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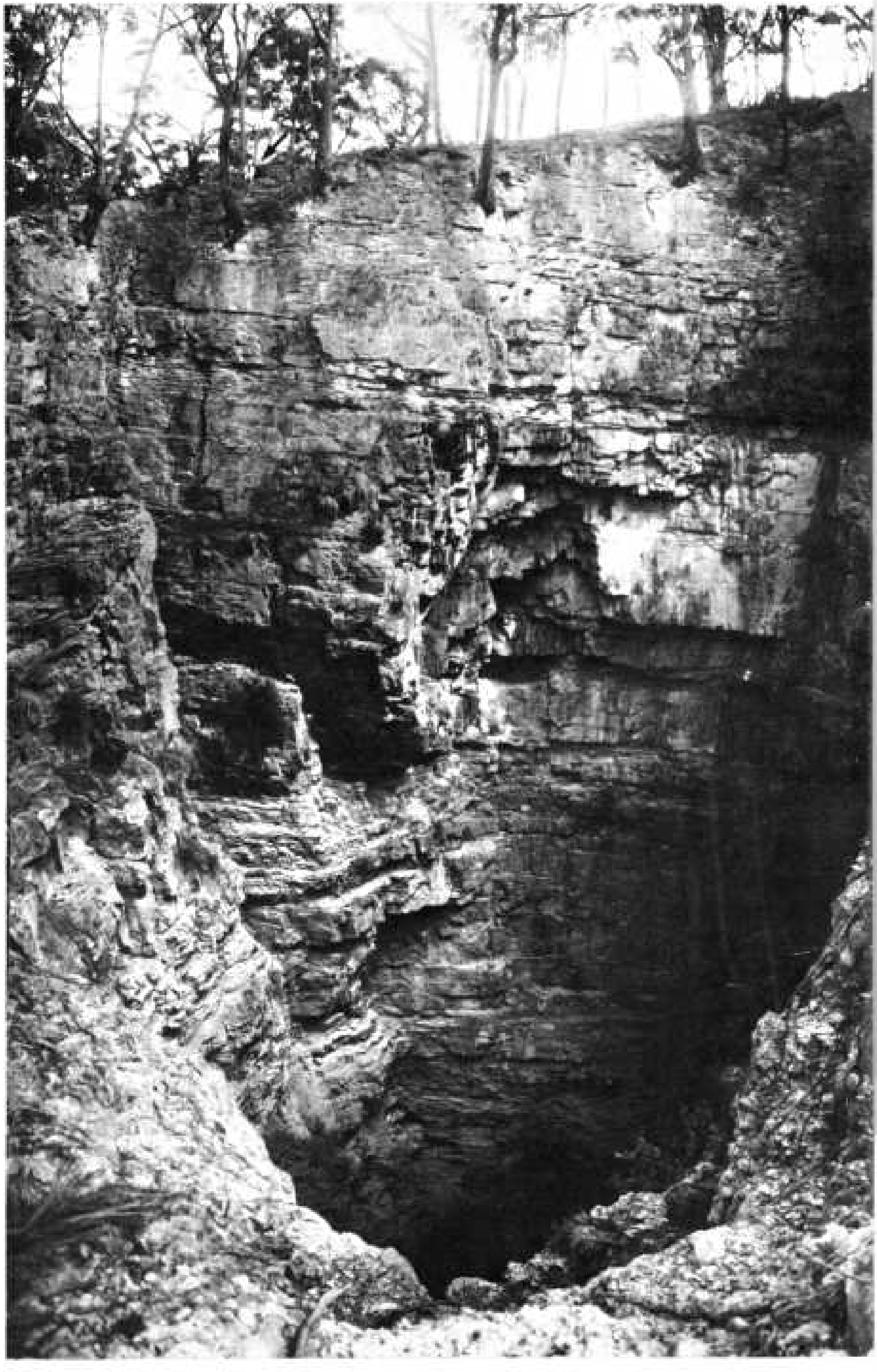

The Big Hole, near Braidwood, N.S.W. Composite print from three 35mm negatives taken with a 28mm wide-angle Elmar lens. Note figure indicated by arrow at top left. Photos and composite by J.N. Jennings. See paper page 3.

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"HELICTITE"

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Edited by Edward A. Lane and Aola M. Richards

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CONTENTS

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ABSTRACTS

IN THE LAND OF BIKPELA RAT MOA, PART 2 : FROM MOUNTAIN PEAKS TO SEASIDE CAVES. By H.M. Van Deusen. Nature and Science, 4 (12), 1967 : 2 - 6.

A popular account of a recent U.S. expedition to New Guinea to study fauna of the forests and grasslands. Caves were explored on the Huon Peninsula at the coast near Finschhafen. Fauna in one cave, several hundred feet long, included flying foxes and other bats, whip scorpions, cave crickets, freshwater crabs and a black-headed python. Another cave, containing a beautifully decorated chamber, also had a considerable bat population. No names or positions are given for the caves. - E.A.L.

THE TUNNEL, A CAVE IN THE NAPIER RANGE, FITZROY BASIN, W. AUSTRALIA. By J.N. Jennings and M.M. Sweeting. Trans. Cave Res. Group G.B., 6, 1963 : 53 - 68.

The Tunnel is one of the major caves of the West Kimberley. It is a relatively simple cave, about 750 yards long, 50 feet wide, and 10 to 50 feet high. The cave pierces the Napier Range and is occupied by Tunnel Creek, a river which flows only during the monsoonal summer wet season, but which leaves permanent pools of water in the cave. The paper provides an excellent map and gives a description of the morphology and the geological setting of the cave. On the surface of the range above the cave is an air gap that is evidently the remnant of a former valley of the river, and superficially there appears to be a simple case of superposition of the river across the range, followed by self-capture. However, the authors show that the history of the cave must be more complex and discuss several alternatives before re-stating the self-capture theory in modified form. - D.C.L.

NATIONAL SPELEOLOGICAL SOCIETY FELLOW

Dr. Aola M. Richards, Co-editor of Helictite, is numbered among the first group of Fellows of the National Speleological Society, U.S.A. This was announced in the July 1967 issue of the NSS News, 25 (7).

ADDENDUM

In Helictite, 5 (4), page 70, the typist inadvertently omitted the heading "Review" before the comments on "Free Living Mites."

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FURTHER REMARKS ON THE BIG HOLE,
NEAR BRAIDWOOD, NEW SOUTH WALES

J. N. JENNINGS

Australian National University, Canberra, A.C.T.

Since the publication of an account of the Big Hole in the upper Shoalhaven valley (Jennings, 1966), further relevant data have become available as a result of another descent of the Big Hole, of recent discoveries in Wyanbene Cave nearby, and of the publication of the first adequate topographical map of the area concerned, R.A.A.S.C. 1/50,000 Sheet 8826-IV Bendoura. Also, certain additional publications of relevance have come to notice. Discoveries at Wyanbene Cave to be mentioned were due first to the Australian National University Speleological Society and later to Sydney Speleological Society and Canberra Speleological Society in combination. The opportunity is taken here to present a slightly revised plan and section of the Hole and to discuss the new facts in relation to the interpretation already published.

The grid reference of the Big Hole is 674895 on the Bendoura Sheet. The height above sea level of the upper lip of the Hole is 2,733 feet, of the lower lip 2,683 feet and of the lowest point in the bottom is 2,359 feet. These are based on estimating the height of the Shoalhaven River at the track crossing to the Hole from the new map, five precision altimeter traverses between this point and the foot of the hill east of the Big Hole, and a miner's dial and tape traverse the rest of the way, together with the miner's dial, tape and ladder survey of the Hole itself. These heights are regarded as more accurate than such as would be derived from direct reading of the height of the Hole from the topographical map.

Neil Anderson did some surveying additional to that which he and Dr. J. Coulton had carried out previously at the bottom of the Hole and this showed (Figure 1) that the major underhang on the western side was more squarecut in plan and the water level slightly lower than shown in the previous figure (Jennings, 1966). The maximum depth from the highest part of the lip is now determined as 373 feet.

The shortest ladder pitch on the lower but less stable northeast wall is 240 feet, whereas the longer pitch on the safer southwest face is 288 feet. In Jennings (1966) it was inferred from the tall cover of tree ferns in the bottom that there had been no major rockfall for many years. However, between November, 1965, and May, 1966, a big mass of rock of many tons fell from the northeast wall and laid flat many ferns. The longer pitch is recommended.

In the previous paper it was argued that the Big Hole is a subjacent karst doline though this could not be proven completely. This kind of doline is one developed in insoluble rocks through the solution of the underlying soluble rock such as limestone or dolomite. The Big Hole is developed within a hill of Devonian quartzitic sandstone and conglomerate and it is inferred that unconformably beneath the hill is a strike belt of Silurian limestone similar to the limestone outcrops of Wyanbene, Marble Arch and Cheitmore. However, no limestone has been found in place or as talus at the bottom of the Hole.

One of the objects of the May, 1966, descent was to collect water from the stagnant pool at the lowest point of the Hole for a chemical test. If this water had been in contact with limestone as well as sandstone, its chemical characteristics, especially its content of calcium and bicarbonate ions, would reveal this. However, it is important to note that a definite conclusion can only be drawn from high values of these ions. Low values for them would be ambiguous. On the one hand they could imply that there is no limestone below; on the other hand it might mean that the water had not circulated deeply enough to encounter underlying limestone.

The results of a partial analysis are as follows:

Temperature when collected on May 7, 1966	11.5°C
pH when collected on May 7, 1966	6.0
Specific conductance at 25°C	53 µmho cm
Total dissolved salts	43.25 mg/l
Suspended sediment	8.2 mg/l
Ca (by atomic absorption spectrophotometer)	2.6 mg/l
K (by atomic absorption spectrophotometer)	4.3 mg/l
Mg (by atomic absorption spectrophotometer)	1.0 mg/l
Na (by atomic absorption spectrophotometer)	4.3 mg/l
SiO_2 (by colorimetric method)	16.5 mg/l
Cl (by the Mohr method)	1.8 mg/l

These results show that the water has not been in contact with limestone. The rather high SiO_2 content for natural water from the area indicates that the water has had rather lengthy contact with rock, yet the low ratio of calcium to the other cations, the low pH and modest total dissolved salts are all against solution of limestone having taken place. The test therefore failed to prove the presence of limestone, though it does not prove its absence as has been said above.

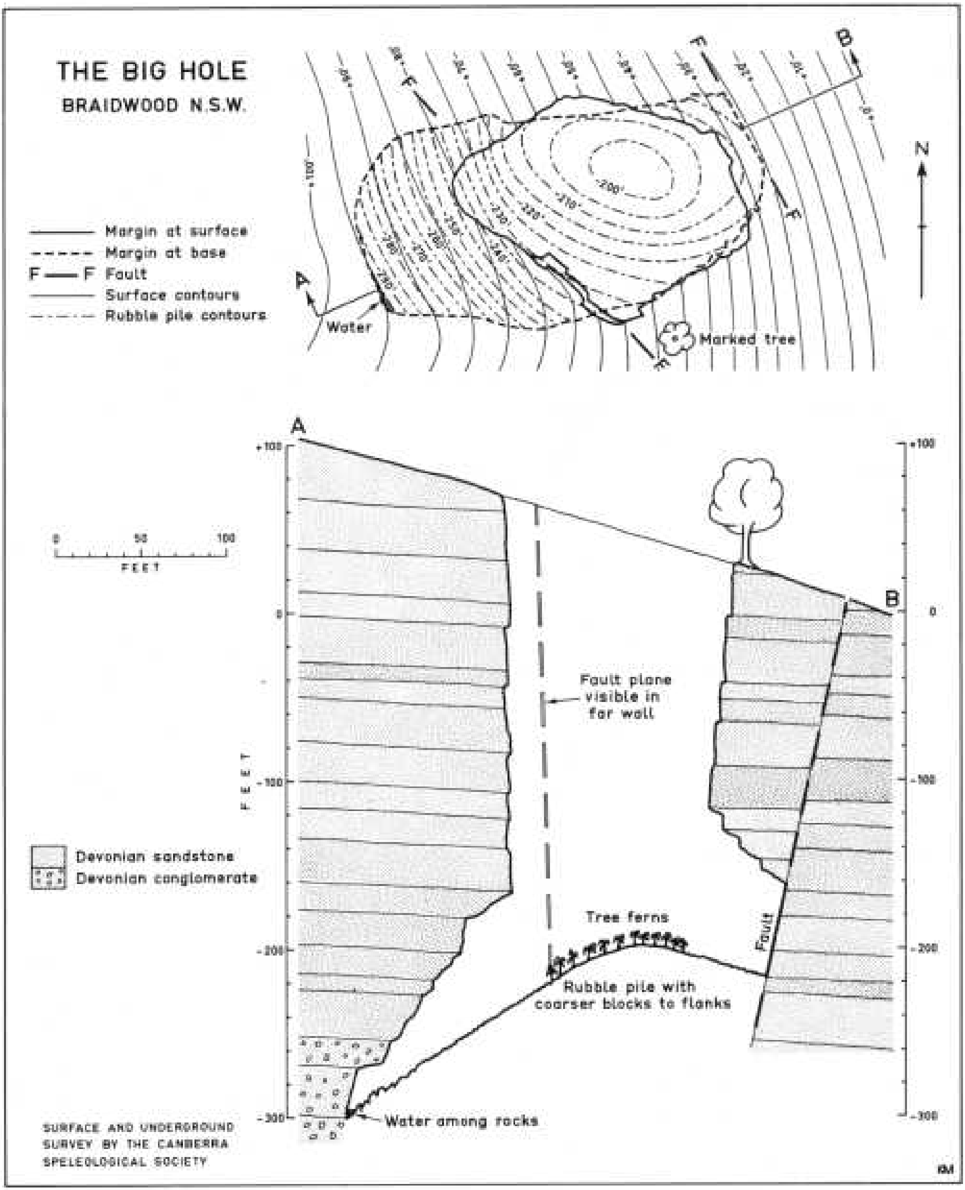

Figure 1. A revised plan and section of the Big Hole. The datum for heights is arbitrary.

A second conclusion of the previous paper was that the unusually high depth/width ratio for this large subjacent doline is due to the fact that the limestone must take the form of a steeply-dipping, short strike belt similar to those at Wyanbene, Marble Arch and Cheitmore. This geological structure confined the subjacent solution to modest horizontal dimensions. Also it was argued that the high depth/width ratio, the very steep walls, and the angular plan of the Big Hole pointed to a sudden collapse into a large cave below rather than to repeated small subsidences through progressive solution at the top of the Limestone just below the Devonian.

The size of the cave required by this explanation seemed something of a stumbling block previously since it would have had to be much larger than any chambers known in the caves of the neighbouring limestone areas. However, the new discoveries at Wyanbene dispose of this particular difficulty. The new part consists mainly of a large oblique chamber in the bedding. Though the vertical height in this chamber is not particularly great at any one point, its overall height from the river at the bottom to the highest part of the roof is of the order of 200 feet. Moreover, linked by a fissure to this chamber, there is to the side what may be the largest aven yet found in Australia. It has been called the Gun Barrel and is about 45 feet in diameter at the base and the height is estimated at 150 feet. There are many non-limestone rocks on the floor of this aven which have fallen from above. Those sampled have all proven to be siltstone and no arenaceous or rudaceous rock has been found. This suggests that they derive from the Silurian sequence, not the Devonian, and so the aven has not stoped through to the unconformity, which outcrops on the hillside above Wyanbene Cave. However, we know now that there are cavities in the limestone of the neighbourhood of the right magnitude to match that which the inferred origin of the Big Hole demands.

A further difficulty about the adopted explanation of the Big Hole was discussed in the previous paper. At that time the relative level of the bottom of the Hole and of the Shoalhaven to the west was not known, but survey had shown the bottom to be well below the valley floor to the east of the hill in which it lies. This latter fact, together with the presence of standing water in the Hole and of a general geomorphology in the Shoalhaven valley which precluded any former lower level of watertables in the area, led to the conclusion that the cave into which the sandstone had collapsed projected well below the local watertable and must have developed phreatically. Moreover, because the limestone body must be closely confined by impervious rock, deep phreatic solution, rather than shallow phreatic, seems to be implied. But speleological theory in recent years has tended against the production of large chambers by deep phreatic solution. This problem remains in some degree because though the base of the Hole is now known to be some 70 feet above the river to the west, the cave below must still have projected well below the level of the river.

Brink and Partridge (1965) have recently discussed the conditions for sudden sinkhole development in the West Witwatersrand Goldfield of the Transvaal. The sequence of conditions they regard as causing dolines to develop catastrophically probably does not apply fully here because in the South African examples the underlying karst rock - dolomite - is overlain by thick unconsolidated deposits, not competent sandstones as at the Big Hole. But one condition is probably applicable in both circumstances and that is the need for some disturbing agency to cause the roof to collapse. In the Transvaal this has been the rapid lowering of water levels in mining operations. Lowering of the watertable can scarcely have been operative in the case of the Big Hole since it still lies above the top of the limestone in which the preparatory cavitation occurred, and the valleys around the Big Hole hill have not yet been affected by the rejuvenation of the Deua drainage system to the east. To postulate an earthquake as the triggering mechanism is not very satisfactory either since this is practically a non-seismic area. The question of the disturbing agency to provoke what must have been the geologically speaking recent catastrophe which produced the Big Hole remains problematic.

Investigation and exploitation of uranium ores in southwestern United States have brought to light cylindrical collapse structures filled with brecciated sediments around which are altered rocks in which the ores occur (Gabelmann and Boyer, 1958). Hydrothermal solutions associated with volcanic activity are thought to have removed carbonate from limestone, dolomite, and calcareous shales and this has caused collapse. Some of these features have the size and the proportions of the Big Hole. For instance, collapse No. 6 in the Temple Mountain area of Utah has a diameter of 100 feet and a displacement of 300-400 feet, filled with a chaotic core of Triassic conglomeratic sandstone (Kerr and others, 1957). In the southern Spanish Valley in Utah, 45 similar structures are known in Triassic sandstones with diameters of a few hundred feet and depths inferred to be several thousand feet (Weir and others, 1961). Here solution of underlying Palaeozoic limestone is regarded as having created the necessary space for the collapses. In all these areas the collapse structures form projections on the present ground surface rather than hollows. But this is the result of erosion and there can be no doubt but that originally some of them must have had surface expression as holes with proportions similar to those of the Big Hole and of a size as big or much bigger than the latter. Mineralization proving the hydrothermal nature of the dissolving waters has been revealed by this erosion.

Application of this theory of origin to the Big Hole would avoid the difficulty involved in interpreting it as due to true phreatic solution by groundwater of meteoric origin. Nevertheless until evidence of young hydrothermal mineralization or other evidence of hydrothermal activity has been found in the area, the theory supported here must be preferred. No high temperature water such as has been found in two caves at Wee Jasper is known in the Shoalhaven area.

In the previous paper on the Big Hole it was stated that in terms of the literature then studied it was exceptionally deep for its cross-sectional area bearing in mind the large size also. However, fully comparable features of apparently similar origin can now be cited in the "furnas" of Vila-Veilha in the State of Parana, Brazil (Bret, 1962). For example, No.1 of these furnas is circular in plan with a diameter of 160 feet and has a depth of 370 feet. The correspondence is complete dimensionally but there is a significant difference from the point of view of the explorer - the lower 160 feet is under water. Whether there have been water-level changes has not been discussed by Bret. All the furnas are in subhorizontal Devonian sandstone, which is impermeable and little subject to solution; this lies unconformably on tightly folded Proterozoic rocks. So the similarity to the Big Hole is structural also and Bret proffered the same theory of origin, namely solution by groundwater in lenses of limestone in the underlying Proterozoic rocks.

Conclusion

The new data from the Big Hole and its vicinity give some further support to the view maintained previously as to its origin, though an approach through water chemistry proved non-committal. Difficulties attaching to an origin by true phreatic solution of underlying limestone through circulations of groundwater of meteoric provenance remain however. Nevertheless, the possibility, not considered previously, that the Big Hole is due to hydrothermal solution in the manner of many collapse structures associated with uranium ore bodies in southwestern U.S.A. finds no support in the regional geology of the Shoalhaven valley, though it could produce features of the right dimensions. Previous lack of a complete parallel to the Big Hole has been removed by reference to the furnas of southern Brazil where a similar origin to the one proposed here is also inferred.

Acknowledgments

The author is grateful to Dr. R.W. Galloway for drawing his attention to the literature on the collapse structures in Utah and to Mr. N. Anderson and Dr. J. Coulton for further measurements down the Big Hole. The laboratory determinations were made by Mr. K. Fitchett, Technical Officer in the Research School of Pacific Studies, Australian National University.

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ABSTRACT

THE RHAPHIDOPHORIDAE (ORTHOPTERA) OF AUSTRALIA. PART 3. A NEW GENUS FROM SOUTH-EASTERN AUSTRALIA. By Aola M. Richards. Pacific Insects, 8 (3) : 617 - 628.

The new genus Cavernotettix Richards is recorded from south-eastern Australia. Three new species, Cavernotettix montanus Richards, C. wyanbenensis Richards and C. buchanensis Richards, all from limestone caves, are placed in the genus. C. montanus and C. wyanbenensis occur in the Southern Highlands of New South Wales - C. montanus on the western side of the Great Dividing Range at the Yarrangobilly and Cooleman limestone areas, and C. wyanbenensis on the eastern side at Wyanbene and Cheitmore. C. buchanensis is found almost at sea level in the Buchan and Nowa Nowa caves just north of Lakes Entrance, on the Southern Coast of Gippsland, Victoria. Yarrangobilly and Cooleman are the coldest caves from which cave crickets have been collected in Australia, with temperatures from about 9.5°C, and they occur at the highest altitudes (1,190 - 1,265 m) from which these insects have been recorded. - A.M.R.

FRENCH SPELEOLOGIST HONOURED

Robert de Joly, foundation President of the Fédération Française de Spéléologie, has been promoted from Chevalier of the Legion of Honour to the rank of Officier of the Legion of Honour in recognition of his speleological activities. He was awarded the previous rank in recognition of his military service.

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ELEVATIONS IN THE MADURA AREA, WESTERN AUSTRALIA

T.M.L. WIGLEY* and A.L. HILL**

The Madura area, Western Australia, is one of considerable speleological and general interest. Chiefly because of its remoteness, available maps of the area are neither as accurate nor as complete as those of more accessible regions. Elevations (heights above mean sea level) are known only at isolated points and not with any great accuracy. In view of their importance in studying the morphology, geology and hydrology of the region, a series of carefully controlled aneroid height determinations was made during January, 1967. The results are presented below and are compared with elevations obtained from other sources.

Two digital aneroid barometers, on loan from the Commonwealth Bureau of Meteorology, were used. These barometers are extremely sensitive, yet are quite robust instruments. They can be read to one hundredth of a millibar and can be used to measure absolute pressure values to one tenth of a millibar, the same order of accuracy as a mercury in glass instrument. Their accuracy for relative work is between these two limits so that pressure differences between two points can be measured with great precision. They are, therefore, an ideal instrument for barometric height determinations since the instrument error is less than the errors which are inherent in the conversion of pressure differences to height differences. Consequently, for elevation determinations over small ranges, results accurate to within a few feet could be obtained. This is much better than the reliability that can generally be placed on dial aneroid elevation measurements.

The elevations presented in this paper were obtained in the following manner. Two barometers were employed. One was used as a control at Madura (point 9 on the accompanying map), and the other, as the "active" instrument, was read at a series of points (1 to 10 on the map) along the routes south from Madura to the sea and back, and from Madura to the top of the Madura Pass and back.

The readings were corrected for ambient pressure changes using the control instrument, and converted to heights above mean sea level with due allowance for the prevailing temperature. This temperature compensation arises from the fact that, if two points are separated vertically by a distance h, the pressures at the two points are related by $h = k \log (P_2/P_1)$, where k depends on the virtual temperature profile between

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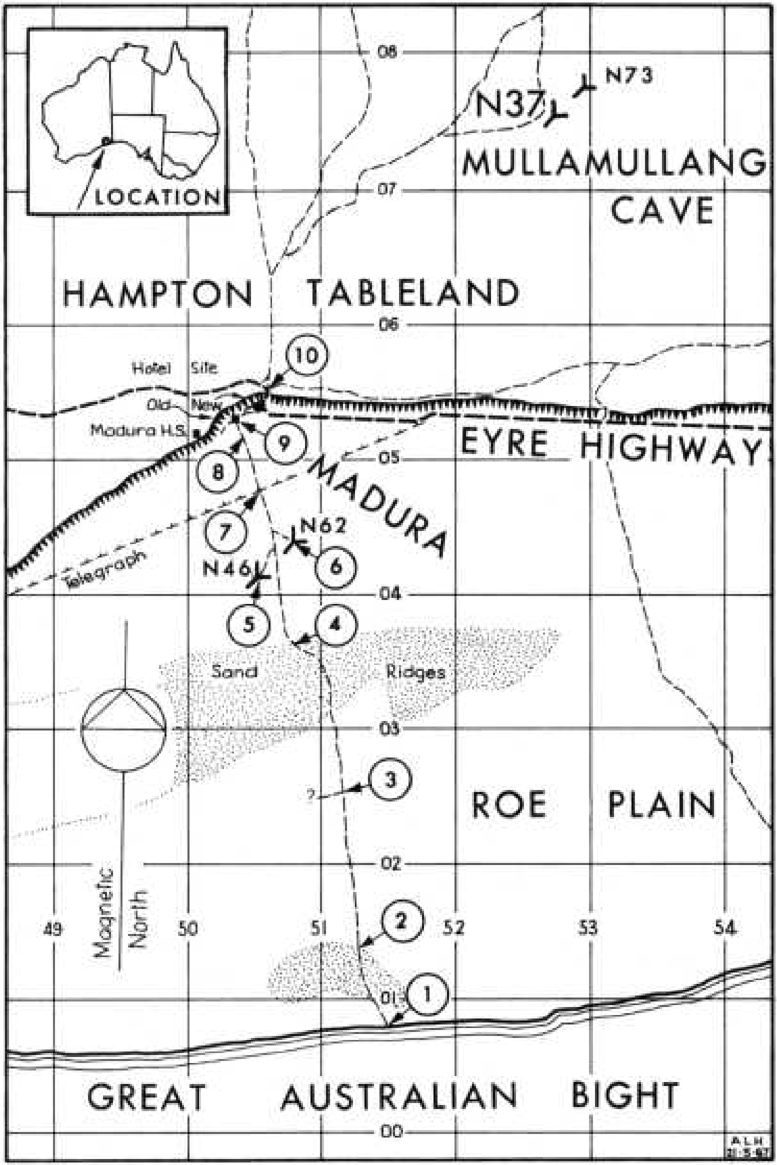

MADURA AREA - WESTERN AUSTRALIA

10 0 Miles 10 20

SCALE 1 INCH = 8 MILES 10,000 YARD GRID

the two points. Since, in this case, the pressures are known very accurately, it is important to allow for the variation of k with temperature. The results are presented in the first column of the following table. The positions referred to in the table are shown on the map. The results, although given to the nearest foot, have an estimated reliability of plus or minus 5 feet.

Observation Points			Elevations		
No.	Description	Grid Ref.	This Study	Hill (1966)	R.A.S.C. Maps
1	Mean sea level	515008	0	0	0
2	Bottom of sand dune	513014	47	-	90
3	Rough track to west	512025	60	-	-
4	Bottom of sand dune furthest from sea	508036	77	85	90
5	Nurina Cave (N46)	505041	82	85	-
6	Madura Six Mile South Cave (N62)	507044	95	-	-
7	Telegraph line	505048	99	-	-
8	Flat area below Old Hotel	504052	112	130	-
9	Outside Old Madura Hotel	504053	160	165	-
10	Top of Madura Pass	506056	355	350	310

In the second column of the table, the results of Hill (1966) are shown while in the third column of elevations spot elevations from the Royal Australian Survey Corps 1:250,000 Maps SI 52-1 Edition 1 (1964) Series R 502 (Burnabbie) and SH 52-13 Edition 2 (1966) Series R 502 (Madura) are shown. The observation points used by Hill are the same as those used in this study. The values quoted from the Royal Australian Survey Corps (henceforth RASC) Maps correspond to points in the immediate vicinity of those used here.

Hill's results agree remarkably well with those presented here. This agreement tends to add some weight to the estimate of 60 feet given by Hill as the elevation of the plain surrounding Mullamullang Cave (N37, grid reference 527075) relative to the top of the Madura Pass (point 10). During the course of the present study, the elevation of the plain near N37 was found to be much the same as the elevation of the entrance to the Small Blowhole N73 (grid reference 530077), but no attempt was made to compare the elevations of either of these points with point 10. The elevations quoted from the RASC Maps (column three of the elevations in the table) show only fair agreement with those in column one. Although the differences may be due in part to the non-coincidence of the observation points, it is considered that the reliability of elevations shown on the RASC Maps (Burnabbie and Madura) is not high.

It is recommended that point 10 be used as a reference point for future work and that the elevation of this point be taken as 355 feet. This reference point is located at plain level by the road junction where the Loongana road branches off the Eyre Highway and is eminently suitable since the neighbouring terrain is relatively level. The RASC elevation at this point is given as 310 feet and, in view of the large difference between this and that recommended above, this value bears closer investigation.

Until a complete hydrological survey has been carried out the exact relation between depth to water rest level ("d", say) and elevation at any point ("h", say) cannot be known. It would be expected that, in the Madura area, the difference (h-d) would be positive (unless pumping had significantly lowered the natural watertable level) and fairly small. At points where reasonably reliable estimates of both of these values have been made, this expectation has been confirmed (Hill, 1966). At point 10, the 355 feet elevation recommended as a reference value gives h-d a value of about 30 feet, a consistent estimate. A 310 feet elevation, however, would indicate that the watertable was depressed below mean sea level, a possibility which seems rather unlikely. The hydrological assumptions outlined above have been made on little evidence, but, nevertheless, they tend to support the elevation results given in this paper.

Acknowledgment

The authors wish to express their thanks to the Commonwealth Bureau of Meteorology for the loan of instruments.

Reference

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HALITE SPELEOTHEMS FROM THE NULLARBOR PLAIN, WESTERN AUSTRALIA

D. C. LOWRY

Geological Survey of Western Australia, Perth

Abstract

Halite has been found in five caves on the Nullarbor Plain, Western Australia. It occurs as stalactites, stalagmites, crusts, or fibres. The climate of the Plain is arid to semi-arid, and the halite is derived from wind-blown salts that accumulate in the soil. The halite forms in the caves under conditions of relatively low humidity (about 70%) and high temperature (about 67°F). Its association with older calcite deposits suggests the climate was once wetter or cooler than at present.

Introduction

The Nullarbor Plain is an arid to semi-arid plateau of Miocene limestone adjoining the Great Australian Bight. The speleothems in the Easter Extension of Mullamullang Cave N37 were first thought to be gypsum, but the writer tentatively identified them as halite by the simple expedient of tasting them, and the identification was confirmed later by chemical analysis (Wigley and Hill, 1966). Halite was also recognised in Thylacine Hole N63 (Lowry and Lowry, 1967) and three other caves. Mr. P.J. Bridge later collected specimens which he passed to the writer for examination, and then to the Western Australian Government Chemical Laboratories for chemical analysis.

Halite is the crystalline form of sodium chloride and belongs to the cubic (isometric) system. The crystals have well developed cubic cleavage and are usually cubic, although other forms are known.

Description

Halite occurs in four main forms in the Nullarbor caves: fibres, crusts, stalactites and stalagmites (Figure 1).

1. Fibres. The fibres are delicate glassy crystals 0.1 to 0.4 mm in diameter and reaching a length of several centimeters. Many of the crystals are curved, and some show minor optical anisotropy, presumably due to strain. The crystals may intertwine haphazardly and resemble glass wool (see bottom picture, Plate 2, in Lowry and Lowry, 1967), or the crystals may form curving bundles closely resembling gypsum flowers (Figure 2).

2. Crusts. Sparkling crusts are composed of approximately cubic crystals of halite. In the specimen examined, most of the crystals were 0.02 to 0.05 mm in diameter, with a few reaching 0.2 mm. In some places the crusts reach a thickness of several inches.

3. Stalactites. Halite stalactites closely resemble those formed from calcite, and both straw stalactites and tapering ones occur.

The straw stalactites are about 5 to 8 mm wide, and exceed 30 cm in length (Figure 3). The interior of each tube is largely choked with crystals having well-formed cubic faces. The exterior surface is usually smooth, although it is sometimes marred by corrosion. The straw stalactites are monocrystalline, and the crystal is oriented with the long diagonal of the cube coinciding with the axis of the stalactite.

Tapering halite stalactites range up to and occasionally exceed 5 cm in diameter and 100 cm in length. One broken stalactite 45 mm in diameter showed a cleavage face 20 mm across on the broken surface suggesting that the stalactite was monocrystalline. It too had the cleavage faces inclined at 45° to its axis.

One distinctive feature of the stalactites is the abundance of liquid inclusions. These inclusions mark growth stages, and some of them contain gas bubbles.

4. Stalagmites. Stalagmites were noted in Thylacine Hole, but were not examined. They are commonly about 5 cm across and, in some places, join stalactites to form columns.

Chemical Composition

A sample of stalactite was collected by Bridge from Thylacine Hole and analysed by the Government Chemical Laboratories of Western Australia. The sample was dried and then dissolved in water. The resulting solution was analysed and the sample was calculated to have the following composition:

Ca	.21 percent
Mg	.19
K	.01
SO_4	.14
CO_2	.05
Cl	58.7
Moisture at 105°C	2.79
Na (by difference)	37.9

Occurrence

Fibres and thick crusts of halite occur in Mullamullang Cave (31° 43'S, 127° 14'E) in the Easter Extension, and probably also in the Ezam Section (Wigley and Hill, 1966). The crusts cover walls and floors, and the fibres grow from the porous limestone. All four forms of halite are found in Thylacine Hole (31° 42'S, 127° 44'E), and stalactites are particularly well-developed. They hang from the roof and also from fallen blocks (Figure 3). In the latter case, the stalactites were built by water which dripped from the roof on to the block and then dripped off the block.

Short halite stalactites and fibres were noticed in Cave N149 (31° 51'S, 127° 41'E), ten miles west of Mundrabilla.

Bridge (pers. comm.) observed halite crystals on the roof and on old calcite stalactites in Webbs Cave N132 (31° 46'S, 127° 50'E). He also recognised halite in the soil and encrusting the end wall of the left-hand branch of Madura Cave N62 (31° 58'S, 127° 03'E). The halite in the soil appeared to have fallen from the roof.

There do not appear to be any references to halite speleothems in limestone caves elsewhere in the world, but they have been recorded in lava caves (Ollier, 1963; Rimbach, 1963) and mines (Spiroff, 1937; Kenney, 1957; Maksimovich and Beltiukov, 1966; and Maksimovich et al, 1966). The last two papers cited describe abundant stalactites, stalagmites, rimstone and flowstone composed of sylvite, carnalite and halite, which were developed in mines in evaporite deposits. Halite stalactites were also described by Kenney who found them in a coal mine.

Origin of the Halite

In Mullamullang Cave, the halite occurs about 280 feet below the surface of the limestone plateau, and about 90 feet above the watertable. Wigley and Hill (1966) noted that gypsum deposits occur between this level and the watertable, and they believed that this represents a significant zonation of minerals. However, in Thylacine Hole the halite is about 80 feet below the surface and about 270 feet above the watertable, while in Madura Cave it is about 40 feet below the surface and about 40 feet above the watertable. This shows that the deposits have no simple relationship with the distance either from the surface or from the watertable.

Ground water in the vicinity of Madura has a salinity of 9,500 to 51,000 parts per million total dissolved solids, and the principal ions, in order of abundance expressed by equivalent weight, are chloride, sodium, magnesium, sulphate, calcium, and bicarbonate. If the halite in the caves was formed by evaporation of ground water, one would expect to find significant deposits of magnesium salts, but these have not been found. However, when sea water evaporates, magnesium salts are among the last to

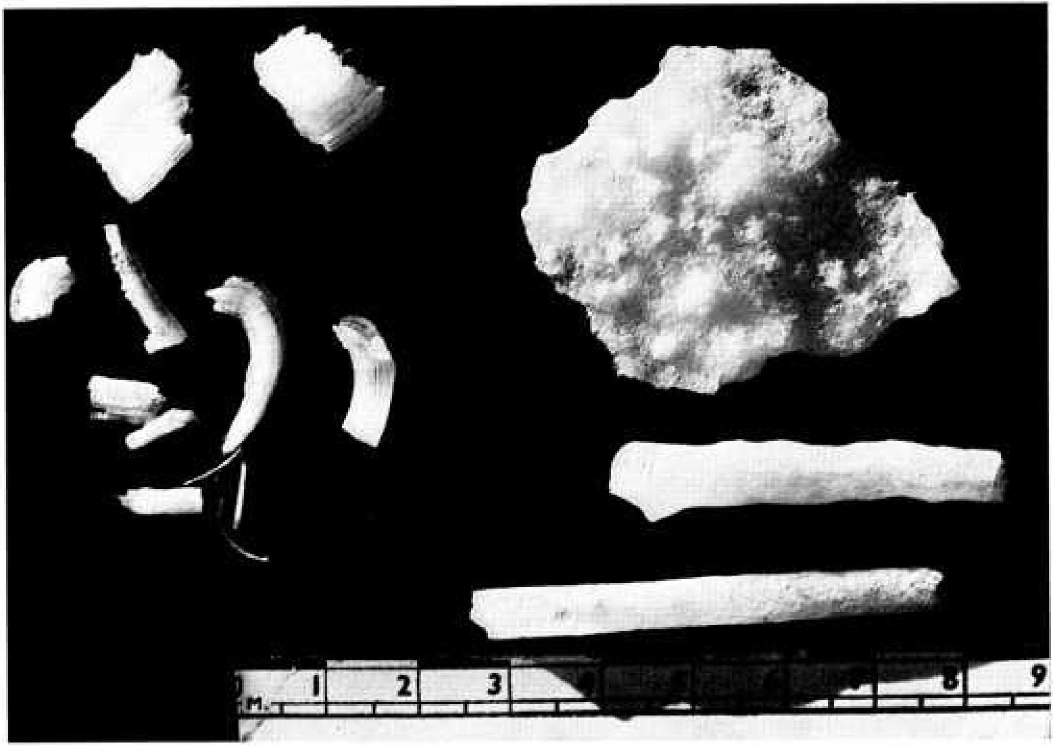

Figure 1. Halite speleothems from Thylacine Hole. Scale in centimeters.

Figure 2. Fibrous halite in the Easter Extension of Mullamullang Cave. The "flowers" are about 15 cm long.

Figure 3. Calcite stalactites (inclined) and halite stalactites (vertical) in Thylacine Hole. Scale, left centre of picture, is 10 cm long.

precipitate, and it must be admitted that sodium and magnesium salts could conceivably be separated by some mechanism of repeated fractional crystallization.

Wigley and Hill (1966, p. 38) suggest that the halite was deposited by vadose water which takes "sodium chloride into solution as it moves down through the very porous country rock." If this means that the halite was derived from connate sea water in the limestone, then it is an unsatisfactory suggestion because it is most unlikely that the halite would remain in rock where cementation, cave formation, and in some cases deposition of calcite in caves, had taken place. They also mention (p. 37) that halite occurs at the ground surface in arid regions, but they do not suggest an origin for such halite. It is not clear whether or not they thought that this was the source of halite in caves, and neither is it clear why they referred to the salt in the mud of Lake Eyre as an example of this type of occurrence.

The halite was probably precipitated from vadose water which had leached cyclic salt from the soil. The ground surface above the caves consists of gentle stony rises and intervening clay flats. The clay of some of these flats contains halite and gypsum and supports a vegetation of samphire (Arthrocnemum). The halite is probably derived from spray or salt crystals blown from the Indian Ocean lying to the south. This is supported by the observation that samphire (a halophyte) is more common near the coast than in the centre of the plateau, despite the fact that the rainfall is higher near the coast.

Given the correct balance of permeability of the clay, rainfall and supply of cyclic salt, water saturated in sodium chloride could seep into the underlying limestone. If the seepage entered a cave and evaporation occurred, halite would precipitate. Stalactites and stalagmites probably develop where a fast seepage reaches the roof of a cave and forms drips, whereas crusts develop where the seepage reaches a wall and forms a film of water. Fibres probably form where a slow seepage evaporates in the pores of the limestone before reaching the surface of the cave wall, so that the crystals are extruded as fibres.

Conditions of Deposition

Given a saline solution entering a cave, deposition of halite will depend on evaporation, and this will be favoured by high temperature, low humidity and air currents. These conditions were met in the Welbeck Colliery in England where the temperature was 81.5°F, the relative humidity 67%, and there was a draught which exceeded eight miles per hour (Kenney, 1957). Conditions favouring evaporation also seem to be met in the caves where halite was observed, although draughts do not seem to be important. In Thylacine Hole in October, 1966, the temperature was 66°F and the relative humidity was 67%. Air movement is common in caves of the Nullarbor

Plain, and there were appreciable draughts in the four-foot wide entrance shaft to Thylacine Hole. However, no draughts were observed in the wider parts of the Thylacine Hole cave where the halite occurs, and it is unlikely that there was ever more than a gentle current of air passed the deposits.

In the Easter Extension of Mullamullang Cave in August, 1966, the temperature was 68°F and the relative humidity 72%. Although no draughts were noticed, there is probably some air movement because there are pressure fluctuations in the main passage with which Easter Extension connects.

Paleoclimatic Significance

Secondary calcite is not common in Nullarbor caves, although there are at least four shallow caves with abundant deposits: Lynch Cave N60 (30° 18'S, 128° 39'E), a cave at 30° 57'S, 127° 04'E, Decoration Cave N84 (30° 18'S, 128° 39'E), Cave N73 (31° 43'S, 127° 15'E), in addition to Thylacine Hole (see top picture, Plate 2, in Lowry and Lowry, 1967). In each cave, the calcite is old and dead whereas the halite in Thylacine Hole is growing at the present time - the halite is clean and there are drips of water hanging from many of the straws. There are several indications that the calcite and halite have not been deposited simultaneously. One good example (Figure 3) shows that there was minor roof collapse between an early period of calcite deposition and the present period of halite deposition. Another indication is that where halite and calcite occur together, the halite always encrusts the calcite and never the reverse.

The change from deposition of calcite to halite suggests that the climate has become drier and possibly hotter. Four reasons for this suggestion are given below.

1. The large expanse of calcite flowstone, and the much greater number of calcite stalactites and stalagmites compared with halite ones, shows there was probably a greater valume of water entering the cave during deposition of the calcite. This is most easily explained either by higher rainfall than at present, or cooler temperatures which reduced evapotranspiration.

2. The lack of old halite associated with the old calcite shows that the solution that deposited the calcite was probably undersaturated with respect to halite. At present, however, it must be saturated or else it would dissolve the roots of salt stalactites as it enters the cave. The change from calcite to halite deposition is more easily explained by an increase in concentration in cyclic salts caused by a decrease in water supply. It might be argued that there could have been the same water supply as at present, but with less cyclic salt. This is an improbable alternative because there is little water entering the cave at present and there is virtually no deposition of calcite. If the water supply had stayed constant,

the time required for the deposition of the calcite would be extremely great.

3. Calcite speleothems are usually deposited by loss of carbon dioxide in a wet cave where the air is saturated with water vapour (Moore and Nicholas, 1964). Halite stalactites, however, can only be deposited in dry caves by the evaporation of a hanging drip of water saturated in sodium chloride. If the change from calcite to halite deposition reflects a decrease in humidity in the cave, it may have been caused by a change from a wetter or cooler climate.

4. Abundant calcite formation in a limestone cave is usually associated with an overlying soil rich in humus (Moore and Nicholas, 1964). At present, the vegetation above the caves containing halite consists only of grasses, salt-bush (Atryplex) and samphire on the clay flats, and sparse myall scrub (Acacia sowdenii) on the limestone rises. There is very little humus in the clay or leaf litter that could cause the rain water to pick up the high concentration of carbon dioxide necessary for the solution of the limestone and its redeposition in a cave. It seems likely that when the calcite formation was deposited, the soil was richer in humus or covered with leaf litter - a feature likely to be present under conditions of higher rainfall.

These four points indicate that the climate was once wetter or cooler or both, and it is not possible to decide which one is correct. However, there is a hint that the climate was at least wetter. The abundance of calcite speleothems forming in caves in Coastal Limestone on the west coast of Western Australia appears to depend largely on rainfall, and the abundance of calcite in Thylacine Hole corresponds better with that in caves in the Yanchep to Augusta strip (annual rainfall 30 to 45 inches) than in the Yanchep to Jurien Bay strip (20 to 30 inches). Since the rainfall in the vicinity of Thylacine Hole is now about ten inches, it suggests that the climate was wetter in the past. This however is only a suggestion because the abundance of calcite depends on many variables other than rainfall.

Age of Deposition of the Calcite

It appears that the Nullarbor Plain was once covered by a thick sheet of residual clay and kankar, and that it was stripped off by wind erosion, possibly about the middle of the Pleistocene (Jessup, 1961; Lowry, in press). In adjoining areas where the clay has not been eroded, rain is largely absorbed by the porous clay, and the little run-off that occurs is not concentrated because there is so little topographic relief. Thus there is very little vertical percolation of water through the limestone and it is unlikely that abundant calcite could have been deposited in caves before the clay was eroded.

If these speculations are correct, the calcite deposition indicates a wetter and possibly cooler climate than at present some time in the late Pleistocene; possibly during the last glacial period.

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