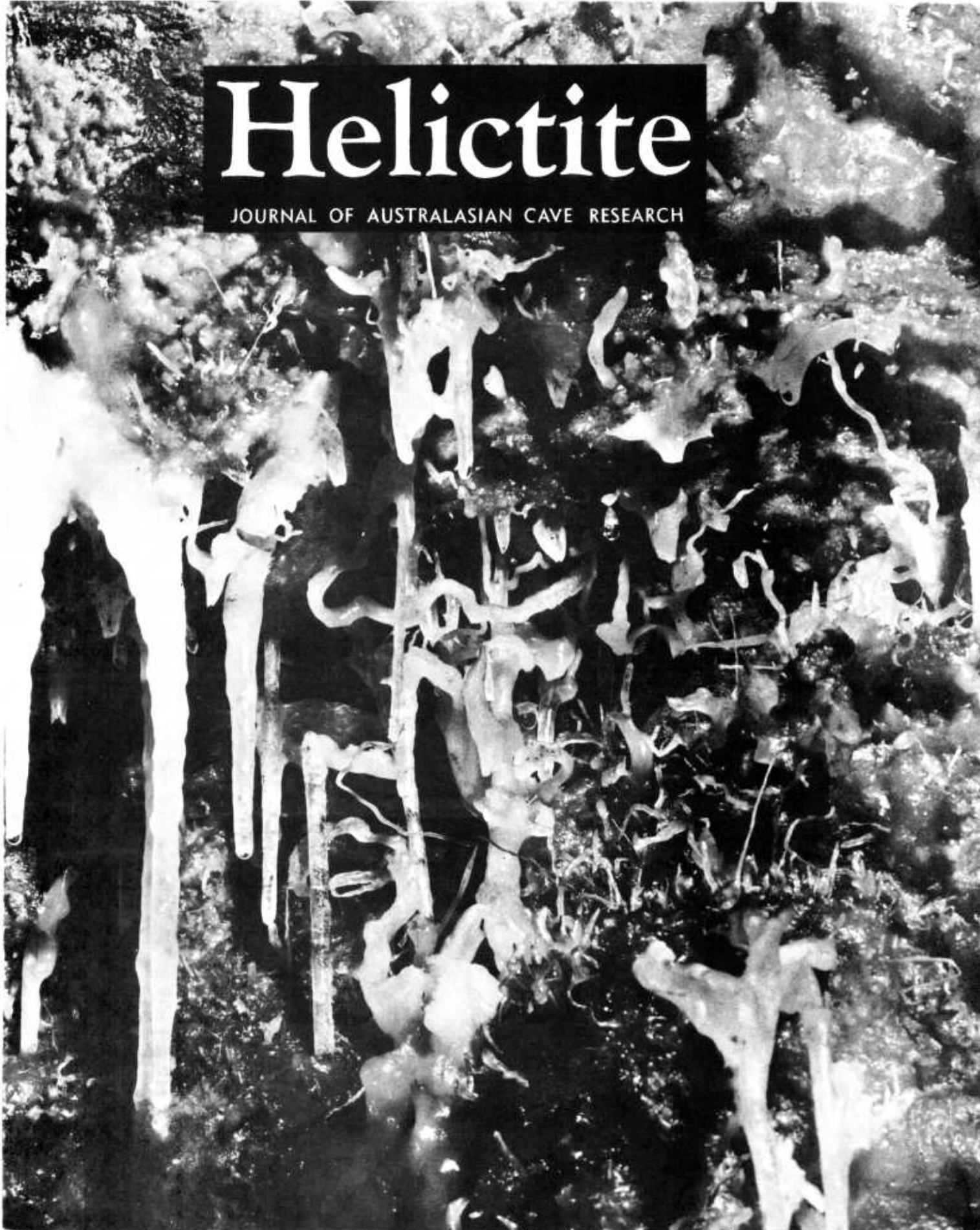


Helictite

JOURNAL OF AUSTRALASIAN CAVE RESEARCH



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BOOK REVIEW

Speleology. The Study of Caves. By G.W. Moore and G. Nicholas. D.C. Heath and Company, Boston. 1964 : pp 120.

This is a popular account of the physical and biological aspects of speleology, which should prove an invaluable scientific introduction to the subject for layman and caver alike, and as such is recommended. The first half of the book is written by Dr. G.W. Moore, a geologist with the U.S. Geological Survey and President of the National Speleological Society. It covers such topics as origin of caves; characteristics of the underground atmosphere; and growth of stalactites and other cave decorations.

The second half is written by Brother G. Nicholas, of the Department of Biology at La Salle College, Philadelphia. This section deals with behaviour and products of cave micro-organisms; habits of cave animals; evolution of blind cave animals; and man's uses of caves.

The volume was prepared in cooperation with the N.S.S. and is illustrated with many excellent scraper board drawings and text figures by John Schoenherr. Although the printing is high-grade offset, the binding is poor.

Written by Americans and published by an American company as part of its Science Resource Series, cave references are essentially North American.

This brief book is packed with information, well presented, up-to-date, lucid, although the brevity (probably required by the publisher) has restricted discussion on theories other than those advanced in the text. The reader must bear in mind that many of the authors' opinions are, in fact, theories and should not be regarded as final. It should be noted, for example, that ecological and biological behaviour of cave inhabiting animals in Australia and New Zealand do not always follow the same pattern as for cave fauna in the U.S.A.

PRESENT-DAY CAVE BEETLE FAUNA IN AUSTRALIA

A POINTER TO PAST CLIMATIC CHANGE

By B.P. Moore, Ph.D.

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Summary

Beetles form an important element of life in caves, where they provide some of the most spectacular examples of adaptation to the environment. The troglobic forms are of greatest interest from the zoogeographical point of view and their present distributions, which are largely limited to the temperate regions of the world, appear to have been determined by the glaciations and later climatic changes of the Quaternary. Troglaphiles, which are much more widespread, show little adaptation and are almost certainly recently evolved cavernicoles.

Distributions of troglobic beetles in New Zealand and Tasmania suggest a linkage with the main glaciations. By contrast, caves of mainland Australia (including the formerly glaciated portion) are sparsely populated and the beetle fauna appears to be limited to troglaphiles and troglonexes. Here, post-Pleistocene aridity may have been responsible for the extinction of earlier troglobic forms.

Introduction

The Coleoptera, or beetles, form one of the most successful groups of animals, and they have exploited all life-supporting habitats except the open sea. Many species are to be found in caves, where they provide some of the most interesting and spectacular examples of adaptation to the subterranean environment. Such forms have been well studied in the northern hemisphere, where much is already known concerning their taxonomy, biology and distribution - a fund of information which has proved invaluable to recent authors (Jeannel, 1943; Vandel, 1963) in their attempts to piece together the world's climatic history with the evolution of cave faunae as a whole.

By contrast, research on cave biology in the southern hemisphere is still largely in the early stages of discovery and description, but good progress is now being made with surveys in both Australia and New Zealand. Already, some interesting parallels and puzzling divergences of evolution in our cave beetles are apparent and these are to be discussed in the present paper.

Note on Classification of Cave Animals

Cavernicolous animals are generally divided into three main groups, according to their degree of association with the subterranean environment.

Troglobites : obligatory cavernicoles, quite unable to exist in epigean habitats.

Troglophiles: facultative cavernicoles, frequently completing the whole life-cycle in caves but having no rudimentations restricting them to this habitat.

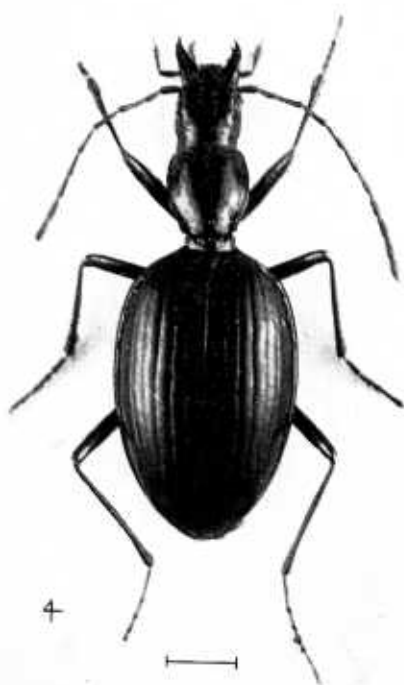
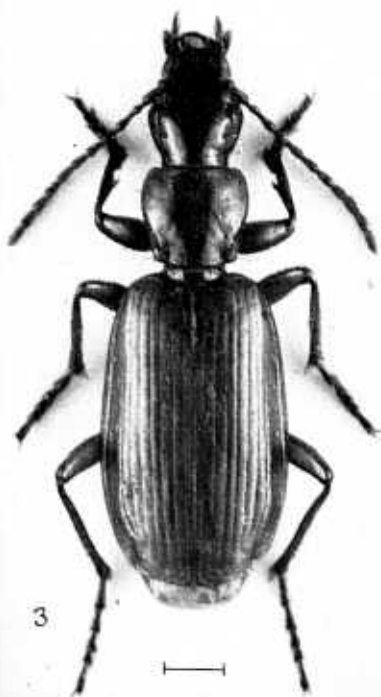
Trogloxenes : facultative or adventive cavernicoles spending only part of the life-cycle underground.

Of these groups, the troglobites are by far the most interesting from the zoogeographical point of view. They are the "living fossils", relicts of once widespread epigean faunae which now find much of the earth's surface hostile to their way of life. Troglophiles, on the other hand, show little adaptation to the cave environment and are almost certainly evolved cavernicoles. Trogloxenes have even less significance.

The Evolution of Cave Beetle Faunae

The above three groups are all well represented in the Coleoptera, of which two families, the Carabidae and the Anisotomidae (= Catopidae) are particularly important. These have given rise to a rich variety of troglitic forms, frequently showing complete loss of eyes, depigmentation and lengthening of the appendages, characters indicating prolonged and extreme adaptation to life in caverns. Leptodirus hohenwarti Schm. (Anisotomidae: Bathysciinae) (Plate 1/1), from Slovenia is a good example. Analogous trends are also manifested in corresponding groups amongst the faunae of wet forest soils and mosses and it is tempting to assume that they share a common ancestry - an assumption strengthened by the existence of quite a large number of highly adapted species common to both major habitats, for example, Aphaenops rhadamanthus Lind. (Carabidae: Trechinae) and many species of the related genus Geotrechus Jeannel.

Present-day troglitic animals are confined to the temperate and subtropical regions and their distributions appear largely to have been determined by climatic changes of the Quaternary era. Many cases are known where a plot of the present distribution dovetails closely with the known limits of maximal Pleistocene glaciation - a concordance hardly attributable to chance. However, it is equally clear from these data, and from ecological studies, that present troglitic faunae comprise groups of differing degrees of antiquity, whose ancestors entered caves in different epochs and for a variety of reasons. Thus, groups of animals whose present distributions most closely match the glacial limits appear to be derived



from nivicoles, or inhabitants of the tundra, which retreated into caves at the onset of a warm interglacial phase. Aphaenops Bonv. and their allies appear to belong here; some of them (e.g. Arctaphaenops Meixner) still inhabit the glacial caves of central Europe, in contact with permanent ice. However, they were apparently unable to withstand the rigours of subsequent glaciations, at least in high latitudes, notably Britain, where their retreat was cut off by the sea. British caves, though seemingly quite suited to animal life, are conspicuously free from troglobic beetles, although aquatic cave Crustacea (Niphargus Schioedte, etc.) are still well represented there (Hazelton and Glennie, 1962). Aquatic forms appear to be more effectively shielded from adverse climatic changes than their terrestrial counterparts.

Cave animals of temperate regions may also be derived from elements of cool-loving, wet-forest faunae of early glacial periods, which retreated underground to escape the drier conditions of subsequent interglacials. Their distributions, too, were greatly modified by later glaciations. Many Carabidae and Anisotomidae appear to belong to this class.

Lastly, there are the so-called tropical relicts, remnants of a late Tertiary, warmth-loving fauna which survived the glacial epochs in the warmer caves. Perhaps the best example is the terrestrial isopod family Trichoniscidae (Crustacea), with isolated genera now extending from California to the Caucasus (Vandel, 1963).

Recent work in New Zealand reveals the existence of a number of troglobic animals, notably Carabidae. These, in general, offer close parallels in phylogeny and development with those of Europe and America, although in New Zealand, no troglobic Anisotomid is yet known (May, 1963). Here, again, the known distribution patterns suggest a linkage with the Pleistocene. Mrs. B.M. May informs me (in lit.) that so far no true troglobite has been found north of about latitude 38.5°S, about 100 miles from the Pleistocene snowlines of the North Island. On the other hand, in the South Island, where glaciation was widespread, troglobites are much more scattered and diverse. Thus, the New Zealand troglobic beetles are probably relicts of cold-adapted hygrophiles of an early Pleistocene glacial epoch.

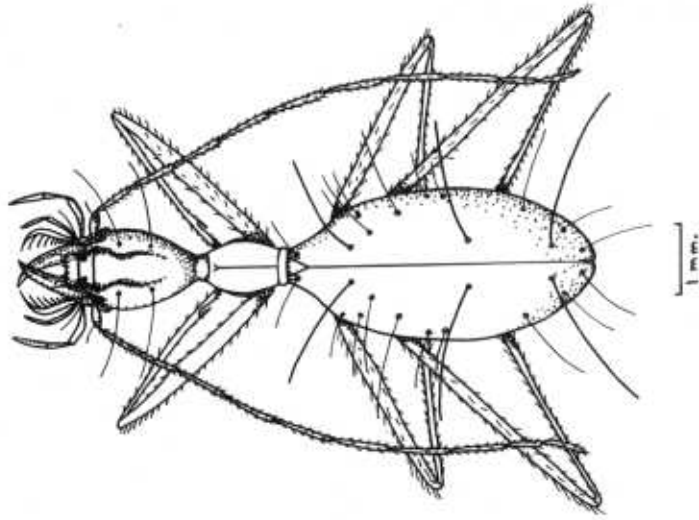
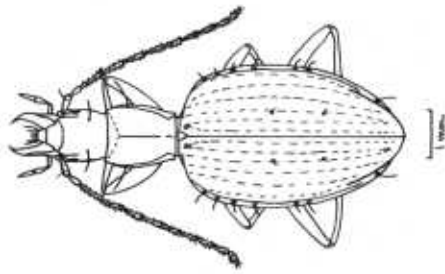
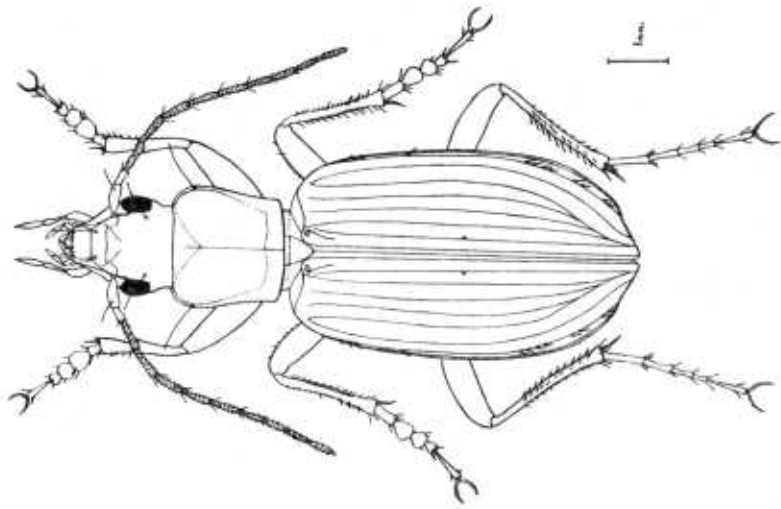
Until quite recently, cavernicolous beetles were almost unknown from the Australian continent. However, it now appears that Carabidae in particular are more plentiful in mainland caves than was formerly supposed. Two new genera, Notospeophonus Moore and Speotarus Moore, of the subfamilies Harpalinae and Lebiinae, respectively, have been described (Moore, 1962, 1964), consisting of five species and two subspecies. These range from Naracoorte, in eastern South Australia, northwards to at least as far as the Queensland - New South Wales border. Neither subfamily had previously been recorded from caves in any temperate region (although a cavernicolous Harpaline has since been reported from New Zealand (Britton, 1962), so the

Australian fauna is atypical by world standards, but the species show relatively little adaptation and, indeed, have all the appearance of troglaphiles. N. castaneus Moore (Plate 1/2) is a typical example. It shows a certain degree of depigmentation and elongation of the appendages, in comparison with its epigeal relatives, but the presence of well-developed eyes and wings indicates a short history as a cavernicole. This is supported by the insect's occurrence in the comparatively new lava caves of western Victoria, which may date from as late as the early Recent (Ollier, 1963), as well as in the older limestone caverns of Buchan, in eastern Victoria, and Naracoorte. Moreover, it is noteworthy that both Notospeophonus and Speotarus (Plate 1/3) are closely related to widespread epigeal genera (Lecanomerus Chd. and Anomotarus Chd., respectively) of which occasional species also occur in caves.

The Tasmanian Idacarabus (type species : troglydytes Lea) (Plate 1/4) represent the only known Australian troglotic beetle genus. These insects, which are known from caves at Ida Bay and Hastings, in the southeast corner of the Island, seem to be associated with the larvae of the glow-worm fly Arachnocampa tasmaniensis Ferguson (Mycetophilidae). They still possess very small eyes, but the wings have degenerated to mere vestiges. The sub-family Merizodinae, of the Carabidae, to which they belong, is allied to the Trechinae, but otherwise comprises geophilous forms with an essentially "antarctic" distribution (New Zealand, Victoria, Tasmania, and temperate South America). No truly troglotic Trechine has as yet been discovered in Australia, although this group is dominant amongst cave beetles in New Zealand and elsewhere. Other beetle families (Staphylinidae, Histeridae, Lathrididae, Cryptophagidae, Ptinidae, Tenebrionidae, etc.), which occur in Australian caves, are represented merely by troglaphiles and troglonexenes.

Although further discoveries may confidently be expected in Australia, it seems unlikely that they will materially affect the general emphasis, and the overall picture, in comparison with that presented by New Zealand, remains one of a sparse and rather atypical cave beetle fauna. This picture is quite the opposite of that given by the respective epigeal faunae as a whole (Tillyard, 1926), and the anomaly seems best explained on the basis of differences of comparatively recent paleoclimate and of earlier faunal history of the two regions. The situation in Australia is, indeed, more akin to that in Britain where secondary extinction of cave fauna appears to have occurred, although probably for very different reasons. Surviving troglotes in both these regions are mostly aquatic forms (some interesting troglotic Atyid shrimps have recently been described (Holthuis, 1960) from underground waters in northwest Australia).

The extents and chronology of Pleistocene glaciations in Australia are not known precisely, but it seems agreed that much of highland Tasmania (Jennings and Banks, 1958) and a small area centred upon the Snowy



Three levels of evolution in cavernicolous Carabid beetles. Left, a troglodyte (Notospeophonus castaneus Moore from Western Victoria) with well-developed eyes, moderately long appendages and few sensory setae. Centre, a non-specialized troglodyte (Idacarabus troglodytes Lea from Tasmania) with degenerate eyes, moderately long appendages and few sensory setae. Right, a specialized troglodyte (Aphaenops leachensaulti Bonv. from the French Pyrenees) with no trace of eyes, very long, slender appendages and numerous, long sensory setae.

Mountains (Browne, 1957) were at some time under permanent ice. Periglacial and subalpine forest areas would then have been fairly extensive and would have provided favourable habitats for Trechinae, Merizodinae and similar beetles. To some extent, this position is reflected in present distributions of these groups, which are widespread in Tasmania and in southern Victoria, with scattered stations in the Dividing Range as far as the Queensland border, and with an isolated outpost in the southwest (P.J. Darlington, private communication).

The onset of hotter and drier interglacial conditions would have restricted these beetles to just such refuges and, one would expect, also to caves. Thus it is interesting to note that whereas these surface shelters still harbour Trechinae with much reduced eyes (Moore, in preparation), no such cavernicolous form is known. Many of the mainland caves now appear quite suited to beetle life, yet they are sparsely populated and singularly barren of troglotic forms. Here, the hot, arid conditions of inter- and post-glacial epochs (particularly the latter) may have played a decisive role. These conditions were probably more severe in mainland Australia than elsewhere and we know that they led to widespread extinction of hygrophilous plant and animal communities. It seems quite possible that certain cave-frequenting beetles may have been extinguished in the same way, perhaps as late as the early Recent, leaving openings which have, in part, been taken over by the more mobile and less demanding troglaphiles. Perhaps it is significant that few if any truly earth-loving Trechinae now occur in the immediate vicinities of any of the main cave systems.

Jenolan and Bungonia, in New South Wales, are well within the range of the troglophile Trechimorphus diemenensis (Bates) and caves there have been colonised by this species. However, T. diemenensis is quite exceptional amongst the Australian members of its group in being wing-dimorphic (two different types of wings), and it undoubtedly owes its present extensive range to the mobility of its macropterous (fully-winged) form. Such examples from caves as have been dissected prove to be slightly brachypterous (short-winged), suggesting a recently established population, whereas most specimens from the drier fringe areas are fully-winged. The species is probably still extending its range and a complete analysis of the distributions of fully-winged and flightless forms, when based upon adequate material, could yield useful information about its former habitats and present directions of spread. Meanwhile, it may confidently be asserted that this, Australia's only cave-frequenting Trechine, is no more than a post-glacial troglophile.

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Caption to Plate 1, between pages 4 and 5

Cave Beetles from Europe and Australia. (1) Leptodirus hohenwarti Schm. (Anisotomidae : Bathysciinae) from the Grotte der Tretten, Slovenia. (2) Notospeophonus castaneus Moore (Carabidae : Harpalinae) from Byaduk Caves, Victoria. (3) Speotarus lucifugus Moore (Carabidae : Lebiinae) from Bat Cave, Naracoorte, South Australia. (4) Idacarabus troglodytes Lea (Carabidae : Merizodinae) from Ida Bay Cave, Tasmania. The scale-line represents 1 mm in each case.

(Photos : C.N. Lourandos, Division of Entomology, C.S.I.R.O.)

A B S T R A C T S

KARST IN AUSTRALIA. By G.A. Maksimovich. Gidrogeologiya i Karstovedeniye, v. 1 : 153 - 171. Perm, U.S.S.R., 1962.

The bulk of this paper published in the Russian journal, "Hydrology and Karst Studies," is devoted to brief descriptions of karst areas of Australia, though a page or two are devoted to New Guinea, New Zealand and other islands of the Southwest Pacific. It is based on some 30 Australian papers, four New Zealand ones, and another 25 references of a secondary nature from the European literature. The most recent reference is dated 1959. Geomorphology and hydrology are the author's chief concern although there is some reference to cave biology and to the palaeontology of cave deposits. The problem of the age of the karst development in different regions is broached at the end.

With the difficulties of distance and language which interpose between the author and his subject, it would be surprising if there were not errors and omissions. Thus we find that the underground waters of the eastern part of the Eucla basin are said to be used for irrigation and the author is not aware that the caves near Camooweal are in dolomite, not limestone as was thought when Danes wrote his important papers on Australian karst at the beginning of this century. Many significant papers, such as those of Thomson and King on the Nullarbor, Sweeting on Buchan, have not been made use of.

However, it is surprising how few major cave areas known to us are not referred to explicitly and in these cases it is usually easy to see why. Kangaroo Island, Katherine, N.T., small patches in the Eastern Highlands such as the Kempsey, Wee Jasper and Cooleman Plain areas escape attention, for example. In fact, it is remarkable that the account is as good as it is in terms of coverage and factual accuracy, and that it is as interesting for an Australian speleologist to read as it proves to be. The reviewer is indebted to Mr. C. Kirilov of the Australian National University for a translation. - J.N.J.

(An independent translation was also prepared by Mr. C. Court of the University of Sydney and sent to the Editors of "Helictite.")

THE BYADUK LAVA CAVES. By C.D. Ollier and M.C. Brown. Vict. Nat., 80, 1964: 279 - 290.

Description and plans of several of the Byaduk Caves, about 12 miles south of Hamilton, Victoria. The caves are in a lava flow up to two miles wide which came down a valley for about 15 miles from the now extinct volcano, Mt. Hamilton. The caves are aligned along the centre of the flow and are grouped into systems which interconnect. The tunnels are exposed to the surface through collapses. - E.A.L.

THE LIMESTONE RANGES OF THE FITZROY BASIN, WESTERN AUSTRALIA. A TROPICAL SEMI-ARID KARST. By J.N. Jennings and M.M. Sweeting. Bonner Geographische Abhandlungen, 32, 1963 : pp 60 + 10 figs. and 18 plates.

The field work for this paper was carried out in 1959 in the 180 mile long Limestone Ranges of the Fitzroy Basin, Northwest Australia. Little attention has been given in the past to karst areas, such as this, in tropical arid or semi-arid regions. The chief centres of karst morphological study have been in areas of temperate, sub-polar and tropical humid climates. The authors chose the Fitzroy Basin for study because it possesses larger areas of thick, pure limestone than elsewhere in tropical Australia, together with an available relief. Their fieldwork was in the nature of a reconnaissance, especially as regards underground exploration. They outline the physical geography of the region and the geological structure of the limestone ranges in relation to the landforms. A number of pages are devoted to the karst landforms and their sequence and descriptions of the gaps and gorges in the ranges.

In a discussion section, the authors consider the Limestone Ranges in relation to various ideas expressed by authorities on karst, and compare the area with the Nullarbor Plain and the Katherine area in the Northern Territory of Australia, as well as with overseas areas, particularly in Brazil. They say that the Fitzroy Basin karst appears to be a distinctive one in which lithological and structural factors, small available relief and especially climatic conditions are operative. The early stage of the karst development is dominated by karst corridor topography and resembles a "giant grike-land." These giant grikes can be regarded as extremely structurally controlled dolines, for which competent limestone and strong jointing are necessary. The close field of karst corridors seemed best attributed to a combination of a short, wet season when surface solution was very active, together with a long, dry season when conditions inhibited the development of soil and rock mantle which might tend to obliterate the previous etching out of structural weaknesses.

The authors discuss larger, polje-like depressions and the Ranges' marginal amphitheatres, as well as a variety of features developed over a wide period of time. They found the area rich in caves, although the limited relief together with strong surface solution seemed to restrict the occurrence of large and complex caves. Despite a probably slow rate of development, advanced stages of karst landform development were found. These probably resulted from prolonged opportunities for development uninterrupted by glacial periods. The paper has many excellent illustrations, plans and maps, including a large coloured map of the morphology of the Limestone Ranges and immediate surroundings. - E.A.L.

A SHORT NOTE ON THE KARST AREA OF PAPUA. By J.G. Smith. N.S.S. News, 21 (5), 1963 : 59.

A note on the karst of the foothills belt of Western Papua. This area of 40,000 sq. km is one of the world's least known regions of karst development. The author visited here in the course of a recent geologic reconnaissance expedition. With several companions, after travelling by canoe and on foot, the Maruboi Bat Cave was found in the Middle Purari River District. The cave is a subterranean cutoff about 300 metres long that diverts a stream under a spur of its entrenched valley. This and other caves in the valley are populated by "hordes" of giant fruit bats, which are considered very good eating by the Papuans. - E.A.L.

REPRODUCTION AND DISTRIBUTION IN MINIOPTERUS (CHIROPTERA). By P.D. Dwyer. Aust. J. Sci., 25 (10), 1963 : 435 - 436.

This is the first record of the little bent-winged bat, Miniopterus australis Tones, in New South Wales. It is shown to be wide-spread through the coastal northeastern portion of the State, at least to 31°20'S, but does not occur at similar latitudes west of the Great Dividing Range, or on the northern tablelands. This has extended its range about 530 miles south from Rockhampton 23°30'S, its previous southernmost limit.

The genus Miniopterus is typically tropical and subtropical in distribution, and its worldwide distribution is discussed. Observations of a maternity colony of M. australis at 31°S are recorded. The species is intimately associated with a much larger breeding colony of M. schreibersi, which it is believed produces the necessary conditions for development of young of M. australis at this latitude. While M. schreibersi has adapted itself to live and breed at 30°S and 45°N, climatic barriers limit the distribution of M. australis to the south and west. - A.M.R.

NEW ZEALAND CAVE FAUNA. 2 - THE LIMESTONE CAVES BETWEEN PORT WAIKATO AND PIOPIO DISTRICTS. By Brenda M. May. Trans. Roy. Soc. N.Z. Zoology, 3 (19), 1963 : 181 - 204.

This paper records the results of a survey of fauna occurring in limestone caves between Port Waikato and Piopio in the North Island of New Zealand. Collecting methods are described. Of the species collected six percent are considered troglobites; 43 percent troglaphiles; 23 percent troglaxenes (tolerant) and 29 percent troglaxenes (intolerant). Troglobites occurred among Collembola and Coleoptera (Fam. Carabidae). Theories of regressive evolution are reviewed and their application to New Zealand species discussed. It is thought that troglobic Coleoptera were isolated in caves in the hot dry interglacial stage of the lower Pleistocene nearly two million years ago. Global affinities of the cave fauna are considered. - A.M.R.

FEEDING BEHAVIOUR AND ENEMIES OF RHAPHIDOPHORIDAE (ORTHOPTERA) FROM WAITOMO CAVES, NEW ZEALAND. By Aola M. Richards. Trans. Roy. Soc. N.Z. Zoology, 2 (15), 1962 : 121 - 129.

Cave crickets are scavengers and omnivorous in their diet. Fungi and animal food can be obtained inside caves; but mosses, liverworts and angiosperms are also eaten in the epigeal regions. However, where a river flows through a cave, plant debris is washed inside and left stranded on the walls or on the surface of the water. Where electricity has been installed in caves, mosses and ferns are able to grow near the light source. In both cases they form a food supply for the insects making it unnecessary for them to go outside the cave. In other parts of the world, Trichoptera and Lepidoptera form most of the animal portion of the diet of Rhaphidophoridae. However, they have never been found in the faeces of New Zealand cave crickets. There Hemiptera, Diptera and Rhaphidophorids themselves are eaten instead. Rat faeces also form a part of their food supply. The main enemies of cave crickets are glow-worms, spiders and opiliones. - A.M.R.

MAMMAL SUB-FOSSILS FROM NEAR PORTLAND, VICTORIA. By N.A. Wakefield. Vict. Nat., 80 (2), 1963 : 39 - 45.

This paper records a collection of bones from Fern Cave, a small cave near Portland, Victoria. The species represented include macropods, bandicoot, dasyurids, the larger possums, wombat, dingo and introduced mammals. The cave is primarily a "death trap", but the author suggests part of the deposit may be attributed to the prey of owls. The complete fauna consists of modern species. This indicates that the period of deposition may be no more than the past few hundred years. The bones provide records which extend the known range of several species of native mammals. - A.M.R.

SEASONAL CHANGES IN ACTIVITY AND WEIGHT OF MINIOPTERUS SCHREIBERSI BLEPOTIS (CHIROPTERA) IN NORTHEASTERN NEW SOUTH WALES. By P.D. Dwyer. Aust. J. Zool., 12 (1), 1964 : 52 - 69.

In northeastern New South Wales M. s. blepotis occupies caves and mines in three distinct climatic regions: the subtropical coastal belt, the tablelands (cold winters), and the inland slopes (intermediate winter temperatures). Conspicuous seasonal differences in level of daytime activity are evident at roosts. In the summer the bats typically disperse rapidly from clusters, but during the winter they are relatively sluggish and may remain clustered for more than half an hour after disturbance. Selection of different roosting sites and a change in the roosting attitude of the bats accompanies the changes in level of activity. During the winter, feeding activity is considerably reduced except perhaps for colonies in the warmest of the coastal areas. Conspicuous regional differences in seasonal weight changes occur so that bats from the tablelands increase in weight before winter but coastal bats do not. "Prehibernation" weights of bats from the inland slopes are intermediate between those from coastal and

tableland areas. For the bats from the tablelands, about 22 percent of pre-hibernation weight is lost during the winter.

On the assumption that level of activity reflects body temperature, it is suggested that summer M. s. blepotis characteristically regulate their body temperature but that wintering individuals are essentially poikilothermic when roosting. It is concluded that the capacity to lay down fat reserves before winter, and to select appropriate habitats and temperatures, combined with the seasonal change from a maintained high summer metabolism to a poikilothermous winter pattern, are significant factors in the adaptation of M. s. blepotis to the winter conditions of northeastern New South Wales.

THE BREEDING BIOLOGY OF MINIOPTERUS SCHREIBERSI BLEPOTIS (TEMMINCK) (CHIROPTERA) IN NORTHEASTERN NEW SOUTH WALES. By P.D. Dwyer. Aust. J. Zool., 11 (2), 1963 : 219 - 240.

The essential features of reproduction in the bent-winged bat (M. s. blepotis) in eastern Australia between latitudes 28° and 32°S are as follows: Spermatogenesis is initiated in late November and December and the testes reach maximum development during April, those of yearling males not attaining the size reached in older individuals. Spermatozoa are abundant in the epididymides from May to mid-July with some males retaining a limited store through the winter. Most copulations occur during the period May-June and pregnancy ensues at once with retarded embryonic development through the early months till about mid-September. Females do not become pregnant in their first year. Litter size is one. Parturition occurs during December and early January at maternity colonies which are formed through October and November by females from a number of surrounding caves and mine colonies. Such colonies reform at the same locality each year and may comprise more than 10,000 adult females. The young are born naked with forearms of about 15.75 mm and, although flying at seven weeks, do not reach adult proportions till nearly ten weeks old. Adult females are nursing young throughout this period. Once the juveniles become independent the adult females leave the maternity colonies and through late March a mass exodus of juveniles occurs so that the colony is deserted early in April. Many juveniles return to the maternity colony temporarily when it is re-established in the spring following the season of their birth.

THE RHAPHIDOPHORIDAE (ORTHOPTERA) OF AUSTRALIA. 1. TASMANIA. By Aola M. Richards. Pacific Insects, 6 (1), 1964 : 217 - 223.

A new genus Micropathus Richards is described, which contains two new species, M. tasmaniensis Richards and M. cavernicola Richards. These two species occur abundantly in caves, and comprise the total known raphidophorid fauna from Tasmania. M. tasmaniensis is found in the southeastern part of the island, and M. cavernicola in the northern and western districts. There appears to be no overlap in their distributions. The two species are quite distinct, although closely related. - A.M.R.

THE DEVELOPMENT OF COCKLEBIDDY CAVE

EUCLA BASIN, WESTERN AUSTRALIA

By D.C. Lowry, M.Sc.

Geological Survey of Western Australia

Introduction

At present, the best account of cave formation in the Eucla Basin is that of Jennings (1961). However, the paper does not contain detailed information or maps of Cocklebiddy Cave, and this account should help to fill that need. The cave is the westernmost deep cave in the Eucla Basin (see area map in Anderson, 1964). It has received little attention from cave exploration parties from the Eastern States of Australia.

Description

The gross morphology of the cave is best understood by a study of the accompanying maps (Figure 1). Most of the cave is surveyed to C.R.G. Grade 6, but the lake section is no higher than Grade 4.

The collapse doline has a little surface drainage feeding into the southern end, from where it drains northwards to a 20 ft high bluff at the cave entrance. The stream disappears into fallen rock on the cave floor, but re-emerges in the flatter portion of the cave and flows into the lake.

The doline is partly filled with a horizontally bedded fill of red clay and rock fragments, which thickens northwards to form the bluff at the cave entrance. The fill contains many small unidentified bones and also the shells of a gastropod which is living in the area at the present time.

The floor of fallen, jumbled blocks descends rapidly from the entrance. This rockfall is somewhat unstable, and recent movement of some of the blocks is suggested by the distribution of algae on them. Near lake level, the floor flattens out and is modified by the intermittent flow of water from the surface; the fallen blocks are smoothed and, in places, are covered with mud and gravel. The floor of the lake is also formed of fallen blocks, but these are coated with several inches of red calcareous mud. In cross section the roof profile is that of an arch with steps formed by horizontal beds - the stable shape formed by collapse (Jennings, 1961).

Large-scale scalloping is present on the walls close to the edge of the lake. This will be discussed in some detail because of its bearing on

the interpretation of the origin of the cave. In limestone caves, the presence of scalloping is usually taken to indicate solution by a moving body of water; and weak large-scale scalloping seen in other deep caves of the Nullarbor has been given this interpretation (Jennings, 1961). However, the scalloping seen in Cocklebidy is clearly not of this origin, but caused by weathering proceeding at the present day, and is probably formed in the same manner as the "tafoni" in Weebubbie Cave (Jennings, 1961). The scalloping is formed by the irregular retreat of the limestone face caused by powdering of the surface layer. The powder falls away and accumulates on ledges and floor. However, most of the floor is swept clean by the stream from the surface, although in one protected part the powder blankets fallen blocks to a depth of about one foot.

Close to the eastern wall of the cave near lake level, a thin coating of powder was found lying across the path of a stream which must have last flowed only three or four months before. This shows clearly that powdering is proceeding at an appreciable rate today. It also appears that much of the weathering has occurred since the last major roof collapse - one of the steps instead of having a planar or convex profile formed by breakage, has a profile modified by weathering to a concave profile. The present-day weathering of the roof above the lake is indicated by the falling of small, soft fragments when the roof was bumped by the hydrogen-filled balloon used in surveying.

The weathering mechanism is by no means clear. Jennings (1961) suggested that the honeycomb weathering (or tafoni) in Weebubbie Cave might be due to fluctuations in the humidity of the atmosphere. However, the absence of scalloping on fallen blocks indicates that the weathering only takes place on limestone in situ and this suggests that the movement of intergranular water may be involved. The limestone is friable and appears to have a fairly high porosity and permeability, thus allowing free movement of groundwater. It is possible that evaporation takes place within the few millimetres of rock at the surface of the wall, and that the salts thus precipitated wedge off the surface grains of limestone. The writer is not aware of any published description of this mechanism, and is not in a position to demonstrate its validity, but it should be borne in mind as a possibility.

A feature of the limestone near the surface of the Eucla Basin is its perforation by anastomosing tubes about one inch in diameter (Jennings, 1961). This perforation is seen extremely well in several of the fallen blocks in Cocklebidy Cave and, clearly, was developed before the collapse occurred. Jennings attributed the perforation to phreatic solution when the watertable was close to ground level, probably brought about by a high sea level during the Pleistocene. The writer agrees with this suggestion.

The cavern is controlled by north-tending joints which can be seen in the roof above the lake. One joint is opened a few inches, but it is not

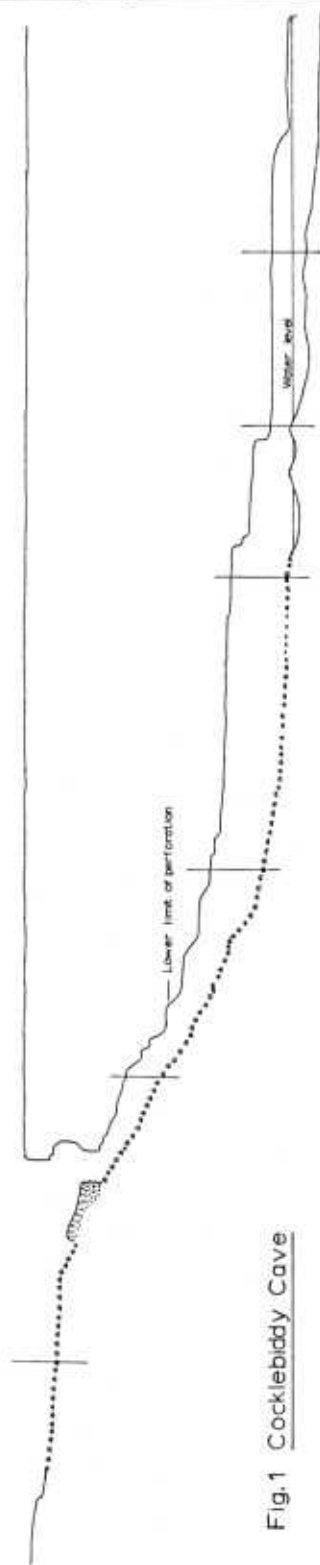
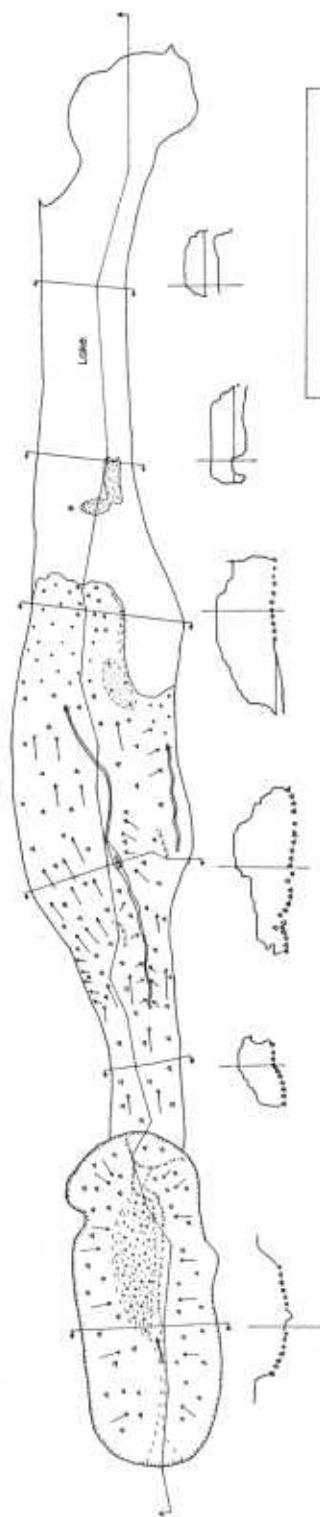
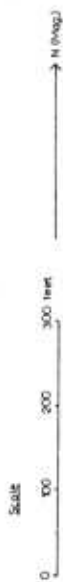


Fig.1 Cocklebiddy Cave



LEGEND

- Direction of slope
- Drainage course
- Burr
- Line of section
- Fallen rock
- Water-transversed debris
- Sand
- Clay



Figs. 2a - 2d Stages in the Development of Cocklebiddy Cave

(Vertical scale exaggerated about three times)

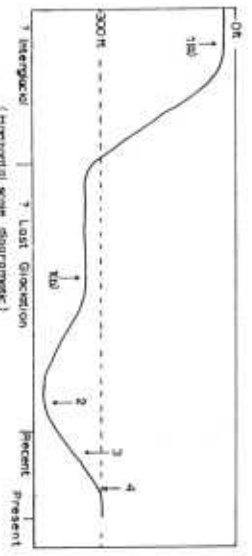
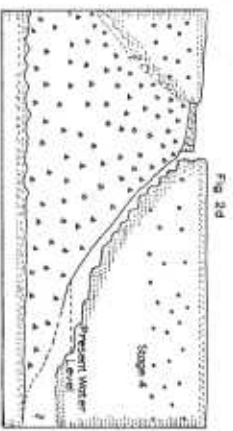
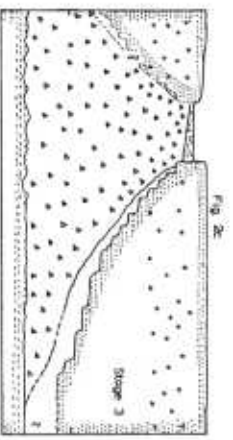
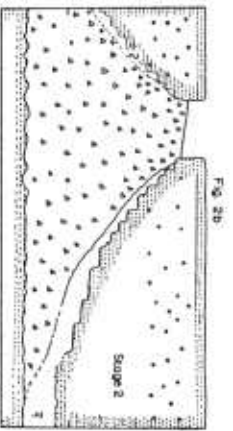
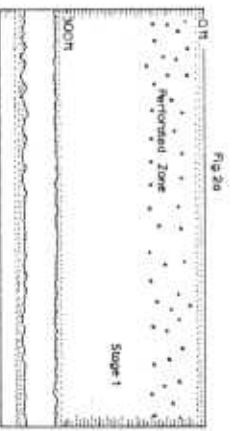


Fig 3 Deduced Movement of the Water Table Related to Stages of Cave Development

clear whether this is due to solution beneath a higher watertable in the past or to solution by descending water of the present day.

The longitudinal section shows that the present lake level has little or no effect on the general shape of the cave. The roof descends in a series of steps until it passes beneath the surface of the lake, while the irregular sloping floor of fallen blocks continues on beneath the water. The only effect the lake has on the morphology of the cave is to form a base level for the dissection and deposition of the intermittent stream from the surface.

Discussion

It can be seen from the above description that there is no evidence to show that the present cavern space was formed by corrosion or corrasion of the limestone. Instead, the indications are that the space was once occupied by solid rock which collapsed downwards. This clearly applies to the upper portion of the cave and, because of the smooth sweep of the floor and roof profiles, it is reasonable to believe that the lower part of the cave was formed in a like manner. It seems that this original cavern space into which collapse occurred lies submerged beneath the lake, and that the cave in effect, sloped its way towards the surface and eventually broke through to form a collapse doline. The present cave is therefore the irregular space left between the fallen rock and the solid rock. The present cave may connect with the original cavern further north, but exploration is prevented by the watertable which now intersects the cave 305 ft below the surface of the Plain.

This inaccessibility makes it impossible to investigate the origin of the original cavern and its relationship to the watertable at the time of formation. However, for tenuous reasons, the writer favours development close to the top of the watertable. There is no evidence of solutional cave development in the walls of the present cave, and this feature could be expected to be present if the original watertable had been higher than the present one. Furthermore, any major enlargement by a vadose stream descending from the surface is ruled out by the absence of any surface drainage which could provide such a stream.

Fallen rock occupies approximately 1.5 times the volume filled in an unbroken state, so the original cave must have been of huge dimensions to allow a large cavern to remain above the fallen debris - debris which probably exceeds 200 ft in thickness at the entrance. An alternative answer is that enlargement is occurring today. Although there are no visible signs of solution taking place in the lake, it is conceivable that this may be taking place say 50 ft below the lake surface, and by sapping the base of the rockfall, lowering it and enlarging the cavern above.

Stages of Development

The development of Cocklebiddy Cave can be divided into four stages.

1. Figure 2 (a). In the first stage there were two events: (i) the perforation of the limestone near the surface, and (ii) the development of a large cavern along a vertical joint, more than 300 ft below the surface. These two events must have occurred under very different hydrological conditions, but it is not certain which was the earlier.

2. Figure 2 (b). Collapse of the cave roof occurred, the collapse eventually reaching the surface. The time involved is not clear; it is unlikely to have occurred as a single fall and was probably spread over many centuries.

3. Figure 2 (c). Soil and debris washed in from the surface, partly filling the collapse doline and eroding a gentle surface depression to the south. This depression may, alternatively, have been an earlier feature governed by the underlying joint.

4. Figure 2 (d). The surface drainage broke through into the cavern and entrenched itself into the fill. At the present day, the walls are being scalloped by weathering and the lake floor is being coated with mud. The cave floor, near lake level is being modified by the stream from the surface.

Time Correlation

The information and deductions given above can be assembled into an account which is speculative in several aspects but which the writer believes to be the most probable on the information available.

The only stage which shows any prospect of being conclusively dated is three - the infilling of the doline. This should be possible because of the presence of bones in the fill, but to date no collections have been made or study attempted. However, as noted earlier, the fill contains shells of gastropods similar to those living in the area today, and taken in conjunction with the apparent freshness of the fill, the writer favours a recent age for the deposit. The freshness of the dissection of the fill suggests that Stage 4 (the opening of the cavern) took place only a few hundreds of years ago.

Jennings (1961) suggests that the perforation (Stage 1 (i)) occurred during an interglacial period of eustatically high sea level, and to find an adequate elevation must look to the early or mid-Pleistocene. Barrett (1963) makes a similar suggestion for a New Zealand cave. The writer suggests that the original cavern below Cocklebiddy Cave may have been formed

during a glacial period when the sea level (and probably the watertable) was lower than at present. If Stage 3 occurred in recent times, the final development of the original cavern and its collapse possibly occurred during the last glaciation. The reason for the collapse may have been excessive lateral development of the cave by solution, but the writer favours a small drop in the watertable which drained the cave and removed the water's hydrostatic support. These speculations are summed up diagrammatically in Figure 3.

The other deep caves visited by the writer seem to follow the same pattern, but in the case of Madura 8-Mile North Cave and Kestrel Caverns No. 1 and No. 2 (see Anderson, 1964), the fallen rock meets the roof and stops exploration before the watertable is reached.

Acknowledgments

The observations in this paper were made in November, 1963, when the writer was accompanied by Mr. M.C. Davis. Mr. Davis has contributed a great deal to this study, both in assisting with the survey and in discussing the theories. Thanks are due also to Mr. J.N. Jennings whose assistance made possible the planning of a valuable trip.

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A B S T R A C T S

PROPOSITION FOR THE CLASSIFICATION OF CAVE ANIMALS. By K. Christiansen. Spelunca (4e Serie), Memoires No. 2, 1962 : 76 - 78.

The classification of cave animals poses many problems for cave biologists. A number of different proposals have been put forward, mainly based on ecology or evolution, but most have proved unsatisfactory. The system most commonly used today is based on that proposed by Schiner in 1854, but it has been somewhat modified. Schiner proposed the terms troglophile and troglobite, and to these a third category troglaxene was added later. Now another new proposition for the classification of cave animals has been put forward by Christiansen.

He states that the three categories are not satisfactory, and represent an artificial system of nomenclature which is a source of confusion. Troglloxenes, the accidental or temporary cave animals, pose few problems, and the term is retained. However, the terms troglophiles, those animals capable of living and reproducing both inside and outside caves, and troglobites, animals confined to caves, he considers are difficult to delimit and almost impossible to use. Present-day knowledge of epigeal species is not sufficient to claim that certain animals live only in caves. Also, the separation between the cave habitat and the adjacent environment, such as underground water, is so slight that it is often impossible to detect or is even non-existent. Many animals living exclusively in caves are not as well adapted for cave life as others found sometimes in caves and sometimes in the epigeal region.

Christiansen suggests a new classification based on morphology. He divides cave animals into four categories - troglloxenes, epigiomorphs, ambimorphs and troglomorphs.

Epigiomorphs live and reproduce in caves, but show no morphological changes related to cave life. They are typically epigeal in their morphology. Examples of such animals are the guanophiles. Ambimorphs are somewhat modified to cave life, but have retained most of the features of epigeal animals. The majority of animals found in caves belong to this category. In most cases they are found equally outside caves, but they are either rare or in a specialised habitat. Often they appear to be limited to caves, even if physiologically they are capable of surviving outside caves. Troglomorphs are clearly modified for cave life, and are totally different from all normal non-cavernicolous animals. Such forms are easily identifiable as cave animals and have many common features, though belonging to different taxonomic groups. Here evolutionary convergence is very striking, and it finally ends in forms entirely different from related forms living outside caves. Most members of this group are confined to caves, but there are exceptions such as the beetle Aphaenops. This fourth category is relatively rare. It contains such groups as Collembola, Coleoptera and Fish. Most animals found in caves have no representatives in this category, which shows that a narrow adaptation to cave life as a unique society is very rare.

Whether this new classification will prove more acceptable to cave biologists and come to replace the old classification of Schiner depends on further experience. - A.M.R.