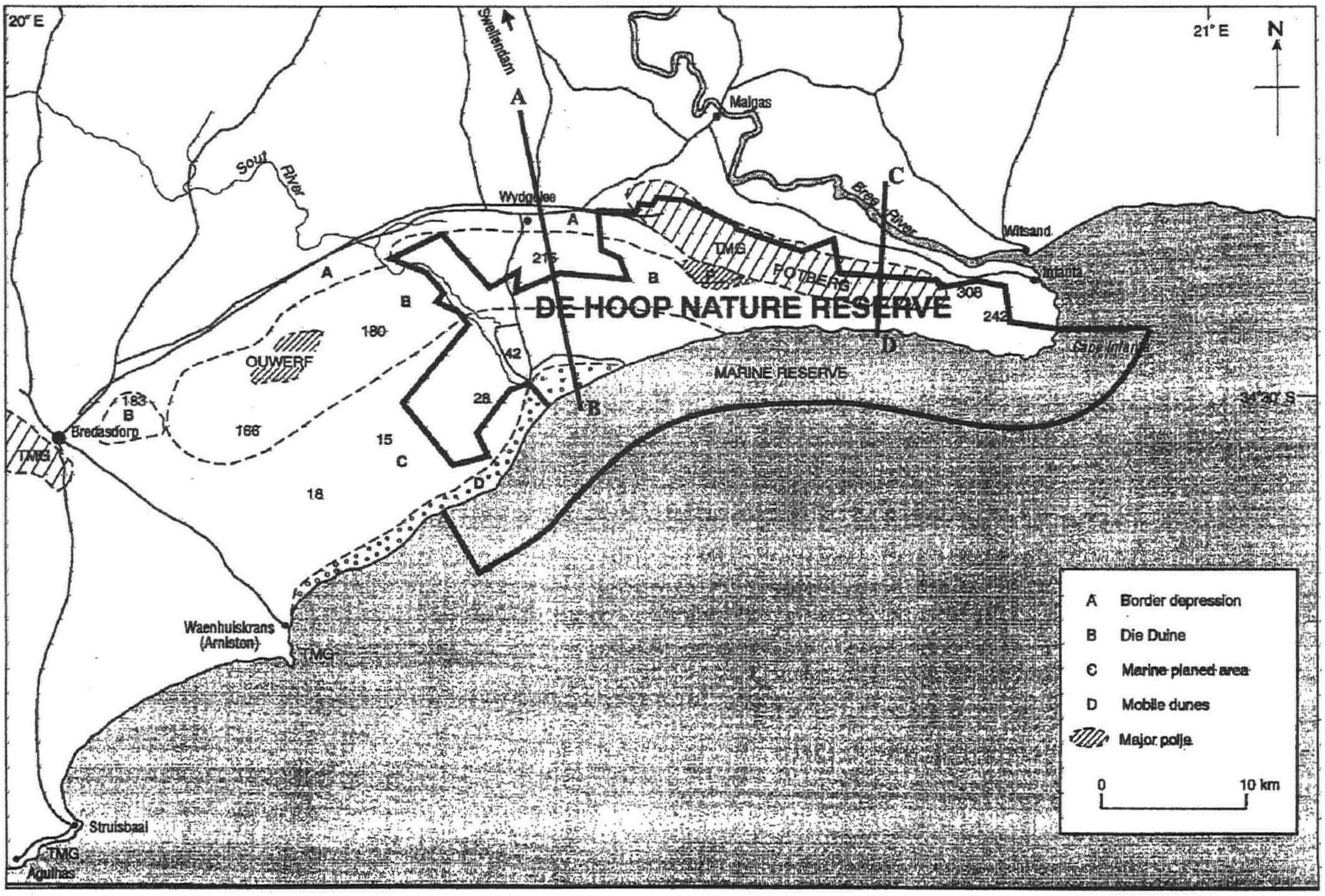


*Figure 2: Major topographic components of the De Hoop Nature Reserve showing the locations of the accurate cross sections. (Outcropping Peninsula Formation ranges designated TMG and hatched diagonally).*

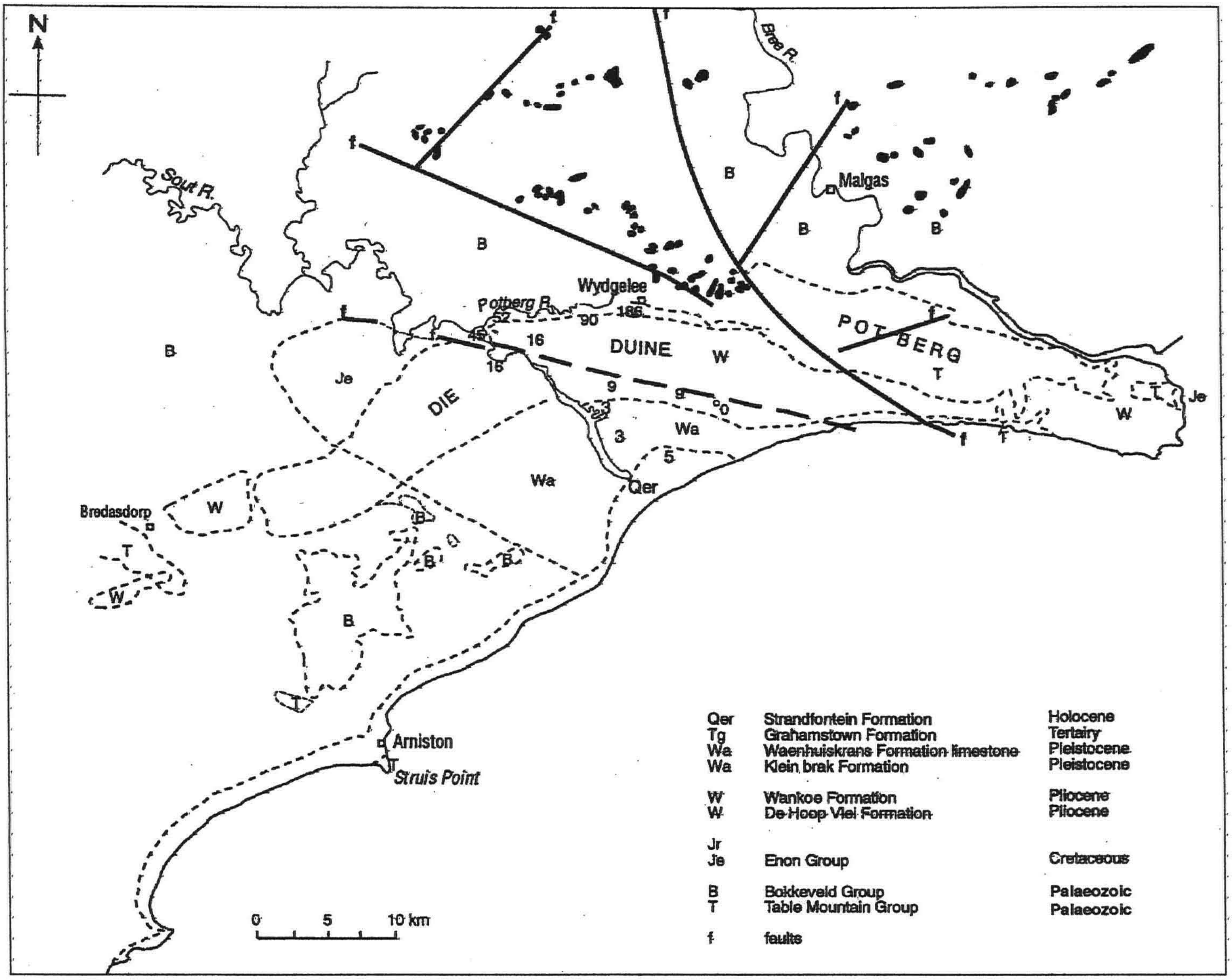


*Figure 3: The geology of the De Hoop Nature Reserve and adjacent areas. Note the buried Cretaceous trough and the faults (based on Malan & Viljoen, 1990 and Geological Survey).*

existence of marine benches at 90m, 60m, 30m and 15m altitude, incised into the Wankoe Formation, reflect the effect of glacio-eustatic marine incursions. These benches demonstrate that the combined effect of differing thickness of limestone left after planation, and the progressively younger time span available for karst evolution, have left their mark on the landscape (Russell, 1989) (Tables 3 and 4). The higher the platform the older and better developed is the surface karst, and the lower the percentage of the original surface remaining. Highly complex uvalas, the product of coalescence, dominate on the higher benches.

Sea level changes must also have affected the altitude of the piezometric surface and therefore the depth to which vadose water could penetrate. The present piezometric surface drops abruptly from Die Duine, where evidence suggests it is at 90m altitude and thus 90m beneath the summit, to the coast. The average altitude of the present piezometric surface is 9m beneath the Dronkvlei area east of the fault, and at 3m and –5m within the trough. The deep uvalas of Die Duine can be attributed to a progressively deeper vadose zone as well as to a longer time span for development. The pan doline karst close to the present coast at altitudes below 20m is a function of weakly lithified thin limestone with a restricted vadose zone as well as a shorter time for karst development.

The glacio-eustatic sea level changes also facilitated sand pulses onto the limestone. The sandy soils within the uvalas on Dronkvlei at 30m, and those inland on the higher benches, show greater soil development than those adjacent to the white Strandveld Formation current dunes. Elsewhere in the southern Cape karst belt, red dunes are the older form. They overlie and abut low cliffs above the 20m level. Pinkish sand deposits on the 90m bench may be relics from such red dunes. Texturally the Wankoe Formation weathered material, the red dunes and the pinkish-brown soils are virtually identical with the current dunes. They are all aeolian near-shore deposits. The presence of so much sand means that the true depths of the larger hollows are rarely known.

### The time factor

The oldest limestones are Pliocene in age, so the time span available for development of the De Hoop karst is restricted. Die Duine stands at an altitude adjacent to the African Surface remnants. The limestone was formed as the shore deposit for that African coast and subsequently lithified. Its karst is older than any other in the Reserve. The marine benches, cut across Wankoe limestones below Die Duine, are progressively younger with lower altitude and towards the coast. The pan

| Surface altitude | % Depression area/total area | Pitting Index |
|---|---|---|
| 90m | 57 | 1.7 |
| 60m | 50 | 2 |
| 30 - 40m | 25 | 4 |

*Table 4: Degree of karst hollow development on different surfaces (after Russell, 1989). Pitting index may be defined as depression area to total area.*

doline karst of the 15m to 20m surface is the youngest. However there is little distinction in characteristics of the uvalas on the three higher benches.

## CAVES

The De Hoop Nature Reserve, situated some 50km ENE of Bredasdorp in the Overberg part of the southern Cape, is the best known site for caves in the Cape coastal limestones. Limited exploration, reflecting the 400km round trip from Cape Town and the flat, superficially featureless, veld make it fairly certain that there are more caves than the few that have been recorded. Indeed, the absence of landmarks made it very difficult to define the position of the entrances before the availability of GPS technology. In most places the veld is so dense that it is possible to walk within one metre of an entrance and not see it. Nevertheless, the members of the Cape Peninsula Speleological Society have a long-term project to survey and record the caves.

### The De Hoop Guano Cave

This cave is about 400m long, situated 2$^1/_2$km southeast of the Windhoek farm, above the eastern shore of the De Hoop Vlei (Craven, 1985). It was mined for guano in the 1940s (Anon., 1943), and achieved notoriety as the site of the Cape's second outbreak of acute benign pulmonary histoplasmosis (Craven & Benatar, 1978, 1979). This is the only cave in the area that is situated on the lower slopes of the Hardeduine, about 30m above the plain.

### Windmill Pot

Windmill Pot used to be the easiest cave to find in the area because it was situated 2km southeast of Dronkvlei, immediately adjacent to a windpump at a boundary fence. The fence has long since been removed. Entrance is via a 17m drilled shaft above which the pump (now moved a few metres to the side) was originally placed. At the bottom of the shaft is a pool of water and a few, short, low passages (Macpherson, 1960).

### Hot Pot

Hot Pot is situated about 1$^1/_2$km southeast of Dronkvlei in a shallow pan doline. It was first reported in 1960, and noted to have dry air and no draught – hence the name (Macpherson, 1960). An 8m pitch, well-guarded by vicious bees, leads to 710m of typical low crawls, hard rocky floors and no formations (Hitchcock, 1985). The cave deposits have revealed a useful collection of faunal remains (Gow, 1980).

### Nikki's Pot

This is situated about 3$^1/_2$km southeast of the De Hoop farmhouse, at the side of the track to De Mond. It is a conspicuous 10m-deep shaft with a >1m-deep sandy floor (Craven, 1980).

### Onmeetbare Diepgat (= Bottomless Deep Hole)

This is a conspicuous doline, about 20m deep by 20m in diameter, situated 2$^1/_2$km eastnortheast of the farm Dronkvlei. Entrance is gained by digging out a short crawl at the eastern end of the doline, which leads to a 300m more or less horizontal and walkable passage with two lakes and a stream (Walker, 1959; Blacquiere, 1965; Breedt, 1971). The presence of running water confirms, as local farmers have long known, that water can be found by drilling boreholes. Another interesting feature of this cave was the discovery therein, in total darkness, of a troop of baboons, which may have been attracted by the water (Jongens & Coley, 1964).

There are several short caves in the shallow pan doline southeast of Onmeetbare Diepgat:

### Binocular Pot

Binocular Pot has two adjacent 8m-deep pitches leading to a 105m low crawl (Gartz, 1989a).

### Keyhole Cave

Keyhole Cave is about 5$^1/_2$km north of the sea, in the veld southeast of Onmeetbare Diepgat. There is a 7$^1/_2$m pitch with a 27m crawl at the bottom (Gartz, 1989b).

### Edward's Pot

Edward's Pot has a 16m pitch with a 10m crawl at the bottom (Truluck, 1991).

### Danielskuil

Danielskuil, similarly in the veld southeast of Onmetbare Diepgat, has been lost for over 30 years (Blacquiere, 1962). Its situation remains unknown.

### Scott Pot

This is situated in the Melkhoutkraal veld north of the access road to the De Hoop farmhouse – another 10m-deep pitch with a mere 25m of passage at the bottom (Gartz, 1989c).

## CONCLUSION

The De Hoop Vlei Reserve and the adjacent military area together conserve a part of an important karst area developed on Tertiary limestones of aeolian origin. The karst is significant for its high karst density and a range of karst hollows. Cave development is localised and appears to have been facilitated by proximity to the underlying fault trough.

This karst is an example of syngenetic development. It developed on the back-shore dune series, which localised doline development within interdune swales. The topography of Die Duine reflects an initiation on Tertiary coastal dunes adjacent to the African land surface with its deeply weathered remnants and silcrete duricrusts. Subsequent transgressive / regressive sea level changes explain the karst of the progressively lower altitude benches seawards of Die Duine and the decreasing complexity of hollow form as a function of less time and limited depth of limestone to permit vadose infiltration.

The De Hoop area karst is important too, by comparison with other South African karst areas, for its high karst density. The density is also higher than in the eastern extension of the limestone belt. The reason may be attributed to the same Cretaceous fault trough, which enables more effective piezometric gradients to develop.

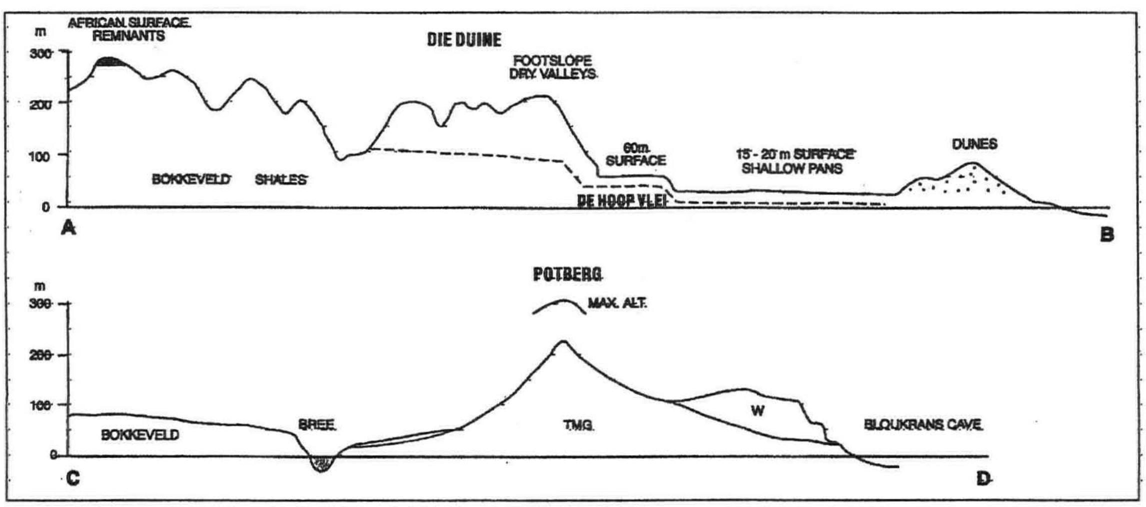


*Figure 4: Topographic sections across the De Hoop Nature Reserve.*

*a) A–B along longitude 20° 25'E immediately east of De Hoop Vlei, which delimits the four major topographic components.*

*b) C–D along longitude 20° 45'E across Potberg to the coast (for position of sections, see Figure 2).*

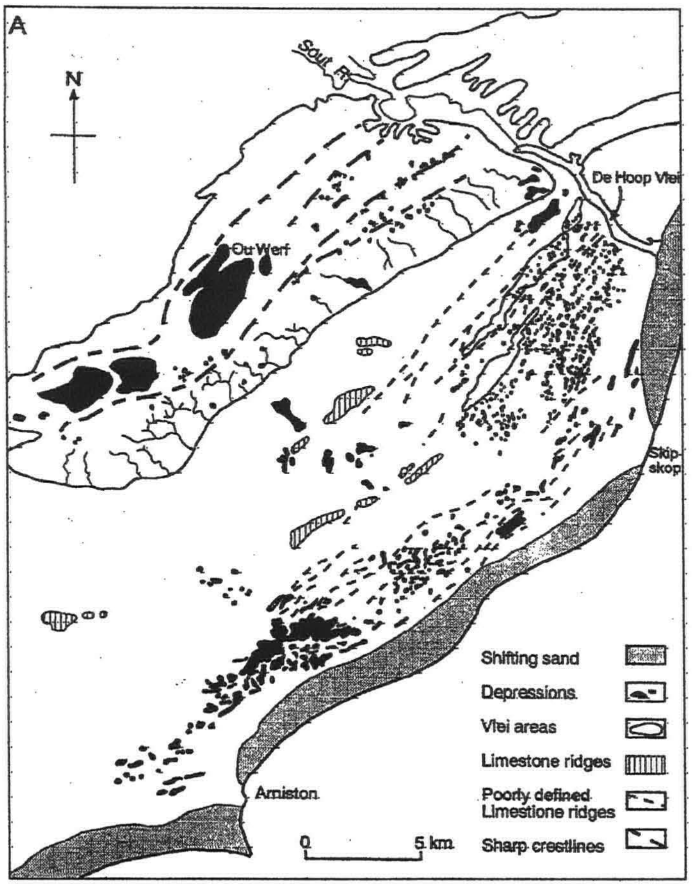


*Figure 5: Detailed maps of the negative karst relief (shaded black) based on air photo analysis with ground control (from Russell, 1989).*
*a) West of De Hoop Vlei.*

## ACKNOWLEDGMENTS

The idea for this paper originated with a request for a scientific overview of the De Hoop Reserve. The draft was in preparation in South Africa when news was released of the tragic death of Lin Russell and her younger daughter. The geomorphology in this paper is based on research by Dr L Russell and was collated by MEM, who had supervised the research. The original dissertation (MSc) and thesis (DSc) are lodged in the library of the University of Fort Hare, Eastern Cape Province, South Africa, and one author also holds copies. The paper is dedicated to an excellent karst geomorphologist and her family. Her research was facilitated by support from staff of the De Hoop Vlei Reserve and funded through grants from the University of Fort Hare.

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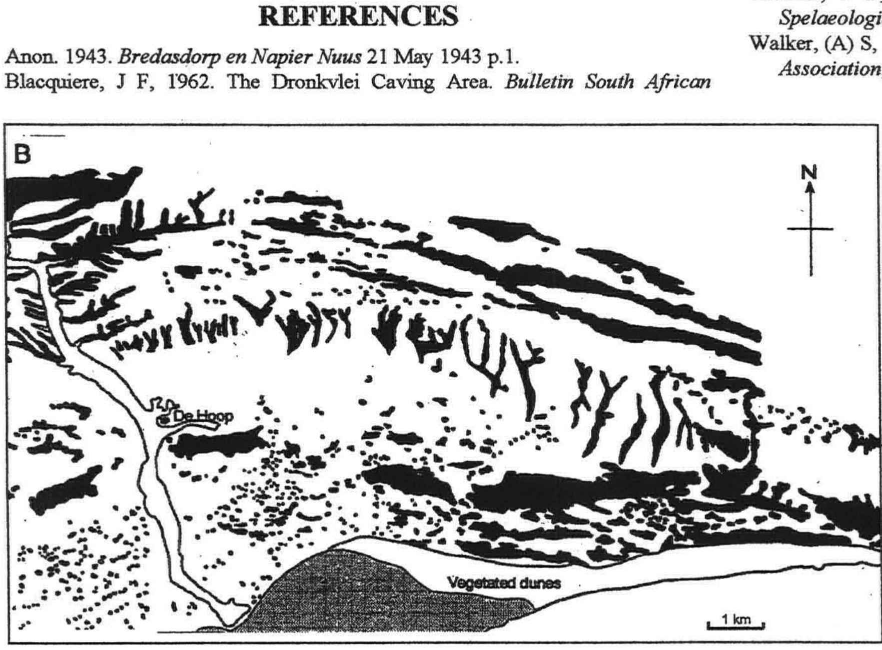


*Figure 5b: East of De Hoop Vlei.*