Vol. 7, No. 3 JULY, 1969 PRICE 60c.

Helictite

JOURNAL OF AUSTRALASIAN CAVE RESEARCH

Calcite crystals in Puketiti Flower Cave, near Pio Pio, North Island, New Zealand. See page 42.

Photograph by John Pybus.

" H E L I C T I T E "

Journal of Australasian Cave Research

Edited by Edward A. Lane and Aola M. Richards

VOLUME 7, NUMBER 3 Published Quarterly JULY, 1969

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Price of this issue: To non-subscribers, A$1. Additional copies to subscribers, 75c. Included in annual subscription, 60c. Annual subscription A$2.40, post paid Australia. All foreign subscriptions A$2.60, post paid. All subscriptions taken on basis of full volume of four issues. Correspondence, contributions and subscriptions to "Helictite", Post Office Box 183, Broadway, New South Wales 2007, Australia. "Helictite" is printed and published by E. A. Lane.

PUKETITI FLOWER CAVE, NEW ZEALAND

(The following notes were written by Mr. John Pybus, a foundation member of the New Zealand Speleological Society, to accompany a series of photographs he took of the Puketiti Flower Cave. One of these photographs is used on the cover of this issue of Helictite, and other photographs from this series will appear in later issues.)

The Flower Cave is on the Puketiti Station, 30 miles south of the main Waitomo Caves and west of Pio Pio, North Island, New Zealand. The cave was discovered at Easter, 1963, by Peter Barrett, John Hobson, Daphne Hobson and Peter Diamond, members of the New Zealand Speleological Society.

The entrance to the cave is a small cleft and a 40 ft descent is made to stream level. The stream passage, containing some deep pools and large rocks, is followed for about 900 ft. A side passage is then followed for about 400 ft and then a narrow branch for 1,500 ft to the Flower Cave.

The Flower Cave proper consists of approximately 1,200 ft of gypsum and all kinds of decoration covering the walls. Long selenite hairlike needles droop in clusters; a corkscrew shaped helictite turns 40 times in an almost perfect spiral 16 inches long; gypsum "wool" or "fluff" occurs in masses of threadlike crystals. In parts of the cave a crust of gypsum has been forced off the wall to reveal crystals of gypsum, at right angles to the wall, pushing the layer away; the overall appearance resembles a hair brush with the bristles facing the wall. Along the same passage were dense arrays of gypsum flowers, many radiating from a single stem.

A highlight of the cave is at the far end and is reached by an 18 ft slide along a low tunnel floored with gypsum "sand." Here is a former pool, now dry, 6 ft by 15 ft, and adorned with masses of calcite crystals, some of which appear on the cover of this journal.

The preservation of this cave is of great importance both for its magnificance and its scientific importance. A close scientific study is warranted of the gypsum formations and their co-precipitation with calcite. New Zealand cavers and speleologists from other countries who have been shown the Puketiti Flower Cave believe its crystal decorations are among the best in the world.

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CAVE MICROCLIMATE : A NOTE ON MOISTURE

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Abstract

The moisture budget of a cave atmosphere is examined quantitatively. The results indicate that caves can be divided into two distinct classes depending on whether the cave atmosphere is or is not saturated. A further consequence of the theory is that greater climate fluctuations are to be expected in caves in which unsaturated conditions prevail. This generalisation may have significance in studies of cavern breakdown and in ecological studies in caves.

Introduction

The humidity of the air is one of the more readily apparent climatological factors inside a cave. In fact, high relative humidity and nearly constant temperature popularly characterize the cave environment. The simple qualitative explanation of these conditions - that they are caused by the relative abundance of water underground and by the insulating property and high heat capacitance of the rock - are not entirely satisfactory. The situation is generally quite complex, and is most obviously complicated by the fact that frequently there is considerable circulation of air within, and to and from, caves.

General discussions of cave microclimatology are rare in speleological literature and even rarer in meteorological literature. Although a number of authors have presented facts concerning particular caves, only a few (for example, Geiger (1965), Lawrence (1955) and Moore and Nicholas (1964)) have discussed the cave environment from a more general point of view. General treatments of specific aspects of the cave microclimate have also been given on occasion; for instance by Wigley (1967) and Plummer (1964) (cave "winds") and by Eraso (1965) (temperature). In the following paper, humidity is considered from a general viewpoint and the mechanisms which control the moisture content of the air inside a cave are discussed in detail.

Discussion

The moisture variable, "Relative Humidity," is used frequently in popular literature. In some ways this is an unfortunate circumstance, for relative humidity depends not only on the actual moisture content of the air but also on the temperature.

"Mixing Ratio" is a more basic moisture variable. It is defined as the ratio of the mass of water vapour to the mass of dry air in a sample of moist air. In theoretical discussions, mixing ratio is generally used since it is a direct measure of the amount of water vapour in the atmosphere. In particular cases, however, derived variables (such as relative humidity) may be important. For example, the expansion and contraction of hair as the moisture content of the air varies is directly dependent on relative humidity; this is the basis of a useful meteorological instrument, the Hair Hygrometer. Inside a cave, as will become evident below, mixing ratio is the fundamental variable.

Let us consider a cave in which there exists some supply (source) of water vapour to the cave atmosphere. This could be, for example, a stream, a static pool, or even moist walls. If the cave was completely sealed, any slow circulation of air inside the cave would lead eventually to the complete saturation of the cave atmosphere. The physical movement or circulation of air is a much more efficient distributor of moisture than molecular diffusion and it is this air movement which is an important controlling factor in determining the moisture distribution within a cave. ("Circulation" is used here to cover all air motions from the immeasurably slow to winds of appreciable velocity.)

Suppose now, that the cave does have a connection with the outside atmosphere. We will consider only the region of such a cave where the climate is very nearly constant (the "deep-cave" zone), and ask the question: How does the atmosphere in this zone approach or maintain an equilibrium state with respect to moisture content?

The deep-cave zone is connected through other parts of the cave to the outside atmosphere. In general, some mixing of air from the deep-cave zone with the air in adjacent parts of the cave will occur. Although this mixing may only be slow, there will be, at any particular instant, a net movement of air either into or out of the deep-cave zone (i.e. a circulation of air between this zone and other parts of the cave). Assuming that the air in the deep-cave zone is homogeneous (i.e. ignoring any possible vertical or horizontal stratification of air temperature or moisture content), then air that moves out of this zone cannot change either its temperature or mixing ratio. Air that moves in can, however, effect such a change since it may be either drier or moister (or warmer or cooler) than the deep-cave air.

Considering this situation quantitatively, we study the behaviour of the system over a period of time, T, say. For part of this time (t_o) there will have been a net movement of air out of the deep-cave zone, and, for the remaining part (t_I) there will have been a net inward movement of air. Hence,

$$t_o + t_I = T, \qquad (1)$$

and

$$t_o \, U_o = t_I \, U_I, \qquad (2)$$

where U_o and U_I are the average flow rates (in mass units per unit time) for outward movement and inward movement respectively. (In Equation (1) it has been assumed that any zero-motion periods are taken arbitrarily to be either in or out.)

Equation (2) is simply a statement that, over a sufficiently long period of time (which T is assumed to be), the total mass of air in the deep-cave zone is conserved. This is in spite of the fact that, although the volume of the deep-cave zone (as a container of air) is necessarily constant, the mass of air inside this container is not constant, since the air pressure inside the deep-cave zone, in general, varies with time. Equation (3) can be written as

$$t_I \, U_I = \int_I U dt = \int_o U dt = t_o \, U_o \qquad (3)$$

where $U = U(t)$ is the mass flow at any time t, and the integrals are taken over times of in-motion and out-motion.

To calculate how much moisture was transported into and out of the deep-cave zone during the time period T we need only multiply the integrands in Equation (3) by the mixing ratio. If $W = W(t)$ is the mixing ratio of the air which moves into the deep-cave zone then W U is the flow-rate of water vapour and

$$\int_I WU \, dt$$

is the total mass of water vapour which the zone gained during time T (more specifically during the fraction t_I of T when the net air movement was inward). This can be written as

$$\bar{W} \, U_I \, t_I$$

where $\bar{W}$ is the average value of W defined by

$$\bar{W} \int_I U dt = \int_I WU \, dt.$$

$\bar{W}$ is effectively the average mixing ratio of the incoming air. Similarly, if w is the mixing ratio of the deep-cave air, the total amount of water vapour lost from the deep-cave zone when the net flow was outward is given by

$$\bar{w} \, U_o \, t_o.$$

In general these two values will not be equal, and there will be an overall transport of moisture out of the deep-cave zone equal to

$$\bar{w}\, U_o\, t_o - \bar{W}\, U_I\, t_I = U_o\, t_o\, (\bar{w} - \bar{W}), \qquad (4)$$

where Equation (2) has been used to obtain the right-hand expression.

Equation (4) is completely general and can, in fact, be applied to any part of the cave. Since we are considering the deep-cave zone in particular, we can assume that an equilibrium state (constant temperature and mixing ratio) exists in this zone. Then, since the mixing ratio inside the deep-cave zone is a constant (w_o, say) we have

$$\bar{w} = w_o.$$

The average mixing ratio $\bar{W}$ is determined, indirectly, by conditions external to the cave and will not be constant. The right-hand expression in Equation (4) is therefore not constant and will vary for different choices of the time period T. This expression, however, gives the total mass of moisture lost from the deep-cave zone due to the circulation of air during the time T. Since T has, in effect, been chosen so that the mass of air lost from the deep-cave zone is zero (see Equation (2)), and since we are considering the equilibrium situation in which the mixing ratio remains constant, it is necessary that the total mass of atmospheric moisture lost from the deep-cave zone during time T be zero. The moisture loss given by Equation (4) must therefore be balanced by the addition of water vapour by evaporation from the water source in order to maintain equilibrium.

If we write E for the mass of vapour added to the deep-cave zone by evaporation over the time T, then we have

$$U_o\, t_o\, (\bar{w} - \bar{W}) = U_o\, t_o\, (w_o - \bar{W}) = E.$$

Hence, the equilibrium value of the mixing ratio, w_o, is given by

$$w_o = \bar{W} + \frac{E}{U_o\, t_o}. \qquad (5)$$

This expression is valid for all caves. Since $U_o\, t_o$ and $\bar{W}$ depend on climate conditions external to the cave, the maximum value of w_o which could be attained in any particular cave must be determined by E, since this is a property of the cave itself. In turn, E is determined by the size of the water source and by the effectiveness of the air circulation within the deep-cave zone. (Other things being constant, the rate of evaporation from a water surface is dependent on the circulation rate past the surface (see, for example, Brutsaert (1965)), so that circulation will be the dominant factor in the mixing of moisture evaporating from a water source inside a cave.)

Through Equation (5) deep-cave climates can be divided into two distinct classes. The first class is when w_o takes its maximum possible value, that corresponding to complete saturation. This will occur whenever the size of the water source and the effectiveness of the circulation are such that the potential value of E is greater than E_{min} where

$$E_{min} = U_o t_o (w_s - \bar{W}).$$

Here w_s is the saturation mixing ratio at the deep-cave temperature. Since the degree of supersaturation possible in a cave atmosphere is small, the total amount of moisture evaporated into the atmosphere, E, will be constrained to a value approximately equal to, and no smaller than, E_{min}. Hence the value taken by E is determined by $\bar{W}$, maintaining a value just sufficient to keep the air saturated as $\bar{W}$ varies.

Provided a suitable water source exists, the magnitude of the circulation need not be very large to maintain saturated deep-cave conditions and many caves therefore will satisfy the criteria for saturation. Caves which either contain streams or have considerable seepage of moisture through roof or walls have abundant water supplies. In general, the air circulation within such caves will be sufficient for them to have saturated deep-cave atmospheres. Caves having more than one entrance can be expected to be saturated (assuming that they do have regions in them that can be called deep-cave) provided only that they contain water sources, since such caves generally exhibit appreciable air movements. (It should be noted that an exception may occur in the extreme case when the air movement within a cave becomes so great that equilibrium is never reached and the cave climate undergoes continual modifications by the mixing of cave air with air from outside the cave.)

For caves in this first class, where the deep-cave air is saturated, it is clear that they will be characterized by having a superabundant supply of water vapour; E will generally be less than its potential value. The second class of cave climate occurs when this is not so; when E realises its potential at a value below that needed to produce saturated conditions (E_{min}). This can happen only if the circulation within the cave is very slow, or if the size of the water source is small (or zero). Caves of this second class, therefore, satisfy the relation

$$E < U_o t_o (w_s - \bar{W}).$$

In the limiting case of a completely moistureless or dry cave, where E is zero, Equation (5) becomes

$$w_o = \bar{W}.$$

One would expect that conditions inside a wet cave (i.e. a cave containing a water source; not dry, but not necessarily saturated) would be suitable for maintaining the deep-cave air in an unsaturated state on relatively infrequent occasions. From Equation (5) it can be seen that unsaturated deep-cave conditions are more probable the further the average mixing ratio of the air which moves into the deep-cave zone ($\bar{W}$) is below the saturation mixing ratio, w_s. Unsaturated caves therefore will be more probable in warmer and drier climates. It would be expected, too, that small single-entrance caves may not be saturated even when large water surfaces are present in them, since the air circulation in such caves is generally very slow. Some of the caves of the Flinders Ranges area of South Australia may be cited as examples of this. The larger, deep caves of the Nullarbor Plain, southern Australia, also fall into this category since, although they may exhibit air movements of considerable magnitude in some parts, air circulation is generally insufficient near the water sources to effect saturation throughout the inner reaches of these caves.

Conclusions

The factors which control the deep-cave moisture level can now be summarised. They are: firstly, the size of the water source; secondly, the magnitude of the air circulation within the cave (with very small and very large magnitude circulations being not conducive to the occurrence of saturated deep-cave conditions); and, thirdly, the climate outside the cave (since this determines $\bar{W}$), warm, dry regions being unfavourable for saturated conditions.

The moderating effect which saturated conditions have on cave climate can be seen by generalising Equation (5) to cover zones other than the deep-cave zone;

$$\bar{w} = \bar{W} + \frac{E}{U_o t_o} . \qquad (6)$$

Variations in the average mixing ratio of the zone ($\bar{w}$) are determined by external conditions through $\bar{W}$ and $U_o t_o$. Any differences in the degree of variability of $\bar{w}$ between saturated and unsaturated caves can be attributed only to differences in E. In a saturated cave, E can vary by relatively large amounts since it must change to compensate for changes in the quite highly variable $\bar{W}$. In an unsaturated cave this is not the case. E must be more nearly constant since it can only vary as the circulation rate varies. Because of these two different mechanisms for the variation of E, variations in $\bar{W}$ will tend to be reflected in variations in $\bar{w}$ in unsaturated caves, whereas, in a saturated cave, changes in $\bar{W}$ will be largely compensated for by changes in E. Moisture conditions are therefore more variable in unsaturated caves; caves located in warm, dry climates. In other words, one would expect saturated caves to have more nearly constant climates and that climatic fluctuations would be greater throughout caves which do not have fully saturated atmospheres. This is a fact which may have considerable importance in the relation of cavern breakdown processes to climate conditions within and external to the cave, and in ecological studies, and the generalisation of these studies, in caves found in arid climates.

One final point is evident from the preceding section. This is that the fundamental parameter which expresses the equilibrium moisture conditions inside a cave is the mixing ratio. Caves can be divided into two classes according to whether the mixing ratio of their atmospheres is equal to or less than the saturation mixing ratio corresponding to the temperature of the cave atmosphere.

Discussion in this paper has been largely restricted to the deep-cave zone and no mention has been made of the changes in the temperature and moisture content of air as it moves from the outside into a cave. Some of the circumstances under which one would expect caves to be saturated or unsaturated have been outlined and explained, and it has been shown that, in unsaturated caves, wider fluctuations in climate can be expected. Although no specific examples have been given to illustrate the points made, it is contended that the moisture conditions prevailing inside any cave can be discussed in terms of the model proposed above.

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CAVES OF VAKUTA, TROBRIAND ISLANDS, PAPUA

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Introduction

In a previous paper (1968a) we described caves of Kiriwina, the largest of the Trobriand Islands, a group of coral islands situated 100 miles off the northeast coast of Papua. This paper records caves of Vakuta, a smaller island south of Kiriwina.

Vakuta is shaped like a boomerang (Figure 1) and is separated from the southern tip of Kiriwina by Kasilamaka Passage, about half a mile wide. The area of Vakuta Island is approximately 11 square miles. The island contains three villages, the most important being Vakuta Village which has a Methodist (now United Church) Mission. A track links Vakuta Village to Kasilamaka Passage which can be crossed by native canoe; the track continues on Kiriwina to Losuia, 40 miles north.

Vakuta Island has a population of about 500. The Vakutans are of the same mixed Melanesian-Polynesian stock as the people of Kiriwina. Woodcarving is not practised to the same extent as in Kiriwina and the quality is generally low. However, some canoes have particularly well decorated prows. The influence of the Mission is very evident in the dress of the Vakutans and in the village, old cast-off clothing, often quite dirty, is the rule. In the fields the women wear grass and fibre skirts though the men were not seen to wear a pubic leaf as usual in Kiriwina, but shorts.

Papuan Airlines operate a weekly flight between Port Moresby and Losuia, the Administration Centre, using Skyvan aircraft. Weekend tourist charter flights in DC-3 aircraft arrive frequently, but irregularly, from Port Moresby and occasionally from Lae and Rabual.

The authors visited Vakuta Island in December, 1968. Guides were recruited locally and we were fortunate to be assisted by Mr. Gilbert Heers, the only European resident of the island, who speaks fluent Kiriwini which made communication with our guides relatively easy. With his help, we were able to obtain accounts of the legends and traditions associated with the caves on the island. We have also had valuable discussions about Vakuta and the customs and legends of the Trobriand Islands with Mr. Lepani Watson, M.H.A., who was born on Vakuta, and Mr. John Kasaipwalova, a Trobriand Islander now studying at the University of Queensland. We are most grateful for the assistance of these people.

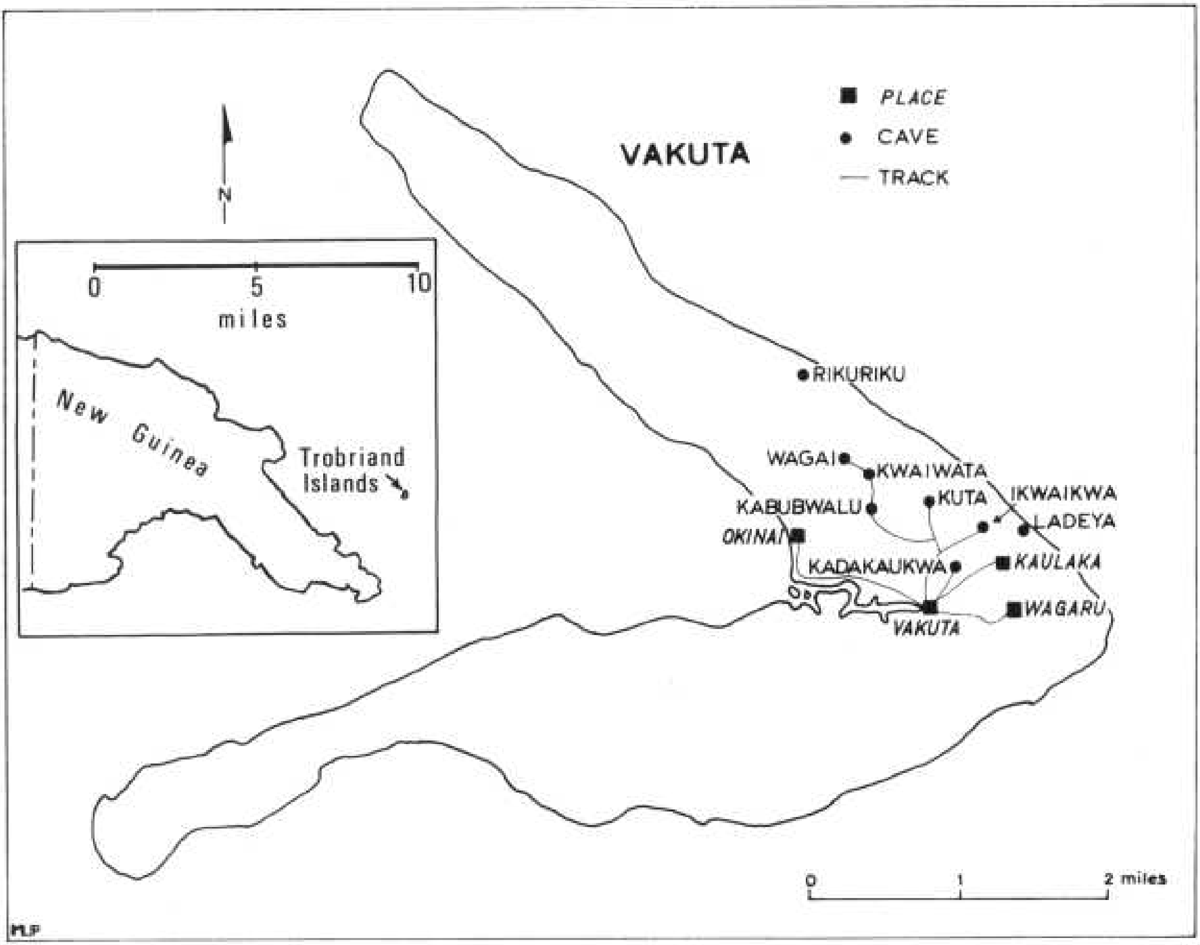


Figure 1. Vakuta Island, Trobriand Islands, Papua.

Although the most accurate map of the Trobriands is an Admiralty chart, the authors used an old U.S. Army map which was based on a pre-war Government survey. The caves were roughly surveyed using 100 ft tape, prismatic compass and abney level.

The village rest-house became the social centre of the village during our stay. We had no difficulty in finding food. A surprising variety of foods such as yams, sweet potato, eggs, pineapples, soursop, tomatoes and fresh coconut appeared and payment was accepted eagerly in stick tobacco and newspaper. Payment in cash was rarely appreciated, though it will become more useful now that a trade store has been established by the Village Co-operative.

To avoid repetitive explanations of features in the accounts of individual caves, various general topics will be discussed first.

Hydrology

The majority of the caves have pools of water at all times, but this is brackish or salty, not fresh as in the Kiriwina caves. The water of one cave, Wagai, is used as drinking water in times of severe water shortage, but fresh water is normally collected from rain. Kuta is commonly used for bathing and for washing clothes. The freshest water appears to be in the highest part of the island, though this impression cannot be confirmed by actual survey.

It has sometimes been suggested that there is a minimum size of coral island below which the island cannot maintain a lens of fresh water, and the Trobriand Islands appear to support this hypothesis. Kiriwina, is sufficiently large, all the water contained in the caves being fresh. Even in the south of the island, where it is narrowest, the fresh water is maintained, and at Sinaketa drinking water is obtained from a sea-level spring only five feet from the shore. In contrast, Vakuta appears to be below the minimum size of island for holding fresh water, and even in the caves with least contamination the water is unpleasantly salty.

Geomorphology

Our conclusions on the geomorphology of the Vakuta caves are very much the same as those we reached in Kiriwina. Vakuta was once a coral reef, and uplift relative to sea-level caused emergence of the reef as the present island. That the caves were initiated near the watertable seems clear from their present position and the fact that many still contain water. None of the caves have the form of long tunnels, such as are common in some coral islands, though that part of Kuta over the lake approaches this form, and Kwaiwata is roughly tunnel-shaped.

Generally, a great amount of collapse and extensive deposition of flowstone effectively conceal the original form of the caves. No initial cavities retained from the time when the island was still a reef were detected, and the caves appear to be normal karst caves. Ladeya is a cenote, typical of a young karst region. None are sea caves and, although on the present shore there is a well-developed notch, there appears to be no significant development of sea caves.

The only feature significantly different from the caves of Kiriwina is that the water is not fresh. In our account of the latter caves we assumed that the lens of fresh water was responsible in some way for the cave-forming solution of limestone. We cannot suppose this on Vakuta and we must conclude that even brackish water is capable of solution to form caves. This is not all that surprising, for it is well-known that even when sea water is apparently saturated with carbonate it can still attack limestone coasts. There is no reason why it should not be able to attack limestone to form caves, as long as there is some mechanism for occasionally changing the local physico-chemical conditions. Occasional changes in salinity after rain would probably be sufficient to do this.

In Bermuda there are caves which are at present inundated with sea water. Bretz (1960) has postulated that the caves were formed at the time of some lower sea level when the islands, standing out of the sea, were large enough to hold a fresh water lens so that fresh water could attack the rock. If our conclusion that brackish or salty water can form caves is true, then the hypothesis of former low sea levels may not be necessary. We cannot reverse the argument and apply Bretz's hypothesis to the caves of Vakuta. If the islands ever did stand higher above sea-level (for which there is no evidence) the caves would be formed well below the present watertable, but in fact they appear to be adjusted roughly to the present level. In Kuta, the deepest part of the lake is only about 10-15 feet below the water surface, and appears to be floored by bedrock, not collapse material.

The Bones

As in Kiriwina, most of the caves have been used at some time as funeral grounds and there are plenty of human bones in them. Skulls and limb bones predominate but we also found less resistant bones such as ribs, clavicles, vertebrae and even finger bones. Some of the skulls had irregular holes, suggesting the owner died of a blow on the head, and some had the small circular holes illustrated in our previous paper. One interesting specimen had two holes on the outside, but only one penetrated the inside of the skull, the inside of the hole being rather more jagged than the outside. This skull shows either the marks of two blows, one of which failed to penetrate the skull, or two drilled holes one of which was abandoned before completion.

Our thinking on these holes has now come full circle. At first we assumed that they were made with a sharp weapon such as a spear point. Then it was suggested to us that a sharp blow would not make a neat round hole, but would shatter the surrounding bone. However, during a fight in Losuia late in 1968, a native was killed by a blow with an iron bar, roughly equivalent to the spear we originally had in mind, and a post-mortem examination revealed a perfectly circular hole 13 mm in diameter (Dr. G. F. Gerrits, personal communication). It seems that a skull full of brains does not shatter as an empty skull would. This evidence fits in with the idea of a blow, but we now have a suggestion from Mr. John Kasaipwalova that the holes may indeed be made artificially after death. It appears that in the old days the custom was to bury the dead until the flesh decomposed and then dig up the bones and inter them (sometimes in a pot) in a cave. If the dead man was very important certain men would gather to mourn him, a task which was both a duty and an honour. They had to be fed and rewarded with "pemkwala" - presents of pigs and other valuables - by the close relative for as long as the ceremony lasted.

In normal circumstances giving pemkwala was an honour, but it could grow to embarrassing proportions so an attempt was made to speed up the process. Instead of removing flesh by the slow decomposition following burial, the mourners rapidly stripped it off with knives or axes, and the bones were then boiled and smoked. Boiling pots were stored in the caves for use whenever necessary and one pot could be used to prepare many bodies. There is therefore the possibility that the pots are not so much funeral urns as undertaker's tools. The biggest obstacle to the rapid reduction of a body to bones is presented by the brain, and Mr. Kasaipwalova thinks the circular holes may have been drilled to let out the brains.

Mr. Lepani Watson M.H.A. has also suggested that the holes may have been for threading so that the skull could be carried around for a while by the man's widow, which was a custom at one time. However, this explanation would not account for the skulls with only one hole, and in the only photograph we have seen of a widow with a skull it appears to be unthreaded.

In Kiriwina we reported one cave, Kuvwau, which had been barricaded by coral blocks at one time. In Vakuta we found many more examples of this, and in several caves we found small walls sealing off small "crypts" in which bones had been placed. These crypts were especially common in Kabubwalu, and the top photograph in Plate 1 illustrates an intact one. Many more have been broken down, but are still recognizable, especially in Kuta.

Pottery was once common in the caves, but it has been removed by archaeologists, soldiers and many other collectors. We found pottery fragments in Ikwaik and Kadakaukwa and these have been deposited with the Department of Prehistory, Australian National University, Canberra. The pottery is of an old type, quite different from that now used in the Trobriand Islands. The style of pot is shown in the bottom picture, Plate 1.

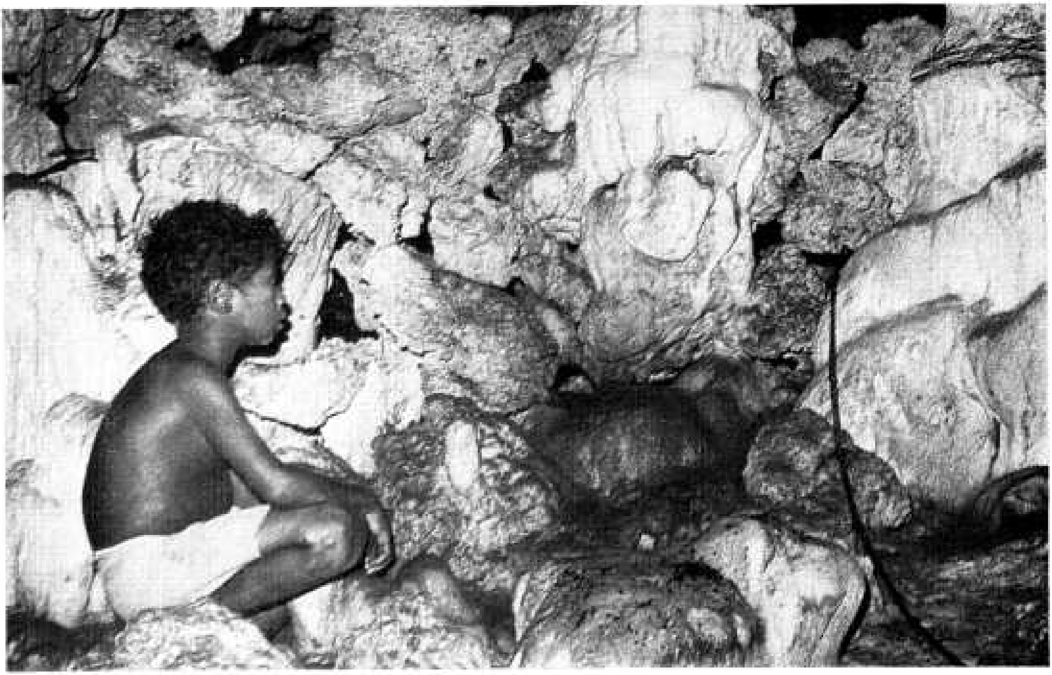
On Kiriwina, a number of giant clam shells were associated with the bones, but on Vakuta bailer shells (*Melo* sp., prob. *aethiopicus*) were found, together with small sea shells. Clam shells were rare. Human bones and a bailer shell can be seen in the top picture, Plate 2.

Association of Caves with Megaliths

Megaliths are large stones found standing in groups. They appear to be the remains of what were originally roughly rectangular structures. Megaliths of Kiriwina have been described by Austen (1939), and Ollier and Holdsworth (1968b). We discovered a new group at Wagaru on Vakuta Island.

It appears very probable that the megalithic structures were originally funerary monuments, and there are records of pots and human bones being found beneath fallen stones. A possible association with caves seems fairly obvious. Possibly the greatest chiefs were buried in megaliths, the lesser men in caves.

PLATE 1



Above: Wall sealing off a crypt in Kabubwala Cave.

Right: Old-style pottery found in caves of the Trobriand Islands.

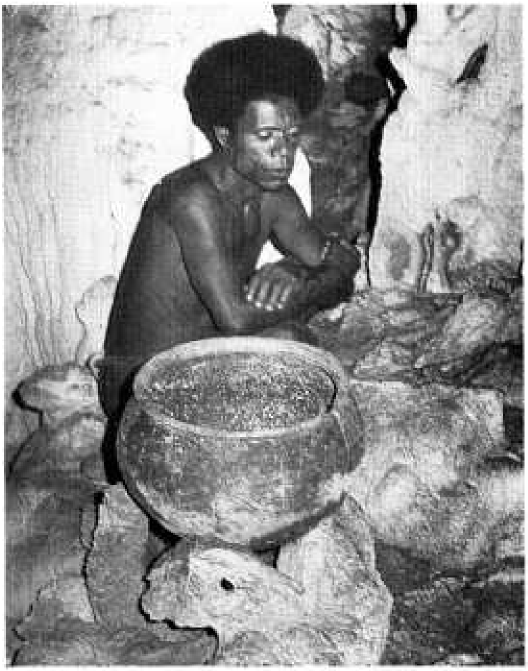


PLATE 2

Above: Human bones and bailer shell, Kabubwalu Cave.

Right: Collapse entrance, Ladeya Cave.

Quite a different association between caves and megaliths is present in local legend. The original Trobriand Islanders are believed to have emerged out of the ground at Labai Cave, Kiriwina. However, other legends suggest that people emerged from many caves. The first people to emerge built houses of stone, which are of course the megaliths, but later people built houses only of wood. On this basis each megalith should have an associated cave, and caves from which people are thought to have emerged should have a megalith. Where this correspondence is not present, it is explained away by saying that the megalith fell down, or the cave was filled in. Generally it is claimed that a cave was filled in because the people were afraid of it, or of the spirits in it, but we have also been told of a more selfish reason for filling the cave - to stop any more people coming out and causing clan feuds.

In the Trobriand Islands there are more than 50 places of emergence, or "bwala." In each case, one, two or three people are said to have emerged, of whom one or two are women (sisters), sometimes accompanied by a man who is invariably a brother. One of the women is then credited with starting a "dala," that is a sub-clan or family line. Each clan (Kubila) has many places of emergence where the different dala originated, but in a few instances two separate dala of different clans emerged from one cave, probably at different times.

The fact that megaliths and caves are bound up in legend rather suggests that the megaliths are fairly old and possibly not connected with the present inhabitants at all, and some of the cave burials may likewise be very old.

The Vakuta natives are still quite happy to believe in blocked caves. We were even taken to see a cave that was alleged to contain many intact pots. When we arrived at the spot we could see no cave. Our guides, admitting that they had never been in the cave themselves, asked us to find it with our "glasses." They evidently regarded our compass as an instrument for divining, not just mapping.

To the present day, the natives in each village are divided into Tosunapula, that is the descendants of those people who came out of the ground, and the Luluwa, descendants of people who arrived not out of the ground but merely overland, and who were allowed to stay as vassals of the Tosunapula. The Luluwa have improved their social position by intermarriage, but still have no land holding rights.

CAVE DESCRIPTIONS

Rikuriku Cave

(Meaning: earth tremors) (See Figures 1 and 2).

This cave is reached from Okinai village but is on the opposite, eastern side of the island. It is a large cave, with a typical collapse entrance and a pool of water at the lowest part. There is a legend that this pool is in fact a sump beyond which is another cave. This possibility was not explored thoroughly but it looks rather improbable. It is claimed that some natives have been in it, but having no lamps they do not know how long it is. We were not able to find anybody who had personally passed the sump.

The cave contains many bats, but no bones, shells or pottery fragments were found. At the surface nearby there is some of the slabby coral of the kind used to build megaliths.

Wagai Cave

(Meaning: place of gai, a kind of wood) (See Figure 1).

This small cave has an entrance approximately eight feet wide and four feet high and is descended by a wooden ladder to a water pool about 20 feet by ten. This is the only cave with drinkable water, but is used only when stores of rain water run out, which is not very often.

"Gai" is the native word for black wood, now used for Trobriand Island carvings and formerly used for spears. The cave was discovered by a man wounded through the right calf muscle by a spear made of gai, so he called it Wagai. This name means "place of gai" or "on gai."

Kwaiwata Cave

(Meaning: a direction. Also known as Wagai) (See Figures 1 and 2).

This cave is apparently known by two names, but to avoid confusion with the other cave called Wagai the alternative name of Kwaiwata is preferred. It is a large, tunnel-like cave with branches, and an extension around the collapse entrance. There is a lot of decoration, including pillars, stalactites and gours, some of which are actively forming. The cave contains a lake with brackish water, in which a pink shrimp 1½ inch long was observed. Tree roots extend to and grow in the lake water. Small bats are present.

The cave contains many bones including the skull with two round holes, one of which does not penetrate, a child's skull, a dog skull, vertebrae, collar bones, pelvis and other bones. Many of the bones are well buried, and some have up to ½ inch of calcrete deposited on them. No pottery was found, but there were numerous small sea shells and one broken clam shell.

Kabubwalu Cave

(See Figures 1 and 2).

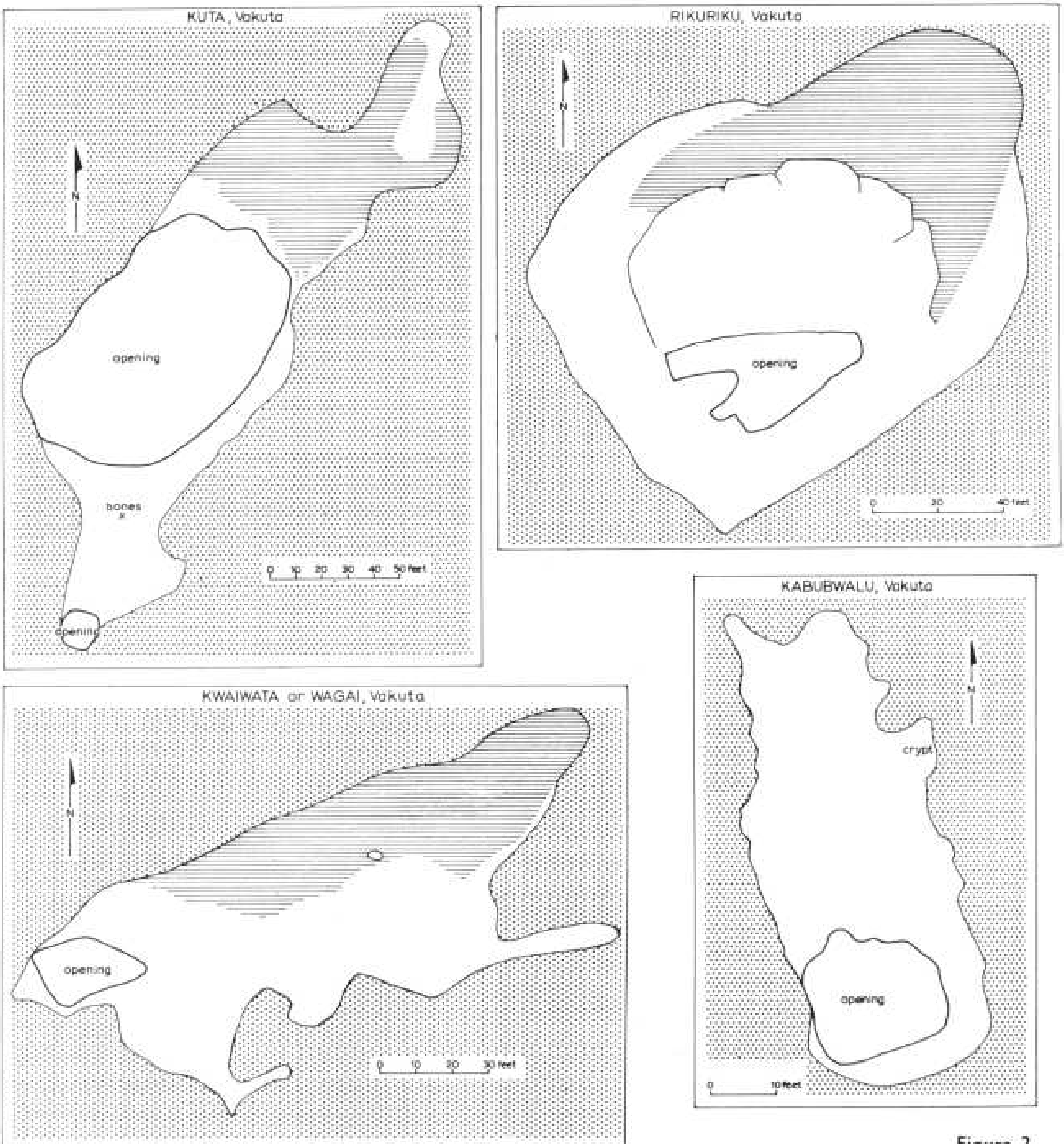

KUTA, Vakuta
N
opening
bones
x
0 10 20 30 40 50 feet
opening
RIKURIKU, Vakuta
N
opening
0 20 40 feet
KABUBWALU, Vakuta
N
crypt
opening
0 10 feet
KWAIWATA or WAGAI, Vakuta
N
opening
0 10 20 30 feet

Figure 2.

This cave slopes down from the entrance, but does not reach water level. The floor is covered with sand and clay. Apart from a few dripping stalactites the formations are dead. There are many small barriers forming crypts, and one intact crypt was found to contain human bones and a bailer shell. (See Plates 1 and 2, top pictures).

At this cave we were told the story of the shells. Bailer shells were used in the past to boil water in. Each woman had one special shell used to bath new born babies, the same shell being used for all the babies of one mother. Small sea shells were used by the woman to drink some of the hot water from the bailer shell after giving birth.

Kuta Cave

(See Figures 1 and 2).

This is a large, easily accessible cave where the natives swim, wash and launder in the lake of brackish water which was even drunk in the past during times of extreme water shortage. The cave has given its name to the whole island - Vakuta, meaning place of Kuta.

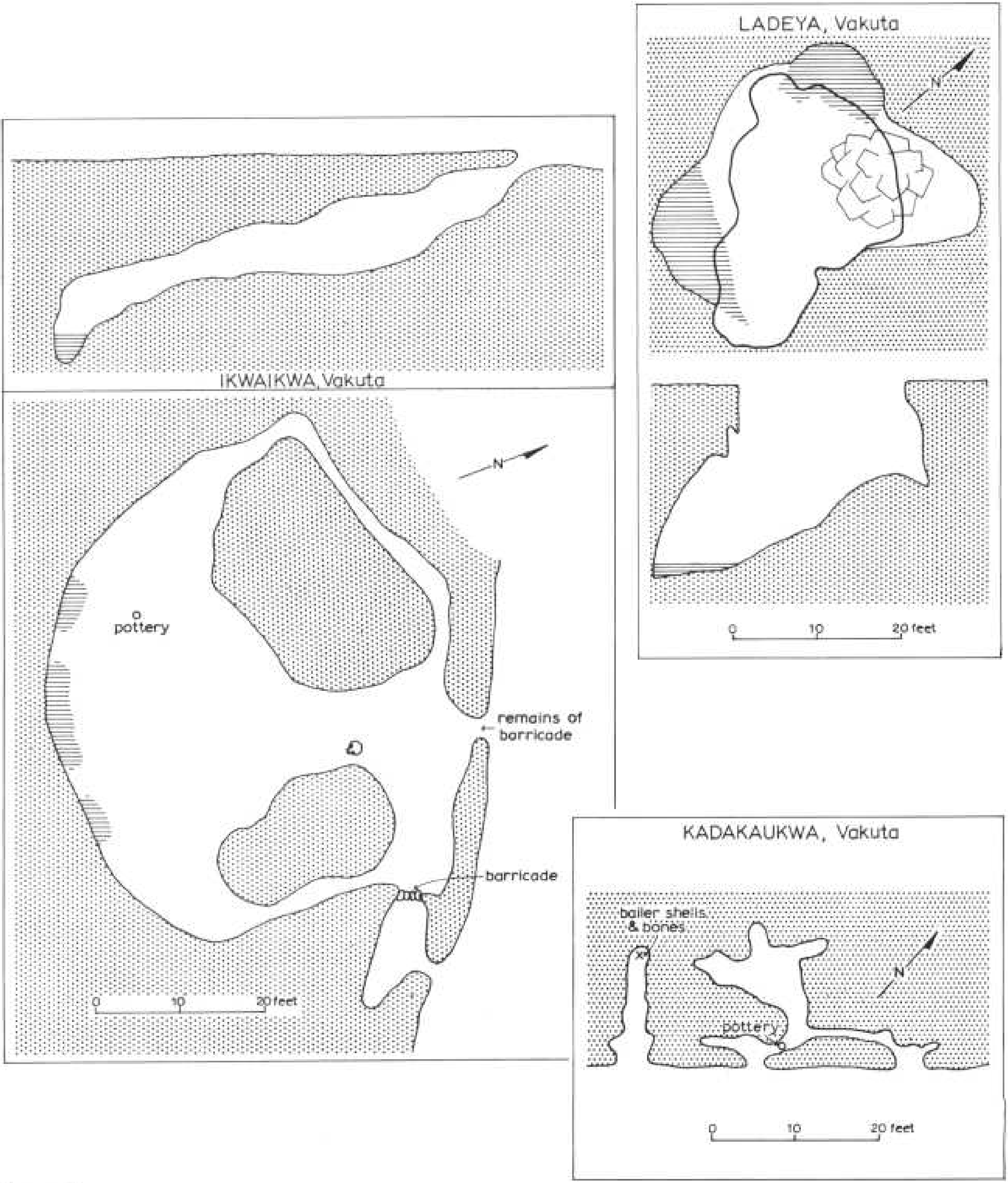
The main part of the cave is a typical collapse, but over the lake the cave has a tunnel-like form which is thought to be the primary shape that the caves of these coral islands have when first formed, before modification by collapse and fill. There is a great deal of decoration, including some stalagmites with no corresponding stalactites; presumably the stalactites have been lost by post-stalagmite collapse. The lake is between ten and 15 feet deep at the deepest part, and some tree roots reach and grow in the water. There are many bats, of several kinds.

Inside the cave there are many bones, including skulls, vertebrae, ribs, shoulder blades, finger bones and jaws. Some have very good teeth, though in one jaw the teeth appear to have been worn to a very flat upper surface. A few bailer shells, many small sea shells and a few mussel shells were found, but no pottery, though a guide told us that there used to be many broken pots with good decoration which were taken by soldiers during the war. An old man said there used to be bones in pots. There are the remains of many crypt barriers near the southern end. One puri-puri stone, used in garden magic, was also found.

Ikwaikwa Cave

(See Figures 1 and 3).

This cave has a number of entrances, all of which have been blocked in the past by coral walls. One barrier is still intact. The cave slopes down from the entrance at about 15 degrees and there are small pools of brackish



LADEYA, Vakuta
N
0
10
20 feet
IKWAIKWA, Vakuta
N
pottery
remains of
barricade
barricade
0
10
20 feet
KADAKAUKWA, Vakuta
bailer shells
& bones
N
pottery
0
10
20 feet

Figure 3.

water at the base. Some good decoration occurs. Bones are present, including a perfect skull. A few small sea shells were present. A few fragments of pottery were collected from under a pile of rocks near the base.

Ladeya Cave

(See Figures 1 and 3).

This is a simple collapse hole of the cenote type, with the floor about 22 feet below ground surface. It is located close to the sea. The hole can be climbed on one side and also descended by means of the trees that grow in the bottom (Plate 2, bottom picture). There is a mound of rockfall under one edge of the hole, and two pools of brackish water. No bones, shells or pottery fragments were found.

Kadakaukwa Cave

(Meaning: way of dog; also a colloquial expression for the beastly behaviour of a man of the lowest social standing. There is said to be a nearby stone resembling a dog, but we did not see it. One old man told us that Kadakaukwa was the name given to a victim marked out for killing and eating and that this cave could possibly have some connection with former cannibalism). (See Figures 1 and 3).

The cave consists merely of a few short tunnels with a sandy floor. A few fragments of pottery were found at the entrance. A bailer shell in a side passage was the only shell found, but there are a great many bones, including one skull with a single neat hole. There is evidence of much repeated barrier building. This cave possibly could be extended by digging, and perhaps offers the best chance of any on Vakuta for finding stratified cave deposits.

Kaulaka Cave

(See Figure 1).

Austen (1939) describes and figures several pots he found (and presumably took) from Kaulaka Cave. Kaulaka is a village and Austen is probably referring to Kadakaukwa Cave.

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A B S T R A C T

WESTERN AUSTRALIA MINES DEPARTMENT ANNUAL REPORT FOR 1967. Published 1968, Government Printer, Perth.

The following items from the Report are of speleological interest: -

p. 74 - 78. Tertiary Stratigraphic Units in the Eucla Basin in Western Australia, by D.C. Lowry, also published previously as p. 36 - 40 of the Geol. Surv. W.A. Ann. Rept. 1967. The article formalizes the stratigraphic nomenclature of Tertiary units in the west of the Eucla Basin. Tate's three-fold subdivision of the limestones is substantiated, and caves in the Madura area (such as Mullamullang) are shown as developed in the middle unit which Lowry names the Abrakurrie Limestone.

p. 78 - 82. The Origin of Blow-holes and the Development of Domes by Exsudation in Caves of the Nullarbor Plain, by D.C. Lowry. Also released as Geol. Surv. W.A. Rec. 1967/12, and published as p. 40 - 44 of Geol. Surv. Ann. Rept. 1967. The article was reviewed by J.N. Jennings in Helictite, 6 : 50 - 56.

p. 169. Part of the W.A. Government Chemical Laboratories Annual Report, 1967. An analysis is recorded of a halite stalactite from Thylacine Hole, Eucla Basin. The analysis was published previously by Lowry in Helictite, 6 : 15. An investigation into other minerals from Eucla Basin caves is reported to be progressing.

p. 173. Part of the W.A. Government Chemical Laboratories Annual Report, 1967. Two investigations are reported to be progressing into unusual phosphate minerals from cave guano deposits. One investigation concerns a collection by G.E. Wilford from Sabah and Sarawak caves; the other is the study of an ardealite crystal from a cave at Jurien Bay, Western Australia.

\- D. C. Lowry.

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SPOROMORPHS FROM THE DESICCATED CARCASES OF MAMMALS FROM THYLACINE HOLE, WESTERN AUSTRALIA

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Abstract

Assemblages of sporomorphs have been recovered from the gut content of desiccated mammalian carcases of ages estimated up to 5,000 years BP, found in Thylacine Hole, a cave in the Eucla Basin. These assemblages suggest the animals lived in an area of vegetation similar to that existing around the cave at present.

Introduction

Palynology is a widely used tool in Quaternary geology, archaeology and related sciences in the Northern Hemisphere, particularly with reference to high latitude peat deposits and their implications of climatic changes associated with the waxing and waning of the Pleistocene ice sheets. There is, at present, little understanding of such climatic fluctuations in middle latitudes of the Southern Hemisphere, and few studies of the modern pollen rain as a climatic indicator.

The study was suggested by Mr. D.C. Lowry, of the Geological Survey of Western Australia, who has been engaged in the geological mapping of the Western Australian portion of the Eucla Basin. An important find during this work was the well preserved carcase of a thylacine (Tasmanian or marsupial "tiger" or "wolf") in Thylacine Hole, a cave about 68 miles west of Eucla (Lowry and Lowry, 1967). In addition to the well preserved "mummy" of this thylacine (Geological Survey of Western Australia Palaeontology Collection No. F6364, on permanent loan to the Western Australian Museum), carcases were collected of other mammals in a less complete state of preservation. It has been possible to isolate pollen grains and spores from the desiccated gut contents of some of these carcases.

Muscle, hair and other soft tissues from thylacine (F6364) and dingo (F6343) have yielded radiocarbon dates of 4,650 + or - 153 and 2,200 + or - 96 years BP respectively (Lowry and Merrilees, 1969).

Samples and Procedure

The gut contents examined came from the following four specimens, of which only the dingo has been dated by the radiocarbon method.

1. F6348 - Megaleia rufa (red kangaroo)
2. F6362 - Trichosorus vulpecula (possum)
3. F6363 - Onychogalea lunata (crescent nail-tail wallaby)
4. F6343 - Canis familiaris (dingo)

Part of one sample was first treated, in the Palynological Laboratory of the Geological Survey of Western Australia, using the method for sediments described by Balme and Hassell (1962). As the resultant assemblage was difficult to work with, due to the presence of extraneous tissue, the other portion of the sample was prepared using Erdtmann's Acetolysis Method (See Faegri and Iverson, 1964). This produced a cleaner assemblage so the Acetolysis Method was retained for all remaining preparations. Where possible, at least two permanent assemblage slides of each sample are kept in the reference section of the Palaeontological Collection of the Geological Survey of Western Australia. These slides are registered under the sample numbers quoted above with an additional numerical suffix for each slide.

Microflora

It must be emphasised that very little work has been done locally on Quaternary and modern palynology. Thus the determinations of the sporomorphs recovered are very tentative and often refer only to broad botanical group. Dr. G.D.F. Smith, Senior Apiculturist with the Department of Agriculture, is working on modern pollen grains and he was most helpful in assisting with the following identifications.

1. F6348 (red kangaroo); sample - probably partially formed faeces; contains:

   Eucalyptus spp. (mainly mallee group, e.g. E. gracilis)
   Melaleuca spp.
   Acacia sp.
   Chenopodiaceae
   Compositae (possibly "everlastings")
   Papilionaceae
   Fungal spores ("bi-porate")

2. F6362 (possum); sample - gut content from anterior part, right-hand side of abdominal cavity; contains:

   Eucalyptus spp. (Salmon-gum type common)
   Melaleuca spp.
   Acacia sp.
   Chenopodiaceae
   Compositae
   Santalaceae (possibly "Quandong")
   ?Gyrostemon sp.
   cf. Banksia-Dryandra (similar characters but unlike any known species)

Fungal spores

3. F6363 (wallaby); three samples were prepared. Of the first two, one was considered to be partially formed faecal pellets, the other most likely stomach contents of the animal. It was hoped these samples would indicate if there was any change in the pollen grains during their passage through the alimentary tract. Unfortunately, very poor assemblages were obtained in both cases so the samples have not been studied further. The third sample was definite faecal pellets and contains:

   Eucalyptus spp. (mallee type)
   Melaleuca sp.
   Chenopodiaceae
   Compositae ("everlastings" type)
   Portalacaceae
   ?*Gyrostemon* sp.
   bi-saccate pollen (?*Callitris*)

4. F6343 (dingo); sample - material shaken from inside the carcase. The palynomorph assemblage is so poor that further work is not warranted.

Discussion

It has been shown that the gut content and faeces of dead animals can be a rich source of palynomorphs. However, conclusions as to what the assemblages mean are difficult to draw, due to the many unknown factors involved from the time the pollen is produced on the plant until the grains are found in the gut of the animal. To gain an insight into the many complications, detailed studies of the pollen content in similar modern animals at various times and places, and study of the pollen rain in the Eucla area (including inside caves) would be essential.

Also, the ages of the samples examined are not well defined. As pointed out by Lowry and Merrilees (1969), the dingo (F6343), although younger, is less well preserved than the thylacine (F6364), suggesting that the conditions of preservation in the cave vary from place to place. However, both the kangaroo (F6348) and the possum (F6362) are in positions near the dingo where the factors affecting preservation are likely to be similar. As the state of preservation of the three carcases is also similar, it is tentatively concluded that they are at least of the same magnitude of age. The wallaby (F6363) was found in a more exposed position nearer to the entrance, where the decay rate is most likely faster, and hence could be of a younger age. It is concluded, however, that at least some of the assemblages obtained are of the order of 2,000 - 5,000 years old.

Churchill (1968) suggests that the climate at Boggy Lake, near Walpole, Western Australia, was relatively wet from 5,000 - 2,600 BC. However, no indication could be seen in the pollen grains from the carcases which were examined of a vegetation representing a wetter climate - for instance, pollen grains of Proteaceae, common components of the present South-West flora, are not present.

Conclusions

The oldest of the desiccated carcases from which samples were examined is considered to have lived within the period of 2,000 - 5,000 years ago (later Holocene); although as previously discussed, the age evidence for the carcases examined is indecisive.

The pollen assemblages obtained from the carcases suggest the vegetation of the area when the animals were alive was similar to that in the vicinity at present. Thus, as no major changes in the vegetation can be detected, the climate also appears to have remained relatively constant during the later Holocene.

Although these conclusions are very limited, the study has indicated that the method could be a very useful tool.

Acknowledgments

I am indebted to my colleague Mr. D.C. Lowry for suggesting this study; Dr. D. Merrilees of the Western Australian Museum for identifying the animals, assisting with the selection of samples and for a particularly helpful criticism of the manuscript. Dr. G.D.F. Smith, Western Australian Department of Agriculture, and Dr. B.E. Balme, Department of Geology, University of Western Australia, assisted with the pollen grain identifications. The Director of the Geological Survey of Western Australia has given permission for this paper to be published.

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ABSTRACTS

SOME CAVE-DWELLING PSEUDOSCORPIONIDEA FROM AUSTRALIA AND NEW CALEDONIA. By M. Beier. Rec. S. A. Mus., 15 (4), 1968 : 757 - 765.

Eight species and subspecies of Australian and New Caledonian cave-dwelling Pseudoscorpionidea are listed and five of them are described as new. *Sathrochthonius tuena* Chamberlain is recorded from Punchbowl Cave, Wee Jasper, N.S.W., and from guano in caves in the Southern Limestone, Jenolan, N.S.W. *Austrochthonius cavicola* Beier is a new cavernicolous species from Cathedral Cave, Naracoorte, South Australia. *Morikawia troglophila* Beier is a trogloxene from Grotte de Ninrin-Reu, near Poya, New Caledonia. *Ideobisium antipodum* (Simon) is also recorded from this cave. *Pseudotyrannochthonius hamiltonsmithi* Beier is recorded from Mt. Widderin Cave, Skipton, Victoria, but is not a cave-dwelling species. *Protochelifer naracoortensis* Beier is a new species from Bat Cave, Naracoorte, South Australia. It is closely related to *P. cavernarum* Beier. Additional records of *P. cavernarum* Beier are made from Cliefden Caves, N.S.W.; Ashford Cave, N.S.W.; Clogg's Cave, East Buchan, Victoria; and Gooseberry Cave, Jurien Bay, Western Australia. *P. cavernarum aitkeni* Beier is a new subspecies from Abrakurrie Cave, Nullarbor Plain, Western Australia. - A.M.R.

SOME MAMMAL REMAINS FROM CAVE DEPOSITS IN THE SOUTH-EAST OF SOUTH AUSTRALIA. By C.R. Tidemann. S. Aust. Nat., 42 (2), 1968 : 21 - 27.

Bone material from three caves in the Lower South-East of South Australia has been examined and identified as far as possible. In all, 26 species of native mammals have been separated, the majority of which came from the Bat Cave, Naracoorte. The other two caves, Yallum Cave, nine miles west of Penola, and a small rock-hole at Tantanoola, yielded much less, both in the number of species collected, and also in the quantity of bone material as a whole. All the bone material was collected from the surface of the cave fill, and is of late recent origin. It represents the mammal fauna of the area immediately prior to European settlement. The Bat Cave and Yallum Cave acted as animal traps, while the rock-hole at Tantanoola was a lair used by dingoes, and probably also the introduced fox. - A.M.R.

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