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SECTION 5
THE NATURAL RESOURCE AND CONSERVATION

HOW WELL OFF IS AUSTRALIA FOR CAVES AND KARST?

A BRIEF GEOMORPHIC ESTIMATE

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ABSTRACT

The cave provinces of Australia are discussed in terms of the geological, physiographic and climatic factors which limit karst development. The optimum terrain for karst is mountainous, wet and with abundant limestone. Australia is dry, flat, and generally deficient in limestone, hence caves are comparatively rare. This overall scarcity of caves makes proper conservation all the more necessary.

In the *Report of the National Estate* (1974), an impressive document despite the short time allowed for its preparation, it is stated on the basis of writing of mine (Jennings 1967) that "Australia generally is poorly endowed with caves, although Tasmania perhaps reaches the world average". I understand that this assessment does not tally with some at least of many submissions made to the Federal Government's Committee of Inquiry by speleological organizations. Therefore I think it will not be out of place on this occasion to defend and explain my conservative standpoint, though I will enlarge its scope to comprise karst rather than caves alone. This extension will not invalidate consideration of the matter since most of our caves are in fact in karst, indeed in carbonate rock, for evaporite karst is virtually absent from our country.

Of course a proper quantitative analysis is impossible at the moment. Inventories of caves are by no means generally available nor are they uniform in basis where available. Where there are many big caves, small caves will go unrecorded; in areas poor in caves, the tendency will be to list them all. In any case numbers alone provide an inadequate basis for comparison; dimensions are clearly necessary. In this latter respect information is even more incomplete and unequal. On the world scale at the moment, cave cadasters probably more closely reflect the distribution of speleological activity than that of caves themselves. Referring to submissions about caves by speleological organisations, the *Report of the National Estate* makes the remark that "this aspect of the National Estate is therefore probably better documented than any other". Australian cavers may take some pride in that. Nevertheless factors of knowledge and ignorance affect assessment of caves and karst in Australia as much as in many other parts of the world. Many caves remain to be discovered in karst areas remote from the main centres of population. I need only remind you that the Nullarbor is some 2,000 km by road from Sydney, the centre of gravity of Australian caving activity, and the Limestone Ranges of West Kimberley some 5,000 km; these are the two largest karst areas in the continent.

Nor is it possible to approach the matter by comparison of proportions of karst rocks to total area in different parts of the world. Although geological maps are now available for the whole world at least on small scales, these represent geological formations which frequently comprise many types of rock within their

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sequences and which commonly change in facies laterally. What are needed are lithological maps and these are much less complete in coverage. Thus maps showing the distribution of limestone and dolomite are not available for most of Australia. Moreover even if we had such maps, they would furnish a weak basis on their own since different karsts vary very much in caves per unit area for many reasons. So one is forced to approach the question inferentially and to a substantial degree subjectively. This is the best that can be done now; if my arguments can be proved wrong, I shall of course be as pleased as anybody by the implication of my errors.

Of the several reasons why there is less karst and why there are fewer caves in Australia than in most other continents or subcontinental areas of equivalent size, the most important is geological structure. Much of the western half of the continent consists of Precambrian Shield, of ancient crystalline basement. Indeed as a whole the continent tends to be older than others. Many of its rock systems antedate significant life forms and much carbonate rock depends for its formation on the calcareous skeletons of marine organisms. On the average the older the rock system the less the proportion of carbonate rocks. From Cambrian times onwards, this may be due mainly to the greater solubility which characterises them and makes them more likely to be removed into the sea during denudation than most other rocks; the older the rocks the more likely it is that this will have happened.

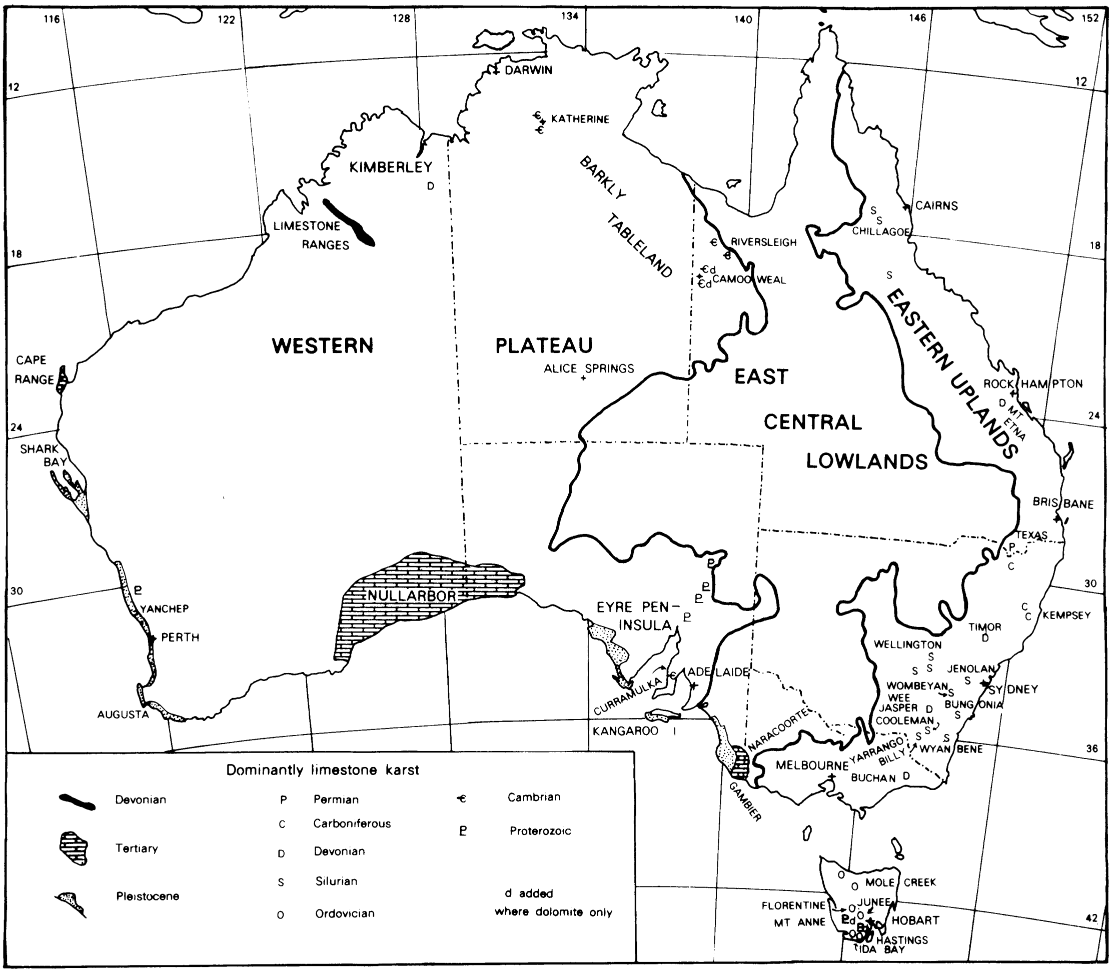

Figure 1. Distribution of Karst in Australia

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Moreover the older the rocks the greater the proportion of dolomite to limestone amongst the carbonate rocks. Primary dolomites are of course particularly important in early geological times but even more voluminous are secondary dolomites due to dolomitisation of limestones. The older the rock formation the greater the chance of this having happened. Of course dolomites are not without caves and other karst features as Buchan in Victoria (Sweeting 1960) and Camooweal in Queensland remind us forcibly. Nevertheless proportionately they are not as rich in caves and other karst features as limestones because they are not so readily soluble and dolomite sand is a cause of blockage of incipient caves.

Tertiary orogenic belts are often, though not universally, rich in limestones and so in karst and caves. Australia is the only continent without such tectonic belts. The accident some 5-6,000 years ago of the flooding of the shallow continental shelf between Australia and New Guinea which created Torres Strait has resulted in Australia being an incomplete continent tectonically, incomplete in a disastrous way for speleologists. Of course this is a narrow nationalistic way of looking at things.

From New Guinea to New Zealand, folded mountain ranges lie within a reasonable distance of this country in terms of modern travel and these ranges have a higher proportion of carbonate rock outcrop than is true for Australia as a whole. There is thus a geological basis for the rapidly growing activity of Australian cavers in this nearby island chain.

Of course not all carbonate rock will form karst and caves even when other necessary conditions are satisfied. High mineral purity and adequate mechanical strength are required for the kind of geomorphic action and response involved. It is hard to make an overall subjective assessment of Australian carbonate rocks in these respects. One may hazard the guess they are as a whole at least up to the world average.

It is not sufficient that a suitable rock shall be present for karst development. Other conditions must be satisfied, notably the availability of water, which can fashion the surface by solution and may develop underground circulation, initially capable of corrosive action alone but later acting corrasively as well when movement becomes sufficiently free. In this regard, there is the blunt fact that, setting aside Antarctica, Australia is the driest continent. Two-thirds of the continent is arid or semi-arid. To speak of the dead heart of Australia is as relevant for the speleologist as it is for other students of nature. Of course, ancient karst features and caves may survive into the present from former times more favourable in terms of water availability, whether this be by dint of increased precipitation or reduced evaporation. Inheritance of this type certainly contributes to the array of caves in this country. This is true, for example, of the Nullarbor karst where present signs of active cave formation are negligible in the presence of some substantial systems. Nevertheless we must be careful not to overstress this factor of inheritance. From the same region comes evidence of prolonged aridity. Whereas Permian sandstones in the Great Victoria Desert immediately to the north are well lateritised, indicative of former marked soil water movement and so of at least seasonally humid conditions, the Colville Sandstone of the adjacent northern part of the Eucla Basin is unlateritised (Lowry & Jennings 1974). This registers dominantly arid conditions since the sandstone emerged in Middle Miocene times. The dead heart of the continent has been so a long time.

The third major factor governing the development of karst and caves is relief to promote active circulation of underground water and also to permit more cave to develop per unit area by storeys. Australia is basically unfavourable in this respect also. It has the lowest mean elevation and the lowest maximum elevation of all the continents. The continent is one of plains and plateaus, rather than of mountain ranges. It is true, of course, that the largest cave system in the world by far, the Flint Ridge-Mammoth Cave system of Kentucky, of over 250 km, belongs to plateau karst. However as antidote we need only remember how long

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Switzerland's Hölloch maintained the greatest length record with some 78 km of length squeezed into a horizontal area of some 5 km by 2 km. It is of course not absolute altitude that signifies but local or relative relief in carbonate rocks. If Hannel's Spur from the Swampy Plain River to Mt. Townsend summit in the Snowy Mts. with its 1,700 m of relative relief had happened to be developed in limestone, there would have been the chance for this continent to have held the world's depth record for a time at least. Nevertheless even in this matter of relative relief, Australia on the average falls behind other continents.

Given these overall drawbacks, what is the pattern of Australia's caving world and what is its nature in general terms? The pattern is to quite a marked extent peripheral. Though precipitation (and the location of speleologists) is similarly peripheral, the prime cause of this marginal distribution of karst is structural. The Eastern Uplands from Cape York Peninsula to Tasmania have formed from Palaeozoic geosynclines. In similar structural conditions have developed the important karsts of eastern U.S.A. and of Britain. The Western Plateau of Australia mainly comprising the Precambrian Shield has important peripheral sedimentary platforms and basins of various ages where the shallow seas of continental shelves have overlapped onto the crystalline basement of the continent from time to time. The East Central Lowlands from the Gulf of Carpentaria to the Murray R. mouth also rest for the most part on similar sedimentary basins but for the most part these lack adequate relief and also carbonate rocks. The one exception to this is South coastal.

Let us now consider the essential features of these peripheral parts from the point of view of karst.

The Eastern Uplands, including Tasmania, consist of dissected plateaus. The former mountain ranges created here by several Palaeozoic orogenies from geosynclinal sediments were all planated by the end of Mesozoic time and then in the Cainozoic these erosion surfaces were uplifted epeirogenetically with some faulting to yield the highest land in the continent. Unfortunately the geosynclines and associated continental shelves were not rich in carbonate sediments, still less in evaporites. This was probably due to great oceanic depths close into the continent (K. Crook, personal communication) and presents a remarkable contrast with the modern presence of the Great Barrier Reefs off Queensland, the biggest reef system in the world today. Nevertheless from time to time small patches of carbonate sediment were deposited amongst the vast bodies of clastic sediment of non-karstic nature in the seas margining the east of the continent and these were successively incorporated into the land by eastward continental drift and mountain building through crustal plate collision.

From these patches have come our many but small impounded karsts of generally steeply dipping Ordovician, Silurian and Devonian carbonate rock, of limestone, dolomite and marble, from southern Tasmania to the north of the Atherton Tableland. Rarer are older Cambrian and younger Carboniferous and Permian karst rocks. Mostly they are exposed in the valleys and gorges which incise the tablelands, rather than on the plateau surfaces themselves, because on the whole they are less resistant to denudation than the impervious rocks. Despite their small sizes of a few km^2, these karsts are frequently furnished with many caves and a variety of karst surface forms , though naturally larger features such as poljes are lacking and uvalas rare. Also because of their small size they are much influenced by surface drainage from surrounding higher impervious rocks with their usually quite unsaturated waters and their gravel and sand armoury. Cooleman Plain in southern New South Wales, which forms part of the upland surface over most of its area illustrates the vital role that rejuvenation of the rivers through uplift has on the underground water circulation in the karst rocks and so on cave development. Away from the gorges still invading this karst there are tiny caves or none at all. A significant theoretical implication is that true phreatic cave formation with slow moving water beneath a planation surface is of modest importance.

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Where the karst rock has been subject generally to dissection and (apart from flooring the valleys) forms barriers across them (e.g. Jenolan, Sussmilch & Stone 1915) or benches along them (e.g. Yarrangobilly), one of the most characteristic attributes is the alternating sequence of quasi-horizontal epiphreatic levels and vadose canyon development. This alternation reflects varying rates of plateau uplift and inversely correlated stream erosion. Today along active cave streams, free surface stream passages may alternate with water-filled sections showing how intimately related these two fast-flowing but different hydrodynamic conditions are (e.g. at Wombeyan). Highly unreliable climates in terms of precipitation such as prevail almost everywhere in Australia still further blur the distinction between vadose and epiphreatic stream activity though frequent wide variation in water levels. Abandoned levels of these caves in the Eastern Uplands in N.S.W., Victoria and Tasmania are commonly very rich in speleothems, perhaps most distinctively in the variety and proportion of eccentric decorations, though this is not to say that all active stream passages are devoid of decoration.

Usually cave streams flow out from passages at or close to valley floors but Bungonia is remarkable for the high level at which springs occur above the gorge bottom; here rejuvenation has proceeded so fast that karst preparation of the lower levels of the limestone has been unable to keep pace (Sydney Spel. Soc. 1972). The caves here show marked vertical developments in part of the same cause, though the greatest mainland cave depth has passed to Yarrangobilly (Pavey 1974). However Bungonia retains certain other distinctions, notably the breaching by the main underground stream of a barrier of impervious rocks (Jennings & James, in press) and much higher carbon dioxide levels in cave atmosphere than is common for Australia, with consequences of great interest, particularly in terms of cave sediments (J.M. James, pers. comm.).

The northern and southern extremities of this eastern belt of uplands require separate comment. In Tasmania, Ordovician limestones dominate the karst scene and a higher proportion of carbonate rocks appears to have accumulated in this southernmost part of the Palaeozoic geosynclinal belt. With this passive factor favouring karst is combined the dynamic factor of higher absolute precipitation and even higher effective precipitation because of lower temperatures on most of Tasmania's karsts. The net result is greater karst and cave development proportionally in this state than in others. It is no accident that the largest known cave system is Exit Cave in wet, cool, rain-forested southern Tasmania. Generally the Ordovician limestone is just as recessive in the relief as N.S.W. and Victorian karst is but resistant dolerite caps preserve it at times high up valley sides and on plateau flanks so that the Australia depth record has long resided in Tasmania from the days of Growling Swallet to the present reign of Khazad-dum. Whatever happens to the length record where sheer area of karst can intervene, the depth record is virtually bound to stay in Tasmania. Corrasional activity is more positively in evidence in some Tasmanian caves than elsewhere in the continent with boulder trains in active transit through them, e.g. Marakoopa Cave, Mole Creek.

Another special character best developed in the southernmost state (and on Cooleman Plain at 1,200 m in southern N.S.W.) is the role of cold climate effects in karst development. Pleistocene proglacial and periglacial conditions seem to have led to conflicting influences on cave development. On the one hand such loads of sediment were set in movement in more ways than one that they led to the blocking of caves and their entrances, with the restoration of surface runoff in karst; on the other hand snow and ice meltwater could be of such volume and so directed onto limestone that cave development was promoted (Jennings & Sweeting 1959; Goede 1969; Goede 1973; Jennings, in press). In this connection it is important to note that permafrost is apparently absent; the cold periods were not sufficiently rigorous.

The Mole Creek karst in Tasmania is somewhat more extensive in area than most in the Eastern Uplands and here our nearest relatives to poljes are found, as well as an indubitable hum in Dog Hill.

But it is not surprising that we must turn to the northern part of the Eastern Uplands to find a dominance of residual karst forms. At Mt. Etna and nearby, practically on the Tropic of Capricorn, the residual hills are more like hums than tropical sinoids or towers but the density of cave development and the frequency of daylight holes in them is more reminiscent of tropical humid karst (Shannon 1970). In the Chillagoe - Walsh River area of N. Queensland (Sydney Spel. Soc. 1969) there is however a typical tower karst if of modest relative relief (no more than 100 m at the most). These intricately sculptured castles of limestone are separated by pedimented plains chiefly truncating steeply dipping interbedded impervious rocks. Network caves with many light holes are developed at plain level almost entirely. Decorations have a dry aspect but are active in the wet season.

In the Southeast of S. Australia, overlapping slightly into western Victoria, is the one karst area of the East Central Lowlands. This is developed in the Oligocene Gambier Limestone, permeable in the mass as well as along joints and horizontally disposed. This is a free karst, reaching to the Southern Ocean. Its most distinctive attribute in the Australian context is the occurrence of fine cenotes, largely water-filled collapse dolines. Some of them extend well below sea level and underground circulation during glacial low sea level times in the Pleistocene probably played an important part in their formation, though the arguments of Galloway (1970) maintaining that these periods were too short for the development of coastal drowned valleys, may apply also to these deep cenotes and Late Tertiary tectonoeustatic sea level changes may also be involved. Interesting cave systems at Naracoorte are not waterfilled and may relate in development either to faultlines or to buried former marine clifflines in the Gambier Limestone.

The Tertiary faultblock terrain of South Australia, comprising the Mt. Lofty-Flinders Ranges and Yorke Peninsula and the intervening gulfs of the sea, is successor to folded mountain ranges of a Precambrian geosyncline and orogeny. Incorporated in these structures are some Precambrian limestones and dolomites. It is possible that prolonged semi-aridity in the Flinders Ranges has hindered cave development there though a few presently inactive caves are known. Evaporites involved in the Blinman diapir have long since been removed. At Curramulka in Yorke Peninsula in horizontal Cambrian limestones there is the striking three-tiered maze complex of Corra-Lynn Cave, perhaps as clearcut an example of joint control of true phreatic solution as is to be found anywhere in this country.

In contrast with these small occurrences of tough, ancient carbonate rocks in complex geological structures comes the huge extent of virtually horizontal, weak Eocene and Lower Miocene limestones of the Nullarbor karst straddling the S.A. - W.A. border, an enormous free karst of some 200,000 km^2. Lowry & Jennings (1974) have recently reviewed the characters of this karst retarded by aridity prevalent since it emerged from the sea in Middle Miocene times. Minimal surface erosion has taken place; instead deflation of an insoluble residual soil cover over most of its extent is one of the more striking geomorphic events. Water action is minimal today in the caves which appear to be largely the work of solution during low sea levels of glacial times when also precipitation was more effective though absolutely less than at present in all probability. This solution has been followed by substantial upward stoping to produce cave forms largely representing equilibrium collapse shapes. Though large and deep caves are few for the area, they are nevertheless voluminous and recent successful diving of waterfilled sections gives promise of extension to what may prove to be very great lengths of which there are surface clues. Particular traits of distinction are halite speleothems and atmospheric weathering of cave walls through salt crystallisation. In these and many other respects the Nullarbor karst bears the stamp of aridity.

From Cape Leeuwin to Shark Bay, W. Australia is fringed practically continuously by a narrow seam of limestone of a kind more extensively developed in Australia than in any other continent. This is Pleistocene dune limestone or aeolian calcarenite. Even though this kind of limestone is found at intervals from N.W. Tasmania through to Cape Leeuwin, reference has been delayed until this juncture because it is in the main Western Australian belt that karst characteristics become most pronounced. Beach sand dominantly of calcareous nature and of biological origin has been blown inland in more than one phase, from at least 100,000 years ago (Teichert 1967); various degrees of induration have since been achieved through surface leaching of calcium carbonate and reprecipitation at lower levels in the profile. Karst and cave development may proceed in part concomitantly with this process of diagenesis, i.e. we have, to a degree, syngenetic karst. Though some karst features such as solution pipes of a rather special kind may occur more or less everywhere through this long coastal limestone belt, more elaborate features including collapse dolines and caves are confined to particular parts (not necessarily the rainiest), from Kangaroo Is. and Eyre Peninsula in the east to the Southwest of W. Australia between Cape Leeuwin to Cape Naturaliste and between Yanchep and Aramall Lake. In these weak materials, still in process of lithification terrestrially, collapse and rockfall are very prominent in the caves but this has not prevented a wide array of speleothem construction from beautifying many of them. Eccentric decorations can be important and the exceedingly long straw stalactites of Jewel and Strong's Caves in the Southwest are outstanding at the world level. Gorges of construction, well represented by Deepdene in the same Southwest, are also peculiar to this special kind of karst.

Though karst development is modest as yet, the Miocene limestone of Cape Range in the Exmouth Gulf area of W. Australia warrants brief mention because it has been folded into an anticlinal ridge of 300 m height by Late Tertiary orogenic movements. Limited times and aridity have combined to restrict cave development to potholes no more than 20 m deep (Cook 1962).

There is far from a poverty of karst forms in the semi-arid but much older karst of the Limestone Ranges of W. Kimberley. Here Devonian limestones have been exposed to terrestrial attack at least through the whole of the Tertiary but probably for a much longer period than that, perhaps back to the beginning of the Mesozoic. They form low ranges up to 100 m high and 30 km wide over a stretch of country some 290 km long, transected by fine gorges of superimposition of rivers extending from the rugged heart of the Kimberleys. Thus this karst is not recessive but stands up in the landscape as at Chillagoe. Minor surface sculpture is developed to an incredible degree and the larger landforms constitute a scenically fantastic and scientifically most interesting sequence from an initial undissected Tertiary planation surface. First this is cut up into "giant grikeland", networks of closed corridors up to 30 m deep and 10-15 m across, hundreds of metres long. From these develop small poljes and rectangular valley systems of box cross-section. Gradually these are pedimented away by lateral retreat of wall-like margins or reduced to a tower karst resembling that of Chillagoe. Cave systems tend to be fragmented by openings to the surface in the giant grikes but the largest system as yet incompletely mapped must consist of some 5-6 km of fissure passage in network array at the levels of the pediments around (Lowry 1967). One great problem attaches to this karst. Is it a product of the very modest rainfall of a short wet season of about 3 months when a few but intense storms occur, supporting but a meagre vegetation? Or is it a karst inherited from wetter climate in the Pleistocene or even the Late Tertiary (Jennings 1969)? As yet the only evidence of climatic change in the area points to drier conditions than at present. Pedimentation reaches its greatest perfection in semi-arid climate and certainly the pediments here are as perfect as any.

Horizontal Cambrian carbonate rocks occur sporadically from the Daly River basin in Northern Territory through the Barkly Tableland into northwest Queensland. Of all substantial areas of potential karst rock these are the least studied in the continent. In the Katherine area limestones, only shallowly dissected or undissected, show limited surface karst attributes, though cave systems of some length, up to 2-3 km, are known, horizontally developed not far below the surface. Like the W. Kimberley caves, they alternate between a long dry season of inactivity and a short season of sharp flooding. Recent stripping of a former sandstone cover may explain much of the nature of this karst.

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Around Camooweal, dolomites give rise to much the same kind of karst, though here the caves reach more deeply - up to 100 m below the surface in some of their horizontal development. Though recent exploration chiefly by the University of Queensland Speleological Society has shown the caves here to be more extensive than previously realised, an old problem (Danes 1916) remains unsolved. Where do the waters of these caves emerge? No large springs are known in the Georgina drainage to the south. It is true that some of the supposed lacustrine limestones of Tertiary age here are more likely to be valley trains of stream origin (P.W. Williams, pers. comm.) and these could relate to past periods of greater spring activity than at present, in part fed from the Camooweal area. Or do these waters pass northwards into Cambrian limestones in the rugged northern fall of the Barkly Tableland in the Riversleigh area where amongst low, dissected karst, some of it consisting of modest towers, large springs are the perennial sources of rivers such as the Gregory flowing to the Gulf of Carpentaria? If the Camooweal caves can be shown to feed the Gulf of Carpentaria in this manner instead of flowing to the Georgina and the L. Eyre basin, it would indeed be a long distance karst hydrological system of considerable interest.

The purpose of this brief, highly selective and subjective survey of Australian karst has been first to sustain a general assessment that quantitatively this continent is by no means rich in caves and associated karst features. This is offset only marginally by a comparative richness in volcanic karst and caves in western Victoria (Ollier 1963) and in several parts of Queensland (Graham 1971). Secondly this survey has tried to illustrate the point that despite this comparative poverty in number and size, there is scenic variety and scientific value of considerable qualitative importance. Rather than diminishing the importance of a proper conservation policy with regard to this portion of the national estate this estimate renders the need for and the wisdom of such conservation both more urgent and more powerful. We must urge this outside the ranks of cavers. Withal let us not distract ourselves by such high sounding phrases from the unpleasant truth that the activity of cavers itself is the biggest danger to this part of our national heritage.

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