KARST IN SOUTHERN AFRICA

by Margaret E. MARKER * and Frances M. GAMBLE **

Resumen

En el presente trabajo se revisa la distribución de las rocas karstificables en África meridional, distinguiendo entre dos clases predominantes: las calizas dolomíticas proterozoicas de textura esparítica, propias de las mesetas interiores, y las calizas arenosas terciarias de la costa, cuya textura es micrítica. La densidad de formas kársticas superficiales es variable y comparativamente baja en relación con otras regiones. Las cuevas corresponden a un origen freático-somero y pueden contener abundantes espeleotemas. Se han podido detectar dos fases principales de crecimiento, aunque la precipitación moderna es menos intensa. El más importante período de karstificación puede ser atribuido a tiempos considerablemente remotos.

Los impactos ambientales sobre el karst de África meridional abarcan desde cambios en la hidrogeología debido a la extracción de agua con fines económicos, pasando por el drenaje de minas y las modificaciones en la cubierta superficial, hasta efectos directos resultantes de actividades mineras, en especial para la obtención de oro, de guano de murciélago y primitivamente de espeleotemas. Algunas rocas madres son empleadas en minería para su aprovechamiento en la fabricación de acero. Hasta ahora los problemas causados por la contaminación son de escasa importancia. Las cuevas situadas cerca de los principales centros de población sufren impactos de utilización que a menudo pasan inadvertidos. Las consecuencias de nuevas instalaciones militares, junto a Bredasdorp están siendo objeto de seguimiento. En África meridional se cuenta con las bases necesarias para la realización de programas efectivos de gestión ambiental.

Abstract

The paper reviews the distribution of karst rocks in southern Africa and distinguishes between two dominant types: the sparitic Proterozoic dolomitic limestones of the interior plateaux and the Tertiary micritic sandy limestones of the coast. The density of surface karst forms is variable and low by comparison with overseas regions. Caves are shallow phreatic in origin and may contain massive speleothem development. Two major phases of growth are recognised. Modern precipitation is minor. The major karst forming period is believed to be of considerable antiquity.

The impacts on southern African karst range from changes to the geohydrology due to economic extraction, mine dewatering and changes to the surface cover, to direct effects of mining particularly for gold, for bat guano and formerly for speleothems. Some host rock is directly mined for use in steel making. Pollution is so far of minor importance. Caves near major population centres suffer user impact which is often inadvertent. The consequences of a new military installation near Bredasdorp are being monitored. In southern Africa the basis exists for effective management programmes.

Potential karst host rocks cover 50.000 km^2 in Southern Africa [1]. This is 1.9 % of the total area. There are two extensive karst host rock types (Table 1): the Proterozoic dolomitic limestones of the interior plateaux and, secondly, the Tertiary Coastal Limestones [2]. The dolomitic limestones are resistant, sparitic, well-jointed and highly lithified ancient rocks. Chemically they are not true dolomites, being $CaMg(CO_3)_2$ rather than $CaCO_3.MgCO_3$, and they do not weather to dolomitic gruss. Beds with low magnesium ratios, almost pure limestones, occur in the middle sequence (Button, 1971). Although deposited in separate, shallow tidal basins, the Transvaal Sequence containing the Chuniespoort

* Fort Hare University
P. Bag X 1314
Alice 5700. Rep. of the Ciskei
** P.O. Box 51218
Raedene. Johannesburg 2124. Rep. of South Africa

[1] Defined as the Republic of South Africa as of 1960, Namibia, Botswana, Lesotho and Swaziland.

[2] The informal term Coastal Limestone was coined by Siesser (1972) to include the Langebaan Formation, the Alexandria Formation, the Bredasdorp Formation and the Uloa Formation.

Formation and the less extensive Duitschland Formation of the Malmani Subgroup are similar lithologically to the Campbell Rand Group of the Griqualand West Sequence of the Northern Cape Province (Brink, 1979). Both Sequences exhibit considerable stromatolite and algal dome development resulting from deposition in a tidal lagoonal environment (Eriksson, 1977).

In contrast, the coastal limestones are soft, variably pure, weakly jointed and dominantly micritic, sandy limestones. These Coastal Limestones outcrop discontinuously on land around the coast of southern Africa from Saldanha Bay to Zululand, but on the Continental Shelf are more continuous (Siesser, 1972; Fig. 1). In addition there are also areas of Palaeozoic Damara marble and associated limestones in Namibia and western Botswana. Palaeozoic Cango Limestones outcrop within the Cape Fold Belt and Tertiary calcretic, impure limestones have limited occurrence along the inner margin of the Namib desert. There is a basic division between ancient, hard carbonate rocks above the Great Escarpment and the younger, softer micritic limestones below. The only exceptions are the Damara marble outcrops within the Namib desert and the Cango Limestone outcrop.

Surface karst forms have a low density overall and strongly karstified areas are very localised. Inland above the Great Escarpment the karst landforms are of considerable antiquity, apparently being initiated contemporaneously with the evolution of the mid-Cenozoic African planation surface. The almost ubiquitous presence of insoluble terra rossa type residues limits surface karst expression and causes infilling of hollows and blocking of major cave systems.

Virtually all major caves are shallow phreatic in origin, drought restricting the presence of point input and therefore vadose development. Speleothems are massive in some caves, indicating two major periods of deposition interrupted by resolution. Recent deposition is on a small scale only.

Below the Great Escarpment the karst of the Coastal Limestones is associated with a suite of Cenozoic marine benches from 250 m altitude to below present sea level (Marker, 1985). The highest density and largest amplitude surface karst forms are associated with the 240 m and 200 m benches (Marker and Sweeting, 1983; Russell, 1985), also suggesting a mid-Tertiary period of maximum development. Caves are rare with the exception of the Bredasdorp area, where they tend to be prefe-

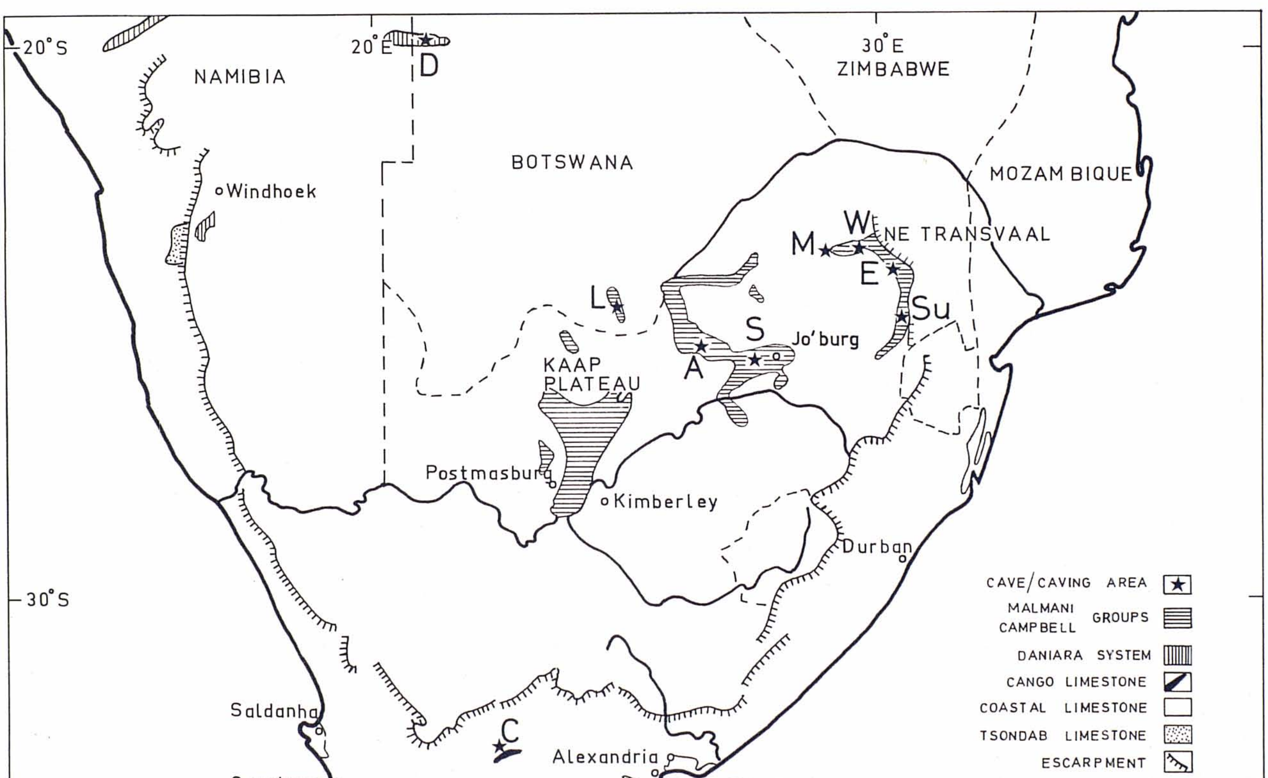

Figure 1: Karst areas of southern Africa (A = Apocalypse, C = Cango, D = Drotsky's Caves, E = Echo, L = Lobatse Caves, M = Makapansgat, S = Sterkfontein, Su = Sudwala, W = Wolkberg).

CLASSIFICATION	LOCALITY	ROCK FORMATION	AREA (km²)	ANNUAL RAINFALL (mm)	TOTAL AREA (km²)
SPARITES	NE Transvaal	Transvaal Sequence	3025	550-1200	
	Marble Hall	Malmani and Duitschland Groups	450	600	
	Central and N Transvaal	(dolomitic limestones)	10450	450 - 600	
	S Transvaal		350	650	
	Botswana		1000	200 - 400	
	Kaap Plateau	Griqualand West Sequence	17500	350	
	Postmasburg-Sishen	Campbell Group	900	300	
	Prieska	(dolomitic limestones)	300	300	
	Botswana	Damara System	115	450	
	Namibia	(marble and limestone)	7775	200 - 400	
	Cango	Cango Limestone	175	350	
					42040
MICRITES	W Cape	Coastal Limestone	525	400	
	S Cape	Longebaan Fm	2575	500 - 700	
	E Cape	Bredasdorp Fm	2300	500 - 700	
	Zululand	Alexandria Fm	1850	1000	
	Namibia	Tsondab Limestone	450	250	
					7700
					49740

Table 1: Karst areas of Southern Africa

rentially located beneath the 60 m and 30 m benches. The cohesive strength of the Coastal Limestones in most areas restricts cave development. Nevertheless the existence of major springs with distinct chemical characteristics suggests that the existence of major conduits is far more general than the existence of enterable caves.

The best-known karst areas are the central and south-western Witwatersrand, in the vicinity of Sterkfontein and Carletonville respectively (Brink, 1979; Gamble, 1981; Moon, 1973), the north-eastern Transvaal (Marker, 1985), and the Alexandria and Bredasdorp areas on the Coastal Limestones (Marker, 1981; Marker and Sweeting, 1983; Russell, 1985). Elsewhere isolated sites have been investigated as in the Namib (Sweeting and Lancaster, 1984; Marker, 1982), but much more detailed work is required.

Impacts on Southern African Caves

Southern African caves are particularly distinctive and vulnerable because of the resistant nature of the host rocks, especially the dolomites, and the semi-arid characteristics of the areas in which most of them have formed through phreatic processes. Resultant cave dimensions are small, cave entrances are usually single, cave temperatures are comparatively high and cave systems are generally dry.

A number of caves intersect the water table with a resultant occurrence of underground pools or lakes such as that in Sterkfontein. Running water is known in only 1 % of the dolomite and limestone caves. This means that weathering and erosion processes are usually very slow and that the food chain is very limited in the majority of caves (Gamble, in press).

The major threats to the cave ecosystem are associated with urban and peri-urban sprawl and with major development projects such as the construction of roads. They are manifiest in both surface and subsurface disturbances, and most commonly include extraction, construction, pollution especially of air and water, research and recreation impacts (Fig. 2).

EXTRACTION affects both the host rock and its secondary contents such as water.

— Dolomite and limestone are used as flux or as a source of manganese for the metallurgical industries, posing ever-increasing threats to the karst areas, including the caves.

- At approximately the turn of the century speleothems were extracted during small-scale mining operations in order to produce slaked lime for the building industry. At present extraction of speleothems is confined mainly to limited removal for research purposes, or to more extensive removal as part of the casual vandal and souvenir trade.
- Since the late nineteenth century deposits of bat guano in local caves have been excavated by farmers as a source of fertilizer.
- In semi-arid to arid areas, where surface water supplies are limited, increasing reliance is placed on ground water. Lowering of the water table results from pumping to facilitate sub-water table mining, and the provision of water for surface activities such as irrigation, and industrial and domestic developments. Sub-water table mining is extensive near Carletonville. In 1970 the town of Bank had to be abandoned because of the hazards resulting from sinkhole development consequent upon the dewatering of the dolomite for gold mining on the West Rand. At present a borehole project of the Department of Water Affairs threatens extensive karst areas in the central Witwatersrand as a result of major water extraction schemes to alleviate the current drought.
  The impact of increasing peri-urban sprawl, particularly in the areas close to Johannesburg, is already evident in the number of long-term boreholes which have dried out as a result of the increasing demand for water on the smallholdings in the area.

CONSTRUCTION and the provision of services are associated with all development activities in karst areas. The specific disturbances associated with these alterations are several and complex, manifest mainly in the alteration of surface water-flow patterns and the consequent dehydration of karst and cave areas. In all instances there is encroachment of artificial surfaces in the form of roads, buildings, parking lots, agricultural lands and some levelling of the area by infilling. All such activities decrease percolation and increase surface runoff.
Increased loading by surface structures may also have some impact, particularly where instability of

PARTY	ESTABLISHED AREA OF CONCERN
NATIONAL LEGISLATION AND CONTROLS	
Dept. of Water Affairs, Forestry and Environmental Conservation	Permits to enter forest and water reserves
National Parks	Act protecting geological forms
National Monuments	Act proctecting individual sites e.g. Sterkfontein Cave
Mines and Minerals	Act pertaining to damage through mining
Dept. of Defence	Permits to enter military areas
Homeland Governments	Permits to enter homelands
PROVINCIAL LEGISLATION AND CONTROLS	
Peri-urban Board	Deterrent notices at caves
Provincial Nature Conservation	Legislation and Ranger control
SPELEOLOGICAL ORGANISATIONS	Conservation - cleaning; gating; advice
PRIVATE PROPERTY OWNERS	Subjective control - mainly acces, e.g. Sudwala Cave and show caves
UNIVERSITY SCIENTISTS	Restricted access to sites, e.g. Makapan Cave
ENVIRONMENTAL ORGANISATIONS	Conservation areas, e.g. Wildlife Society of Southern Africa
PUBLIC PARTICIPATION	
Gem and Mineral Clubs	Speleothem supplies
Gemstone Retailers	

Table 2: Parties to whom cave management is of concern in southern Africa (*after:* Gamble, 1981b).

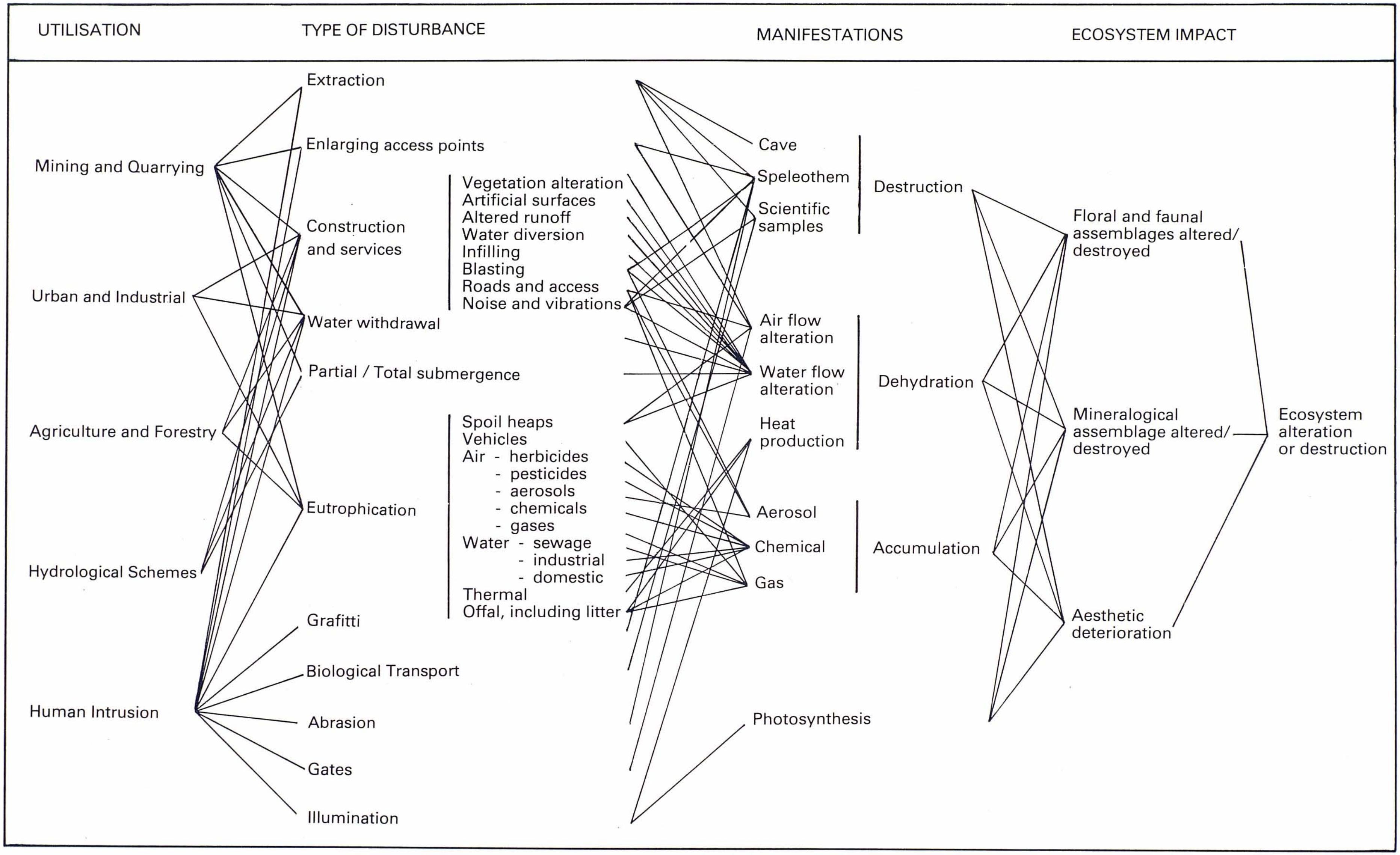

Figure 2: Summary of the disturbances and their impacts on a karst cave ecosystem.
These disturbances are regarded as possible, their occurrence and magnitude being dependent upon the cave itself and the nature of the disturbance.

GEOGRAPHICAL	PHYSICAL	SOCIAL	MANAGEMENT PROGRAMME
Remoteness Rough Terrain Climate Vegetation Homelands Small, inaccesible caves Paucity of caves in South Africa	Cave destruction Cave Hazards Carrying Capacity of cave	Education Haste and thoughtlessness Cultural Diversity Dispersion, Diversity and non-involvement of general population Few speleologists Increased leisure and mobility Industrialisation Construction Economics	Trained manpower Expertise Economics Politics Effective legislation

Table 3: Problems of karst cave management in southern Africa (*after:* Gamble, 1981b).

underlying rock occurs. Vibrations, mainly as a result of blasting, noise and heavy vehicle movement may result in increased joint dimension and in damage particularly to cave systems.
The current development on the De Hoop Nature Reserve at Bredasdorp has been a source of national concern because of the anticipated possible impacts on the karst and cave area.

POLLUTION is derived in varying ways and to varying degrees from all activities in a karst area. It is usually inadvertent, in association with atmospheric, hydrological and solid waste pollution, resulting in the accumulation of gases, aerosols and chemicals. Atmospheric pollution is probably the least obvious, while water pollution is the most ubiquitous. In many areas remote from urban and industrial areas karst regions are subject to solid waste disposal in caves and sinkholes, the consequences of which may be long-term and dramatic.

RESEARCH AND RECREATION of necessity impact karst areas and especially the caves as there is increasing pressure on wilderness areas. Damage to caves is most often in the form of compaction and abrasion, and is usually inadvertent. However, the impacts are usually more direct on a cave system and are very often irreversible. Tourists, scientists, cavers and casual visitors to caves all affect the cave ecosystem to varying degrees.

Awareness of caves which require conservation in their own right and for the protection of visitors is recent. Over time efforts at cave conservation in South Africa have taken several forms (Table 2), such as legislative controls, the construction of gates at cave entrances, the restriction of access by landowners, and educational programmes undertaken by concerned scientists and speleologists. The most important of the controls operating to protect the Southern African caves are cultural hesitation; the natural protection afforded by cave location and configuration; landowner control over access and legislative control such as the National Monuments Act, the Forestry Act and the Transvaal Nature Conservation Ordinance.

The problems associated with cave conservation are similar throughout the world, although each area has certain unique aspects (Table 3). In southern Africa the basis exists for future management programmes and several advantages exist in comparison with other parts of the world particularly in terms of time and circumstance.

References

BUTTON, A. (1971): The stratigraphic history of the Malmani Dolomite in the eastern and northeastern Transvaal. *Trans. Geol. Soc. S A*, 74, 229-247.

BRINK, A.B.A. (1979): *Engineering geology of southern Africa.* V. 1. Building Publications.

ERIKSSON, K.A. (1977): Tidal flat and subtidal sedimentation in the 2250 MY Malmani Dolomite, Transvaal, South Africa. *Sed. Geol.,* 18, 223-244.

GAMBLE, F.M. (1980): Disturbance of underground wilderness in karst caves. *Int. Jour. Envir. Stud.,* 18(1), 33-40.

GAMBLE, F.M. (1981a): The resource potential of Transvaal caves. *8th. Int. Cong. Speleol. Proceedings.* 466-468.

GAMBLE, F.M. (1981b): Problems of management of Transvaal caves. *8th Int. Cong. Speleol. Proceedings.* 469-471.

GAMBLE, F.M. (in press): Caves. *The South African Encyclopaedia.*

MARKER, M.E. (1981): Karst in the Bredasdorp area: a preliminary analysis. *S A Geogr.,* 9, 29-30.

MARKER, M.E. (1982): Aspects of Namib geomorphology: a doline karst. *Palaeoecol. Africa.,* 15, 187-199.

MARKER, M.E. (1985): Karst areas of southern Africa *1st. Int. Conf. Geomorph.* In Press.

MARKER, M.E. and SWEETING, M.M. (1983): Karst development on the Alexandria Coastal Limestone, eastern Cape Province, South Africa. *Zeit. f. Geomorph.,* 27, 21-38.

MOON, B.P. (1973): Factors controlling the development of caves in the Sterkfontein area. *S A Geog. Jour.,* 54, 145-151.

RUSSELL, L. (1985): Karst development: the application of a systems model. *1st. Int. Geomorph. Conf.* In press.

SIESSER, W.G. (1972): Petrology of the Cainozoic Coastal Limestones of Cape Province, *Trans. Geol. Soc. S A.,* 75, 178-185.

SWEETING, M.M. and LANCASTER, I.N. (1984).