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Dr Jiří Daneš (1880-1928)

Karst at Chillagoe, North Queensland

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Helictite was established in 1962 by its foundation editors, Edward A. Lane and Aola M. Richards. It is intended to be wide ranging in scope from the scientific study of caves and their contents, to the history of caves and cave areas and the technical aspects of cave study and exploration. The territory covered is Australasia – Australia, New Zealand, the near Pacific Islands, Papua New Guinea and surrounding areas, Indonesia and Borneo.

In 1974 the Speleological Research Council agreed to support the Journal with financial assistance and in 1976 took over full responsibility for its production. From 1974 to 1997 the Journal was edited by Julia James assisted by other members of the Speleological Research Council Ltd. In 1998 Susan White and Ken Grimes took over as editors with Glenn Baddeley as Business Manager. Stefan Eberhard joined the editorial team in 2003.

In 2000 ownership was transferred to the Australian Speleological Federation, Inc. (ASF) and the Journal is administered by the Helictite Commission of the ASF.

Greg Middleton took over as Chief Editor in 2016. The accidental death of Ken Grimes in August 2016 led to further changes in editors, with Tim Moulds and Kevin Kiernan taking on the role.

The aim of the Helictite Commission of the Australian Speleological Federation is to publish the results of scientific studies in all fields of speleology in *Helictite – Journal of Australasian Speleological Research*.

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Submitted papers will still be reviewed and edited as before, but the layout may be varied to suit a digital format. Each paper will be published on line as it is ready as part of what is intended to be an annual volume. Intending authors should read the latest 'Information for Contributors' on the *Helictite* website.

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Journal of Australasian Speleological Research

VOLUME 44 2018

Contents

Cover: Karst at Chillagoe. Colour plate facing page 124 of volume II in the first edition (1911) of *Dvojím Rájem*, “Through a Double Paradise” by Dr J. V. Daneš and Dr K. Domin, associate professors at Charles University in Prague. Insert is a photo of Dr J. V. Daneš, Czech geomorphologist and diplomat.

Helictite, Volume 44, 2018 consists of a single issue.

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This issue published December 2018.

Editorial

Greg Middleton

This issue of *Helictite* pays tribute to the late John Robert Dunkley, one of the major contributors to the development of Australian speleology in the latter part of the 20th and early 21st Centuries. From his base, initially in Sydney and later in Canberra, he played important local roles in the societies of which he was a member (Sydney University Speleological Society, Canberra Speleological Society and Highland Caving Group) and, nationally, in the Australian Speleological Federation. As well as caving (throughout Australia and internationally), conducting exploration, documentation and research, he was a prolific author, editor, publisher and speleo-historian.

From the time he first came across references to the Czech karst geomorphologist, Jiří Viktor Daneš, by Joe Jennings, John was interested in this character and his contribution to Australian speleology. Once he discovered that Daneš's major (1916) paper, 'Karststudien in Australien', had never been fully translated from its original German, he determined to rectify this omission by translating the paper into English. After a couple of only partially successful attempts, he came in contact with Australian geologist John Pickett who was able to produce a high quality translation. John was delighted with this and pleased to be able to arrange for it to be published in *Helictite*. It is with great pleasure that we present John Pickett's translation in this issue, though sadly ten months after John Dunkley's passing.

In order to provide background on Daneš the man, John, in collaboration with Bruce Welch, determined to research his story and particularly to discover more details of his actual activities in Australia. It turned out to be a more complex and interesting story than they might have expected and they were particularly delighted to unearth the virtually unknown two-volume 1911 travelogue written in Czech by Daneš and his professional colleague, Dr Karel Domin, *Dvojím Rájem* (which translates as *Through a Double Paradise*). The outcome is the second paper in this issue, sadly probably John's last, on Daneš and his Australian travels. All the illustrations in these two papers were scanned from the originals by Bruce Welch.

In keeping with the historical theme of the papers in this issue, also included is Liz Reed and Steve Bourne's investigative historical paper on the mystery first photographer at Naracoorte in 1860 and the finding of an engraved name which removed any doubt that the first photographer was Thomas Hannay. They draw attention to the value of early inscriptions and the need to carefully assess cultural values before removing graffiti from cave walls.

While a very sad duty, it is appropriate to also include in this volume an obituary for John Dunkley, outlining his remarkable contributions to Australian speleology and including as full a catalogue as we have been able to compile of his more important writings.

Helictite, (2018) 44**:** 1-30

Karst Studies in Australia 1916

J. V. Daneš

Translated by John Pickett

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Presented on 28 January 1916 and originally published in:

Karststudien in Australian 1916

Sitzungsberichte der königlichen böhmischen Gesellschaft der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse, Jahrgang 1916, VI, 1-75

[Meeting reports of the Royal Bohemian Society of Sciences, Mathematical-Scientific Class Volume 1916, Part 6, Pages 1-75]

Translated by John Pickett

Translator's Notes

In translating "Karststudien in Australien" I have retained the sentences constructed by Daneš himself, although these are long and frequently complex by modern standards. In other words, my sentences include the sense of all clauses and phrases used by Daneš, and the content bounded by full stops remains the same. Nonetheless, I have endeavoured to include the meaning of each phrase within his sentence, though my final ordering of individual phrases favours ease of reading rather than direct translation.

To provide accentuation German uses spaced ("*gesperrt*") characters, a convention unfamiliar to English readers. I have used italics to render this feature.

Footnotes: Because of the differences in pagination between the original and the translation, footnotes have been relocated and their numbering has been adjusted to suit the new layout.

I am grateful to colleagues Armstrong Osborne (Sydney) for assistance in ensuring precise terminology for karst features, and to Prof. Stephan Kempe (Darmstadt) for a read-through of the translation.

VI.

Karst Studies in Australia

By J. V. Daneš

Presented on 28th January 1916

Introduction

As in all other continents, limestone is a very widespread rock type and in numerous smaller or larger areas and in varying degrees of development, shows those characteristic features which are termed karst phenomena.

Unfortunately, the geographical and geological exploration of the Australian continent has so far not advanced far enough to be able to be informed of all significant limestone areas and all their surface expressions, but it is already possible to separate them into three fundamentally different major groups, according to their nature, age and extent.

The first group is comprised of those spatially insignificant but very numerous limestone areas in the old folded mountains of Australia, which have undergone generally strong tectonic disturbance and often also significant metamorphism. These, because they are small and not hydrographically independent, offer little unusual for the study of karstic phenomena. In the second group belong the great limestone plateaux of Mesozoic or Tertiary age, which make up most singular karst regions which are little disturbed tectonically and are of great extent, whose study, however, is difficult because of their remoteness from habitation and their desert character. The third group includes several cave areas of restricted area, which were developed in Tertiary lime-sand dunes, and apparently are restricted to the coastal areas of south-western Australia.

It would lead too far, were I to mention here all those limestone occurrences of the first group, which are mentioned more or less comprehensively in the geological and touristic literature, it is enough to mention those in which at least the most popular form of karst, namely caves, has been detected and at least partly examined. Most of the Silurian and Devonian limestones of the eastern montane belt of Australia, of the eastern cordillera, are known for their caves; in eastern Queensland there are two generally known and often described cave areas; one by Chillagoe far in the northeast and in the vicinity of Rockhampton (Olsen's and Johannsen's Caves), in New South Wales the caves at Jenolan, Yarrangobilly, Wombeyan Creek and the Wellington Caves.

For my journey to Australia the study of karst was more of a secondary matter, since my first interest was the present position and the development of the continental divide, as well as other problems concerning hydrographic relationships in Australia, nonetheless I still had the opportunity of visiting three of the cave areas in the fold mountains mentioned above: those at Chillagoe (beginning of February 1910), Olsen's Caves (in April 1910) and the Jenolan Caves (in August 1910).

I originally intended to use the latter part of my stay in Australia for the study of the karst of the great Tertiary karst area, which is spread over the north of the Great Australian Bight in the broad surroundings of Eucla (so-called Nullabor Plain), but I then found, with better knowledge of transport possibilities in Australia, a longer excursion in the eastern margin of the great limestone plateau of tropical inner Australia, to the so-called Barkly Tableland in north Queensland, to be more profitable. I am convinced, that here, within the short time of 14 days, achieved more generally interesting observations, than I could have managed in the Eucla area at greater expense of time and money. It was a long and fairly monotonous trip from the terminus of the Great Northern Railway of Queensland in Cloncurry through the dry and wild montane country of the northern "Australian anticordillera" to the tableland at Camooweal, from there, after several excursions to the local cave and doline groups, north to the Gregory River and then through the Carpentaria lowlands via Burketown and Normanton, and through the broad southern part of Cape York to Cairns! The excellent coach connections, which even these far-flung regions of Queensland enjoy, made it possible, to cover this great stretch of semi-desert of varying kind, within six weeks, including detours, and relatively comfortably and quickly.

Since my sojourn in Queensland lasted too long, I was obliged to abandon the original plan of visiting the Eucla area, and could no longer visit even the smallest of the great limestone plateaux, the so-called Mosquito Plains, which are spread over much more closely settled areas on the boundary of South Australia and Victoria. Of the caves of the third group, I only visited those in the neighbourhood of Yallingup, south of Cape Naturaliste, at the beginning of September.

Karst in the surroundings of Chillagoe.[1]

From the basal part of the York Peninsula in north-eastern Australia north of 17° 30' S to the west of the continental divide there extends an ancient range in a SE – NW direction, which is made up of strongly folded, sometime metamorphosed Palaeozoic strata, intruded by mighty stocks of granitic rock. Now the range is deeply eroded, and only the resistant rock types form the short ridges and hills that are seldom higher than 100 m above the level of the surrounding broad valleys, and collectively can probably be considered as the remains of an ancient peneplain, only recently affected by a renewed, though quite shallow erosion cycle. The valley shapes suggest a very advanced, almost mature stage of the new cycle, although I am of the opinion that the broad valley forms develop more rapidly in an arid climate, with stronger mechanical weathering and greater effect of periodic floods, than in a normal humid climate.

In the area to the west of Almaden (intersection of the Mareeba – Chillagoe and Etheridge railway lines) toward Muldiva the first of the limestone hills begin to appear, and continue towards the NW as far as the neighbourhood of the Walsh River NW of Mungana and Redcap. The most distant appear to be those of the immediate surroundings of Chillagoe; this little town is attached to the smelters, in which the manifold ores of the area are processed. The absolute height of this region lies between 400 – 600 m.

The hard, crystalline to marble-like limestones are interbedded with quartzites, hard sandstones, soft and quartz-rich shales, which have been metamorphosed to mica-schist and gneiss towards the granite area. After a relatively superficial topographic study, the relative age relationships of the individual rock types remain uncertain, because of their strong metamorphism and complicated tectonics, the age of the limestones however, on the basis of the fossils found there, seems to have been fairly certainly determined as Late Silurian by Etheridge and Dunstan; originally R.L. Jack had assigned them to the Gympie Division of the Permo-Carboniferous system, and S. Skertchly considered them Devonian. According to Jack, it is possible that this chain of limestone continues further to the north and is connected to the thick limestone complex that was discovered by that author in the headwaters of the Mitchell and Palmer Rivers further to the north.

I could only spend a short time with my friend Dr K. Domin in the area around Chillagoe. Through the gracious co-operation of Mr MacDermott, the commercial director of the Chillagoe Company, we were provided with a man with great practical knowledge of the region, the electrician Mr T. Campbell, who, on several excursions, showed us the "limestone bluffs", the limestone hills in the greater area around Chillagoe, the sharp quartzite ridges and the lower limestone hills south of Calcifer and the limestone hills near Mungana. The best-known caves are located in the "bluffs" to the west and southwest of Chillagoe.

Drainage of the area is now mostly above ground, the main water-course is Chillagoe Creek, which only receives insignificant amounts of water from the caves, and makes only a small part of its course underground. However, it appears that vertical drainage played a greater role earlier on, but that the watercourses that

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[1] R.L. Jack & R. Etheridge, *The geology and palaeontology of Queensland and New Guinea,* pp 119 – 121, 609 – 610, 737.

R.L. Jack, The Chillagoe and Koorboora Mining Districts. *Queensland Geological Survey Report* no. 69, Brisbane, 1891.

D.S. Thistlethwaite, The Chillagoe Caves. *Proc. R. Geogr. Soc. Australasia. Queensland Branch*, vol. IX, 1894.

Sydney R.J. Sketchley, Tin Mines of Watsonville, and various tin, silver, copper and gold mines at Herberton, Montalbion, Irvinebank, Muldiva, Calcifer, Chillagoe, California Creek, The Tate River etc. *Queensland Geological Survey Report*. Brisbane, 1897.

B. Dunstan, Some Chillagoe geological notes. *Annual Report of the Secretary of Mines for the year 1910.* Queensland. Brisbane. 1901. Pp. 196–199.

R. Etheridge, Junr. On the occurrence of the genus Halysites in the Palaeozoic rocks of Queensland etc. *Geological Survey Rept.* No. 190, p. 30–32.

R. Etheridge, Junr., The lower Palaeozoic Corals of Chillagoe and Clermont, Part I. *Queensland Geol. Survey Rept.* No 231.

A. Meston, *Geographic history of Queensland.* Brisbane, 1895, pp. 159 – 160.

J.V. Daneš, Physiography of some limestone areas in Queensland. *Proc. Roy. Soc. Q'sland,* Vol. XXIII, 78 – 79.

In addition to the maps which accompany the particular works of R.L. Jack and S.B.J. Skertchly, which originate from the first period of mining activity in the region, and are obsolete as far as the topography is concerned, the following map gives a relatively good picture of this area: Sketch map of the Herberton and Chillagoe gold and mineral fields. Compiled from official and other sources under the supervision of W.H. Greenfield at the Geological Survey Office, Department of Mines 1902 (6 miles = 1 inch). In Stieler's *Handatlas* (9th edition) the position of Chillagoe, Mungana, Zillmanton and Atherton is wrongly shown.

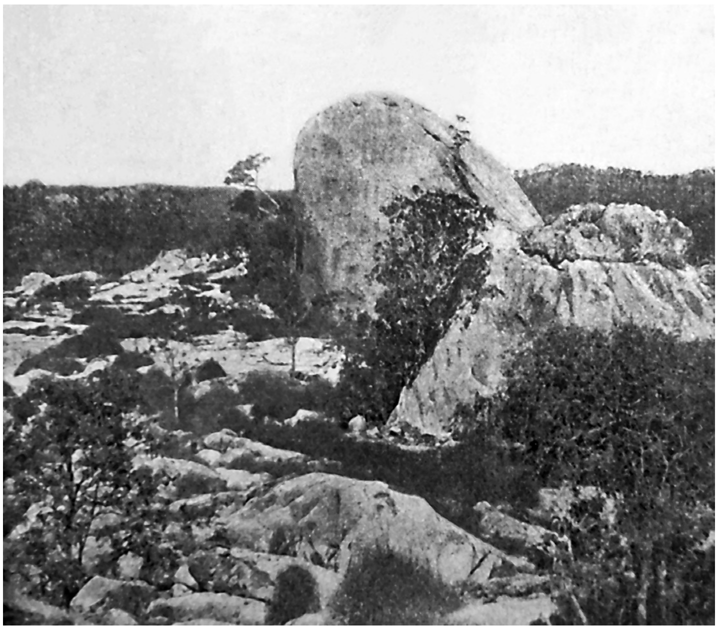
flow in the open valleys gradually took over, since they found on the granite and schists a better substrate than that in the weather-resistant limestone. However, one cannot speak here of a unified karst, either now or in the past, since in the first place the divide for the most part lies outside the limestone area, and thus the watercourses are already loaded with sand and gravel when they enter the area, and secondly, granite, schist and quartzite project above the surface between the limestone hills.

To obtain an overview of the whole area, on the first day we climbed the highest mountain in the environs of Chillagoe, the granitic Metal Mountain. This mountain rises beyond the area of limestone hills toward the northeast and is actually the ruin of a steep neck, whose slopes and peak are formed of great angular blocks, forced apart mechanically. From this peak one sees a chaos of hills and short ridges, which are mostly whitish-grey and jagged, in a broad SW – NE zone, with Chillagoe in the middle with the high smokestacks of its smelters. A picture which is reminiscent of the hills and short ridges of the Cockpit Country or the "Goenoeng Sewoe" type, but which differs strongly in the arrangement of the hilly ridges in a particular direction.

On examining the various limestone "bluffs" more closely one soon sees two types, which are strongly differentiated from one another. Mostly there are sharp, jagged hills, whose steep slopes are furrowed by deep rills, and which terminate above in sharp edges, deeply furrowed by karren; at two localities however, on the so-called Lion's Head Bluff near Chillagoe and at a place between Mungana and Redcap I encountered quite different hill-shapes; quite smooth surfaces on the rocks, only small, rudimentary karren, true evorsion forms [= potholes] and also boulders of quartz and granite; in brief, undeniable traces of strong mechanical aqueous erosion. The poorly developed karren demonstrate that the time at which two mighty streams flowed right across the zone of limestone hills, smoothing the outcrop surfaces with their boulders and sending their waters into the cave passages of the limestone zone, is not long ago. Naturally, since at that time the direction and position of the watercourses were quite different, they have also cleaned out the broad valleys, whose bottoms lie several tens of metres lower than the smooth hill of the Lion's Head, and only after a painstaking topographic and geological survey of the area will it perhaps be possible to characterise these undeniable traces of old watercourses preserved on the limestone, and better give the course, direction and geological age of these old rivers.

Judging by the secondary carbonate deposits the work of carbonate in solution has been great, for not only are the caves full of formations and their walls covered with a thick secondary layer, many chimneys completely filled by calcareous sinter mixed with clay, but also in the valleys there are often deposits of decaying soft calcareous sinter, which surely were deposited from the rapidly evaporating waters; these secondary deposits are several metres thick in Chillagoe Creek before its penetration of a harder granitic stock, where its course was stopped, forming a broad inundated surface during the annual local rains, and where evaporation was particularly rapid, causing the carbonate in the water to precipitate.

The basal area and the lower slopes of the limestone hills differ quite markedly by more abundant vegetation compared to the much sparser plant development on the surrounding terrain of different rock types, which are less advantageous for plant growth.[2] The upper parts of the hills are however mostly bare, and even in the karren furrows there remains only a small amount of karstic clay, because most of it is sluiced away in the rainy season.



Lion's Head Bluff near Chillagoe

Among karst phenomena in the karst area of Chillagoe only the karren and the caves are outstanding and characteristically developed. There are also occasional true dolines and karst depressions, particularly in the Mungana region

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[2] Domin. Queensland's Plant Associations. *Proc. Royal Soc. Queensland,* Vol. XXIII, p. 71.

I saw several shallow basin-dolines, which however do not offer much of interest. One kind of doline, namely collapse dolines, have developed in rather large numbers on the hills, themselves strongly disturbed by dolines, these however are connected all too closely with the cave phenomena that they are, so to speak, only a developmental stage of the cave cavities.

The karren in both their forms are mostly extremely deeply and sharply developed, in the purely erosional ridge-and-furrow form, as well as in the tectonically caused joint form. The steep slopes of greatly furrowed and the less steep slopes are divided into numerous sword-like, extremely sharp shapes, from the tips of which several knife-sharp edges descend several decimetres almost vertically. Only rarely are there the miniature combs and ridges so common in the Alpine and Dinaric karren fields, whose slopes are covered with shallow furrows looking as though they were artificially chiselled.

The vertical dimension strongly outweighs the horizontal, die sharp, narrow pyramids are separated by hollows at least as deep; these generally form miniature quite complex systems of furrows, which, with a more or less steep fall, terminate in expanded joints of the grikes. The grikes are mostly developed in two directions, intersecting at a right angle, and often where the joints intersect there are broad and deep holes, which as narrow chimneys or pipes often extend as far as the cavities beneath. These are then penetrated by water, which deposits secondary clay and lime formations in the subterranean cavities. With time the layer with which these deposits cover even the walls of the chimneys becomes so strong, that the remaining channel becomes narrower and narrower, and is finally choked. Very informative examples of such pipes, filled with calcareous sinter, clay and in places also with bone breccia have been observed in the big quarries in the vicinity of the smelters. I have given several samples of the bone breccia to Professor Spencer in Melbourne, who has determined the bone fragments as those of the extant species of rock wallaby.

The surface of the more extensive hill is highly chaotic and impassable, a `karren field of the wildest sort; there is an indescribable confusion of rock spikes and humps, holes, broad wells, more or less collapsed rock sections, and all surfaces exposed to the rain so eaten through, that the original surface of the beds is only hinted at by the points of the longest, bayonet-sharp rocks.

The attitude of the beds is often extremely disturbed, for the upper part of the bluffs, penetrated by caves, is broken into a multitude of “flakes”, some of which retain their original tectonic position, others however have sunk on one side or another and have often fallen further down. In this fashion the chaos of the karren fields is considerably increased by the disturbed balance of the undermined flakes. It would frequently be hazardous to try and indicate the original position of the blocks.

The limestone beds are mostly ½ - 1 m thick and are often completely eaten through by karren. In some places they can easily be split into thinner plates; the position of the beds is very disturbed; predominant is a strike of approximately SE – NW, the dip however changes often. The limestones are white, in places with red veins, mostly coarse-grained to crystalline, only the thin plates are dense. Apart from the bedding, the joints already mentioned are developed in two directions. One direction is almost parallel to the strike, die other forms a near-right angle with it. These joints are also determinant for the course of the cave passages, so that, for example, at the Mungana Caves the direction of the main disturbance is NE – SW with a dip of 70° SE, and in a small cave passage, uncovered in the quarries of the smelter, one runs SW – NE and dips almost vertically, the other N 35° E and dips less than 30° NW; there the beds strike W 30° N and dip less than 50° to the NE.

Our visit occurred at the middle of the rainy season and it was impossible for us to penetrate far into the water-filled caves of Mungana, but instead we could crawl through the cave labyrinth of the Chillagoe Caves in various directions. With the exception of some cave passages, which extend deeper, the cave passages were relatively dry except for a few siphon-like deep ponds, which however we could bypass in a different direction. It was evident that, even in the case of large floods, the water fills only the deeper spaces, during the dry season there are only a few pools in the deepest spots. One enters the caves over high piles of debris; the natural openings, through which the currents that produced them flowed back and forth, are now for the most part blocked. Cave passages in two directions dominate, ESE – WNW and NNE – SSW, which connect a larger number of larger spaces, which are up to 20 m high and are mostly richly decorated. In some of these spaces the ceiling has yielded to gravity and its debris lies on the floor with broken secondary deposits, and in others one reaches daylight; the roof has broken in and vertical to overhanging walls reach up to 20 – 30 m. The floor of the caves is mostly so covered with clay, that the debris only locally projects above it, the walls are thickly encrusted with secondary deposits. In in a few narrow passages and near a half-collapsed entrance could I observe erosional forms still well preserved, the original forms are already covered by new formations, to the point of unrecognizability. The pipes and chimneys, which open in numbers into the caves, have contributed substantially to this filling-up; some of them remain functional, as demonstrated by a thick layer of clay below their opening, others are apparently completely blocked and the only water that penetrates them in any quantity seeps slowly through. Although it was shortly after extended downpours, it would be too much to speak of seeping rainwater; only relatively few dripstones and shawl-like formations were so wet, that water dripped to the floor from them. During the dry season the moisture must be much less.

On some of the stalactites, broken off 20 – 25 years ago, new deposits can be recognised; and the thin ones it was impossible to measure them, some of the thick ones show an increase of 1 cubic centimetre or somewhat less.

Pothole-like features at the foot of Lion's Head Bluff

The rich development of secondary deposits and the collapse of the ceilings and entrances of the caves are proofs of a very advanced developmental stage and great age of this phenomenon at Chillagoe; at the same time it must be considered that the climatic and topographical relationships of the area are not very favourable for a strong development of calcareous sinter. The small thickness of the cave roofs means that, during the short rainy period, rainwater penetrates and seeps through during the high humidity without leaving much sinter, whereas the caves become so dry after the rain, that very little water enters the caves during the much longer dry season.

Concerning the beauty and variety of the cave deposits, the caves at Chillagoe compare well with many of those "world famous" caves so visited by tourists, but in other respects they are well behind, particularly in respect to the vertical dimensions of the domes they lose out. The most comprehensive description of the Caves, according to Meston was given by the "mineralogical lecturer" William Thompson in the year 1891, more or less independent of which are the descriptions given by R.L. Jack and D.S. Thistlethwaite.[3]

Mr Campbell has made me aware of a peculiar occurrence in a few places. Particularly at the entrances of narrow pipes and cave passages the surface of the rocks is often smoothed in a curious fashion; the cause of this smoothness was given to be the rock-wallabies (*Petrogale* sp.), a kind of small kangaroo, which inhabit the caves in large numbers. For this reason there are relatively few bats in the Chillagoe Caves.

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[3] In the annotations at least I would like to refer to a slightly confusing interpretation of the coralline limestones of Chillagoe. J.P. THOMSON in his essay "The geographical evolution of the Australian Continent" (*Queensland Geogr. Journal* XVI, p. 11, *La Géographie* V. 1902, p. 259) writes: *"The whole of Cape York Peninsula was very likely cut off entirely from the continental area during one of the periods of prolonged subsidence. Evidence in support of this view indeed exists in the Herberton district. Here in the somewhat extensive cave features of the Chillagoe area there occurs a typical example of an ancient submarine reef structure, where the old coral formation has been developed. The locality, although not an extensive one, has evidently been at some remote period invaded by the sea, and probably represents a portion of the channel or strait by which the Peninsula was insulated."* One could easily interpret this passage to mean that it deals with limestones developed in a marine strait after the mountain-building episode; that they are thus significantly younger than the surrounding areas to the north and south. Such an interpretation would be a mistake; since the limestones are Silurian and thus older than the folding of the mountains, we have no proof that, after the great orogeny, a separation of the Peninsula from the rump of the continent occurred in just these latitudes.

Olsen's Caves.[4]

North of Rockhampton the rolling country about 100 m above sea level in the proximity of the mighty Fitzroy River is dominated by a mountain rising high above it, Mount Etna, which is named after the famous volcano because of its conical shape, although it has no genetic similarity with it. Mount Etna is made up of tough quartz schist, and rises above the softer Palaeozoic shales of its surroundings as a monadnock; to the east and west of it there is a series of low, short ridges and hills, "ridges" and "bluffs", which consist of limestone and must also be regarded as monadnocks.

Some of these are penetrated by caves, which have been known for as long as 30 years, and were described by James Smith. The best scientific description is given by William H. Rands, to whom the reader of these lines is referred for further information. Rands considered these limestones as Devonian, on the basis of the fossils found. These were affected at the same time as those of the surrounding terrain by the great mountain building of the late Palaeozoic; earlier perhaps their extent was greater, as now-exposed remains of cave deposits can be found in original position on the planated terrain, some distance from the hills which remain. More than at Chillagoe these limestone hills are differentiated by their vegetation, which covers their bases and slopes, from their flat, shale-underlain surroundings; a quite vigorous "vine-scrub", tropical thicket, is spread over the limestone, whereas only the open, dry eucalyptus forest "open forest" grows on the poor shale terrain.

I was only able to undertake a fleeting visit to Olsen's Cave, and my remarks are restricted to the karren and the caves.

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[4] R.L. Jack & R. Etheridge, *The geology and palaeontology of Queensland*. p. 610 – 612.
Contains quotations from James Smith's description of Olsen's and Johannsen's Caves, which R.L. Jack had in manuscript.

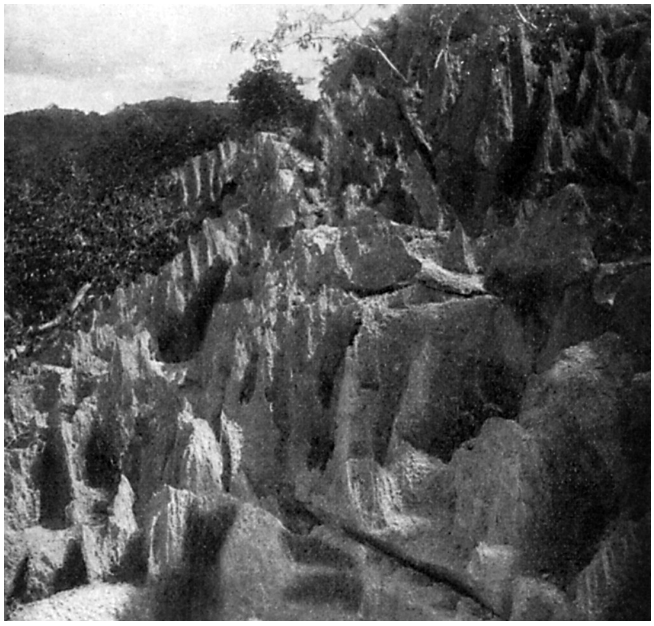
William H. Rands, Olsen's and Johannsen's Caves, near Rockhampton. *Geological Survey of Queensland; Publication* No. 86.

J. Christensen, *Olsen's Caves near Rockhampton.*

B. Dunstan, Phosphate-bearing rocks in the Rockhampton district. Records No. 1, III. *Geological Survey of Queensland Publication* No. 190, p. 11.

Lionel C. Ball, Certain iron ore, manganese ore and limestone deposits in the central and sourthern districts of Queensland. *Geological Survey of Queensland, Publication* No. 194, p. 13 – 14.A. Meston, *Geographic history of Queensland,* p. 160 – 1. Also quotes James Smith.

Daneš, *Physiography of some limestone areas in Queensland,* p. 80.



Karren on the Olsen's Caves ridge

The karren are developed in a form highly reminiscent of those at Chillagoe; the upper parts of the limestone ridges, bare of vegetation, appear as genuine, naturally very small karren fields, which have been affected relatively little by tectonic and gravitational disturbances. Their surface is thus to a certain extent gentler as that of the Chillagoe "bluffs", the karren themselves, the genuine corrosion- and erosion-karren however are deeper and wider than those at Chillagoe. The same shape dominates here as well, narrow, high pyramids with some knife-sharp edges on their flanks, and a very dangerous point, between them such deep, narrow furrows, that often one cannot reach their base with a foot, without exposing oneself to dangerous grazing high on the thigh. The surface of the "karren field" is free of vegetation and clay, as at Chillagoe, as it is completely exposed to the drenching rain of the short rainy season. Neither humic acids nor shadowing by vegetation hinder the complete development of pure karren forms, as they are washed out by rainwater. There is a difference from those encountered in other climates, particularly those where snow plays a role. The forms are much freer, more independent, simpler and more regular. I have seen very similar karren in Java, on the coast of Goenoeng Sewoe[5] on the rock platforms, above which the continuous foggy veil of the heavy beating waves pours. I am convinced, that the development of this type of karren, on the seacoast as in the semi-arid climate of Australia, the mechanical effect of the free, even vigorous

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[5] Das Karstgebiet Goenoeng Sewoe in Java, p. 49.

collision of falling water plays a large role, as well as the chemical activity of the water.

The stage of development that I saw here on the karren of the Olsen's Caves ridge I would define as about mature, one can with difficulty imagine a greater completeness of karren forms; at Chillagoe this stage appears to have been passed; the tectonic moment, namely the much more important role of the grikes, as well as the circumstance, that the balance of the banks is disturbed in so many ways, is certainly also involved.

Olsen's Caves are a network of mostly narrow and low cave passages, which penetrate a hill about 100 m wide in different storeys. Their hydrological purpose appears to be long since over, no vein of water enlivens even the deepest of the known spaces, the ceilings, walls and floor of the grottos are mostly dry and the floors is often covered with a several metres thick layer of bat guano, which together with karstic clay and secondary lime formations surely closes many pipes, chimneys and passages. There have been attempts to use this Guano as an artificial fertiliser. Attempts up till now have been unsuccessful, though I am of the opinion that although its quantity is insufficient for the export market, this occurrence in the possibly near future could be used on a small scale for local purposes and to good effect, should agriculture develop better in the nearer vicinity. At present economic exploitation of the caves has ceased, and even tourism gives them little attention, and that with justification, since in comparison with the Chillagoe and New South Wales caves offer little by way of attractions to the eye seeking rich cave formations. Also, the penetrating, unpleasant smell of the thousands and thousands of bats which still dwell in the caves, may well put tourists off.

The paucity of secondary lime deposits is very characteristic of these caves. The walls are often bare of secondary cover, and even the cave formations are smaller and less common than in other caves of the eastern mountain belt of Australia. I cannot explain such a small participation of groundwater well, as there appear to be no external causes for the dryness of the caves. The climate is sufficiently wet, the surface of the limestone ridge is not covered with soil and vegetation which might otherwise take up the water falling on it, at least partly, and also the thickness of the cave roofs is rather insignificant.

There can be no doubt, that the caves along the cracks have arisen by the erosional activity of a watercourse, which in deepening its bed right across the limestone ridge was not able to retain its position on the surface, but was obliged to take the cave path. Even the shapes of the cave passages give eloquent testimony for such an origin, numerous potholes and similar evorsion features which originate through the spiral motion of gravel- and sand-bearing water, now partly filled by bat guano, betray the vigorous erosional activity of the stream, separated into several water-runs. The erosion probably proceeded quite rapidly and the subterranean river bed shifted deeper and deeper. With some certainty three levels can be differentiated, which represent so to say rest stages in the deepening of the cave passages and are defined by wider caves. It cannot however be excluded that the irregular deepening of the river bed is at least partly due to petrographic differences in the limestone beds.

At present the caves have been abandoned by the watercourses that created them. Thus it is more conspicuous that the caves have retained such a fresh appearance, in other words, that the secondary formations have not achieved great progress in their covering and filling. Truly, as already mentioned, there appears to remain no external cause for this, other than the assumption that the deepening of the erosional base proceeded very quickly and that the whole reversal of the landscape in the region of the caves was achieved in a relatively short time. When the river began to erode its underground course through the limestone ridge the whole surrounding terrain must have lain at the same height or even higher than the present surface of the limestone ridges, which now however, as already mentioned, form monadnocks which project 30 - 50 m above their surroundings. The geological and morphological history of eastern Australia in the latest Tertiary and the Quaternary appears consistent with such a relaively rapid planation process.[6]

According to the explanations of the settlers who accompanied me the neighbouring Johannsen's Caves must be at a similar stage of development; from the descriptions of James Smith and W.H. Rands however they appear to show more cave decoration.

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[6] G. Taylor, *Physiography of Eastern Australia*. Comm. B. Meterology. Melbourne. Bul. 8.

Daneš, On the physiography of Northeastern Australia. *Věstnik k. č. Spol. Nauk* 1911.

Other small karst regions of Australia.

Among the doubtless quite numerous caves which occur in the common limestone layers in the mountains of New South Wales, the Jenolan Caves are particularly well known, a visit to which can be combined with a tour through the Blue Mountains, thanks to an excellent automobile connection. The state geological institute (Geological Survey of New South Wales) has collaborated with the excellent Tourist Bureau of that state to publish a very fine, popularly written and well-illustrated guide to the exceptional cave areas, among which the Caves at Jenolan can be considered the best.[7] I have only visited the Jenolan Caves myself, though the guides mentioned make it possible for me to recognise, at least in broad strokes, the stage of development of the other cave areas.

The Yarrangobilly Caves lie in the catchment area of the river of the same name, in the northern part of the highest mountain group of Australia, Mount Kosciuszko. They can be reached from Tumut or from Cooma by post-coach, lie at a height of about 1100 m and are only the best-known of many caves along a limestone area 10 km long and 1½ km wide. The geological age of this limestone has not yet been determined with certainty, but will be Upper Silurian or Devonian. The caves for the most part appear to have been abandoned by the watercourses which created them. The amount of cave deposit is impressive, the sinter cover of the walls almost complete, with the exception of the cave “The River Cave”, which is designated as “dirty and uninteresting passages” and is traversed by a water body. Many cave spaces have already been breached, as Mr Trickett imparted to me personally, in some spaces there are hills of collapsed debris.

The Wombeyan Caves, which lie on the creek of the same name near its junction with the Wollondilly River, between Goulburn and Bowral, at an altitude of about 600 m, may be of the same style as the Yarrangobilly Caves. Some of the caves described by Trickett seem to be seepage caves, only Creek Cave, eroded by Wombeyan Creek, and a few deeper passages traversed by the same creek are true river caves. In the cavity called Victoria Arch the roof has collapsed sideways and thus a huge natural shaft has arisen.

Wellington Caves lie near Wellington at more than 300 m a.s.l. near the junction of the Bell and Macquarie Rivers, in a low, flat ridge of limestone of Late Silurian or Devonian age. These caves are in their vertical and horizontal dimensions much smaller than the other officially described ones, the fill of secondary deposits is not strong enough to completely cover the primary structure. They have become known through the numerous discoveries of bone of fossil marsupials.

Jenolan Caves lie at an altitude of about 800 m on the eastern flank of the 12 – 1400 m high spine, which forms the continental divide between the catchment areas of the Macquarie and Hawkesbury Rivers, on the upper Jenolan River, a tributary of the Cox River, which empties into the Nepean and with it into the Hawkesbury.

Although situated in a very narrow band – about 200 m – of Silurian or Devonian limestones, the Jenolan Caves belong to the greatest of explored caves areas which, for the beauty of the landscape of their immediate surroundings and the superb development of the cave-decorating elements certainly belong to the touristically most rewarding in the world. The narrow limestone ridge is penetrated by two superb tunnel-caves, through which the rivers still flow at high water. These caves show, in their lower parts, fresh erosional forms, the rivers however had to force a way between mighty debris from the cave roof, and above there hang mighty stalactites. Probably there was here an intermediate ceiling which has collapsed, thus connecting an upper level of the caves with the originally lower river cave. In the upper part of the ridge above the present tunnel-caves a rocky gateway opens beneath a natural bridge. That is the remains of the original tunnel-cave. Those caves open to visitors and which are altogether richly filled with secondary deposits lie in several storeys and are mostly originally river-caves; with the exception of the Easter Cave their roofs remain so firm, that daylight does not penetrate. With the exception of several siphon-like ponds and short stretches of

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[7] O. Trickett, *Guide to the Jenolan Caves, New South Wales,* Geological Survey of New South Wales. P. 76 with good map and vertical section. By the same author are the rather less comprehensive booklets: *Guide to Yarrangobilly Caves. Guide to Wombeyan Caves* and *Guide to the Wellington Caves.*

O. Trickett himself measured the plans and vertical sections, and with the help of several keen cave supervisors has greatly extended the knowledge of caves in New South Wales. The caves mentioned have been carefully prepared for visits by tourists, and fitted with protective devices for the beautiful cave formations. Indeed, the surroundings of Jenolan Caves form a protected area which even the black-brown rock wallabies (Wallabies, *Petrogale* sp.) inhabit in large numbers.

water in the lowest storey the cave passages are without flowing water; the present subterranean watercourses are rather lower, and only at high water are the lower storeys flooded. Seeping water is busily at work; many cavities and passages of the Jenolan Caves contain numerous helictites, which are here called “mysteries”. These are at least partly gypsum dripstones. Those rock surfaces flattened and polished by wallabies occure here in quantity, outside the caves and also in the hollow spaces that are not far from daylight.

The discovery of a human skeleton in one of the caves of the lower storey led to an examination of the chimneys that open into the cave roofs, mostly these are now closed by secondary deposits and collapsed material. The skeleton however could have reached the cave, far from any daylight entrance, by no other way, and it is to be assumed that it fell through one of the chimneys present above the place of discovery.[8]

I was unable to visit the caves in Victoria, South Australia and Tasmania, and have access to no literature, from which I could derive anything related to the morphological development of the cave areas.

Finally, may I be permitted to mention the caves at Yallingup in south-western Australia. These have been very well described in the Western Australian Yearbook and their evolution also excellently drawn by Edward S. Simpson.[9] Here we are not concerned with anextensive connected karst area, nor with a complex of limestone beds, rather only with lime-rich sands, which randomly dominate between the old quartz-sand dunes. They are aeolian and deposited on granitic basement, and are in places up to 100 m thick. The waters which hasten to the ocean along the granite basement have created cave passages in the strongly cemented calcareous sands, into which the roofs have collapsed locally. The caves have been rendered accessible by such collapse chimneys. The secondary deposits, namely the cave deposits, are relatively well developed and their evolution, thanks to a modest activity of seepage water, seems to have been relatively rapid, since respectable stalactites have grown even on parts of the ceiling laid bare by recent falls. The grottoes of southwestern Australia are placed collectively under the protection of a special commission (Caves Board), which issues an annual report on work done towards conservation and better access.

Barkly Tableland and the great karst area of Northern Australia

a) The extent and geological age of the tableland limestones.

From the northern part of Northern Territory into the western part of Queensland extends a low plateau, on which the Georgina and Gregory Rivers rise. This eastern part of the plateau is called the Barkly Tableland and is rimmed on the east by a more or less broad belt of an old, quite low range, which according to Suess’ interpretation forms the northern member of the Australian anticordillera. The main water divide between the continental basin of central Australia and the Gulf of Carpentaria runs almost without expression over the tableland, and it would be a great mistake to presuppose a water-dividing ridge.

The Barkly Tableland[10] was explored for the first time by Landsborough in the year 1861

and named by him, so afterwards the first pastoralists arrived, tempted by the promising speeches of the discoverer, but a crisis in the year 1866 delayed the definitive settlement of this area; even in the year 1876 Hodgkinson speaks of no new station and only at the end of the seventies was the area taken up for a second time and Camooweal founded in 1880. In the eighties most of the pastoral “stations” were also taken up in the western part of the tableland belonging to the Northern Territory.

The extent of the tableland can only be given broadly. Its north-eastern and eastern limit is best determined. To the northeast it drops rather steeply and suddenly to the flat coast of the shallow Gulf of Carpentaria, its 2 – 300 m high, steep margins are dissected by a large number of narrow, almost impassable gorges, and some of the coastal rivers have succeeded in drawing part of the plateau into their catchment. Somewhat to the east of the artificial border of Northern Territory and Queensland (128° E) the edge of the table land turns sharply

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[8] The Discovery of a Human Skeleton at Jenolan Caves. By R. Etheridge Jun., & O. Trickett L.S. *Records Geological Survey N. S. Wales,* 1904. Vol. VII Pt 4, p. 325 – 328.

[9] Edward S. Simpson, Geological features of the South-Western Caves District, and C. Erskine May, Description of the limestone caves of Western Australia. *W.A. Year Book.*

[10] The tableland was originally named Barkly Plains by W. Landsborough, in honor of the Minister Sir Henry Barkly. The spelling “Barclay Tableland” or “Barclay Plains” is thus incorrect.

to the south. The Gulf depression penetrates further and between the broad valleys the remains of an ancient range emerge as a low, desert but ore-rich mountainous area, above which in the west the steep, rather upturned margin of the tableland rises like a sharp but low wall; a few mountains, among which Constance Range west of Lawn Hill is the most important, bear witness that one is dealing with a denudational margin and that the tableland earlier stretched further east. The process of denudation was probably accelerated because this area underwent a greater specific uplift (probably in the Late Tertiary and the Quaternary) than the remaining tableland experienced. At about 19° S on the upper course of the Gregory River the tableland extends further east in several spurs as far as beyond the Thornton River; only the divide between the tributaries of the Gregory and Leichhardt belong with certainty to the old metamorphosed mountains, and it runs to the south with a small bend to the east. South of the track linking Camooweal with Cloncurry recognition of these broad features of the surface becomes uncertain, one only knows that the old mountain range bends to the southwest at this point, but is however much more planed off, so that it loses its mountainous character over long distances. Here and in the southeast as further west it is impossible to give the southern border of the tableland exactly, it is possible, that it penetrates as re-entrants the spurs of the old range, such as Cairns Range, Davenport Range, Murchison Range etc.; further to the north it is apparently connected via Stuart's Plain and the area around Daly Waters with the tableland on the Victoria River, and in the northerly direction it extends, though not without disruption, far into the northern peninsula.

Very little has become known of the geological relationships of this area so far from traffic, and even today is our knowledge of the geographical extent and the geological age of various sedimentary complexes very uncertain. The fact that one part of the area lies in Queensland and the other in the Northern Territory has hindered a unified exploration, as there appears to be absolutely no scientific contact between the State surveys in Brisbane and Adelaide. Every State institute has proceeded according to its own tradition, and a higher regard for the continuity of a geological examination of the whole continent has not been considered.

The itinerary of the first explorer of the Barkly Tableland, W. Landsborough, is almost unusable from the geological standpoint. Hodgkinson, who as Warden certainly possessed much better knowledge of the most important rock types, failed to describe in his report just that part of his line of travel which followed in Landsborough's tracks. This is the more to be regretted as the later official geological expeditions, motivated mostly by practical interests, only touched the outermost spurs of the area. The question of the extent of the Great Artesian Basin and then the research of areas of mining interest were the main lines of activity for the small but active staff of the Queensland Government Geologist, overloaded with such projects, found little time for issues of a more theoretical nature.

The first serious report on the limestone plateau of the Barkly Tableland was brought by R. Daintree,[11] who on the basis of a single discovery (*Tellina*), brought to him second-hand, declared the horizontal limestones in the source area of the Gregory River to belong to the Desert Sandstone Series and of marine origin. (The Desert Sandstone Series was earlier considered Cretaceous or Tertiary, but restricted to the Upper Cretaceous by later research.) The metamorphosed mountains on the lower Gregory were declared Silurian by the same researcher.

Dr R.L. Jack, State geologist for many years, saw only the northern spurs of the tableland at Carl Creek near Riversleigh, in the year 1881. At that time he was uncertain whether he should consider these limestones as Silurian, like the area to the north, or, with Daintree, as Cretaceous, though later he opted for Cretaceous, but older than the Desert Sandstone, namely as belonging to the Rolling Downs Formation.[12] The grounds and proof on which this positive determination was built remained unknown even to R.L. Jack's younger colleagues, W.E. Cameron and L.C. Ball. The scenic botanical character of the tableland, which must have been known to R.L. Jack through dependable descriptions by others, must have contributed much to this decision, for someone who knew the landscapes so well the great similarity of this area, described by others, with the Rolling Downs Country in central Queensland, must have been very obvious, if not decisive. On his great geological map R.L. Jack designates the tableland as Rolling Downs Formation (Lower Cretaceous), supposedly as a great bight, con-

[11] Notes on the Geology of Queensland; *Quarterly Journal of the Geological Society,* 1872, p. 278.

[12] *The Geology and Palaeontology of Queensland*, p. 394.

necting with the main area to the south of the Anticordillera. In another place in his main work[13] in a list of boreholes through the Rolling Downs Formation R.L. Jack mentions two that are located on the Tableland, one in Rocklands (19° 40” S, 138° 15” E) near Camooweal, the other at Avon Downs (20° S, 137° 30” E), already in the Northern Territory west of Camooweal. Concerning the borehole near Avon Downs he remarks briefly, that it lies in Rankin’s Creek at an altitude of 554 feet, and that the water was reached at a depth of 200 feet, however it did not rise to the surface; concerning the borehole near Rocklands he publishes the drilling report sent to him, stating that at a depth of 412 feet the hole was not yet complete. It would be superfluous to examine the drilling report more closely here, R.L. Jack accepted it and maintains that, from top to bottom, basalt, Tertiary, Desert Sandstone and Lower Cretaceous beds were penetrated, I however am in a position to consider this false. It can perhaps not be considered a deliberate falsification of the real facts by the recorder, but rather a careless determination by a less competent person of the rock-types penetrated. So it is quite possible that hard, red secondary filling of some earlier space were named “some sort of basalt” by an ordinary person, and were recorded as “basalt seams´and “basalt and lime rock” in the drilling report. I have examined the area around Rocklands in detail, examined the remaining debris piles with care, and, of more weight, have obtained from Mr H.A. Glissah, manager at Rocklands, the assurance that, to his knowledge, no rock apart from limestone, hard siliceous limestone and secondary cave deposits was encountered in any of the 18 boreholes.

On the widely available geological maps, published by J.B. Henderson of the Water Supply Department in Brisbane, the Tableland is depicted in the same colour as a large part of the neighbouring old range, namely as Palaeozoic “impervious rock-types, which lie below the water-bearing Lower Cretaceous and Triassic-Jurassic beds”.[14] After personal inquiry no other reason for this assumption was imparted, only that in the area north of the confluence of the Georgina and Burke Rivers (NW and N of Boulia) no drilling has discovered artesian water, and thus the occurrence of the same aquiferous beds as in central Queensland can be excluded. The assumption of W.E. Cameron, that the limestones of the Tableland are post-Tertiary formations was emphatically denied by Mr Henderson.

The most recent geological map of Queensland by the Geological Survey shows these limestones as “post-Tertiary limestones” [15] and gives them a rather narrowly restricted area in the catchment areas of Lawn Hill Creek and the Gregory and Georgina Rivers, east to beyond Yelvertoft on Inca Creek. This results from studies carried out by W.E. Cameron, but again only at the extreme northern margin of the Tableland.

W.E. Cameron, on a trip in the year 1900, considerably enriched the knowledge of the geology of the old mountains in western Queensland. The metamorphic rocks of these mountains were earlier grouped as formations of uncertain age, until however R.L. Jack succeeded in obtaining fossil fragments from the area of the Cairns Range on the border of Queensland and Northern Territory, which were determined as Silurian, they were shown on the maps as Silurian, although one was well aware, that such a summary reached well beyond the permitted boundaries of generalisation. W.E. Cameron found that the rocks of the mountainous area in the region of the Cloncurry and Leichhardt Rivers are very strongly metamorphosed, but towards the northwest in the areas of the Gregory and Nicholson Rivers show much weaker metamorphism and are also less disturbed tectonically.

This circumstance is probably due to there being no great projecting granite masses in the north-western region (on the Gregory River), such as often occur near Cloncurry and on the Leichhardt River.

The steeply dipping old schists are unconformably overlain with little disturbance by quartzitic sandstones, particularly in the Constance Range and by almost horizontal limestones on Lawn Hill. Cameron was unable to determine the mutual position of these two stratigraphic complexes with certainty, but considered them as apparently of Devonian age, that is, a little younger than the more disturbed and metamorphosed “Silurian” beds. Cameron also conqu-

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[13] *l.c.,* p. 418 – 419.

[14] *Map of Queensland showing positions of Artesian Bores and Perennial Springs also the approximate area of the artesian water bearing strata.* Brisbane 1908.

[15] Geological sketch map of Queensland showing mineral localities prepared under the supervision of R. Dunstan F.G.S., acting Government Geologist and compiled by H.W. Fox at the Geological Survey Office, Brisbane. 1905.

ered the Constance Range and at a distance of about 1 English mile from the Range determined horizontal limestones lying on the sandstone, these extending far and wide to the west and southwest and forming a sparsely vegetated tableland, at the margins of which the sandstones, dipping to the west beneath the limestones, are demarcated by much livelier landscape forms and darker vegetation. Towards the south, where the track to Herbert Vale Station climbs on to the Tableland, the sandstone surround disappears gradually and then the edge of the Tableland turns to the southeast, where limestone knolls about 50 – 60 feet high lie immediately on a basement of metamorphic rocks. Cameron noted that this border of the limestone plateau, from Lawn Hill Creek in the north to the Seymour River in the south, has been known for quite a while, as it is already shown on the geological map of Queensland from the year 1895, although as "Lower Cretaceous". It appears that R.L. Jack himself saw only a part of this boundary on the Gregory River (Carl Creek), but he certainly found contacts who could give him reliable information. I have myself met a former prospector in this region, who has been living in the region south of Burketown since the year 1868.

Cameron considers these plateau limestones to be much younger than R.L. Jack. The reason is palaeontological proof. In April 1900 two species of gastropods were found in these limestones by E.R. Brackenberg, which R. Etheridge jun. determined as *Helix* and *Isidora*; the fossils were found in a salient of the limestone plateau, which includes the island between Carl Creek Gregory and O'Shanassy.

Not far from this place (near Verdon Rock) the author has found, in the same limestone, bone fragments of marsupials, and his travelling companion Edwin Lowe later found remains of a crocodile skull embedded in hard limestone. On the basis of these discoveries W.E. Cameron made the following diagnosis *"The universal horizontality of the Barklay Tableland junction lying in a basin surrounded by land standing a higher level than its uppermost beds, together with the occurrence of the recent Helix and Isidora, and the marsupial and crocodilean remains point to a much more recent age [than Cretaceous], and the beds no doubt represent a deposit of Post Tertiary Age. The occurrence of the land and freshwater fauna point to the inference that in these recent times the Barklay Tableland was the site of a great inland sea into which carbonate of lime was brought by the streams draining into it, and where it was collected in the shells of molluscs or slowly deposited by gradual evaporation from the surface of the lake during times of drought to form the present exiting bed of limestone.*[16]

To be named as the most recent explorer from the Queensland side is Lionel C. Ball, who undertook two trips to north-western Queensland, the particular purpose of which was a geological examination of the ore occurrences of the so-called mineral field at Burketown. This explorer however interpreted his assignment in a broad manner, and in his monograph[17] he gave a most industriously worked-out picture of the geological situation of the north-western corner of Queensland, the accent being on the immediate neighbourhood of the mines at Lawn Hill and Mended Hill. L.C. Ball consider the Silurian age of the local metamorphic rocks to be proved, and indicates that a similar formation has been found on the MacArthur River in the Northern Territory, which was considered Permo-Carboniferous by H.Y.L. Brown. The quartzitic sandstones of the Constance Range he considers to be of the same age as other similar occurrences further east, which for tectonic reasons cannot be differentiated from the other disturbed beds, and are decidedly older than the horizontal limestone beds of Lawn Hill, which Ball surely with reason considered evidence, and connected them to the tableland limestones. With Cameron however he considers the tableland limestones to be post-Tertiary; new evidence for this he sees in several discoveries of Dentalium to the north of Mended Hill and in the specimens collected by me below the Tarpeian Rock and at about the same place as by W.E. Cameron at Riversleigh. I will return to this evidence later.

Officially then there is general acceptance that the tableland limestones are late Tertiary, or more likely post-Tertiary.

I can only offer a few observations and age determinations for the Northern Territory. Augustus C. Gregory mentioned in his diary several places along his great journey of 1857 between the Victoria and Roper Rivers where horizontal limestones underlie a sandstone which is almost the same as the Desert Sandstone of Queensland[18], and also mentions the

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[16] *l.c.*, p. 190 – 1.

[17] The Burketown Mineral Field. *Geolog. Surv. of Q-sld.* No. 232.

[18] Journal of the North Australian Exploring Expedition. *Journal R. Geograph. Soc.* Vol. XXVIII, p. 84.

"Downs" character of the landscape. The conscientious and highly meritorious H.Y.L. Brown, for many years Government Geologist of South Australia, travelled back and forth through the Northern Territory on many journeys, and from him comes the great geological map of the Northern Territory, on which the occurrences of the tableland limestone appear to have been entered conscientiously. From the extremely modest and laconic reports of this geologist one unfortunately learns little about the detailed form of the surface of these limestones; it is mostly "Downs Country" with abundant grass on dark, rich soil; the limestones only project above the surface occasionally; "gibber plains", gravel surfaces and low gravel hills alternate with the grassy downs, which are surely the last remains of the desert sandstone hills, which have been sacrificed to the denudation. On his map of the Northern Territory[19] Brown designates these limestones as "crystalline limestones, and dolomites with flint and chert, limestone conglomerate etc." of indeterminate age, but apparently Palaeozoic. The blue colour of these limestones covers great areas of the map, which however are separated from one another by large areas of other coloration and white areas. At the eastern border with Queensland they begin in high latitudes (from about 19° 20" to 21° 20" S), take up the entire upper catchment of the Georgina, then covers quite large areas near Brunette Downs (19° S 136° E), differentiated from areas designated as "Upper Cretaceous", further to the west a broad area along the continental telegraph line between 15° and 16° S, large areas along the Victoria River north and south of the 16° parallel and a particularly big area which extends from the catchment area of the Daly River in a north-westerly direction as far as the plains of its lower course. Had one also taken into consideration A.C. Gregory's diaries, one would have been well able to connect this latter area with that along the telegraph line, since the researcher confirmed limestone at several places on the Dry River. A few small blue patches connect the large areas and confirm the great extent of these tableland limestones even further, particularly in the south-east. As I heard by word of mouth from Mr Brown, he was originally of the opinion that this limestone plateau was only to be considered as a continuation of the Rolling Downs, and that his own limestones belong to the same geological age, but later a not entirely trustworthy fossil discovery at Alexandra Downs, along with more of his and H. Basedow's further discoveries of Cambrian fossils at the Daly River, moved him to ascribe a much greater age to the entire limestone complex. At two places in the Daly River area traces of Cambrian fossils (Salterella) have indeed been found, which, placed in connection with trilobite finds (Olenellus at Alexandra Downs Station, Agnostus and Macrodiscus at Tennant's Creek) represent sufficient grounds to ascribe the great tableland limestone area of the Northern Territory to the Cambrian, in the opinion of H.Y.L. Brown and H. Basedow.[20] These limestones lie horizontal and discordant on the folded Precambrian at the Daly River.

Compared with what we observe in Queensland, that is a fine result, *the tableland limestones are post-Tertiary in Queensland and Cambrian in the Northern Territory!* Can one ask for more!

In my opinion however one can bring these extremely divergent age determinations into agreement quite easily. In the catchment of the Gregory River and its tributaries this plateau limestone lies thoroughly discordantly on the older formations, which have been referred to the Palaeozoic (Silurian – Permo-Carboniferous), it must thus be younger than these, but is still older than the so-called Desert Sandstone Formation, which, though it has mostly disappeared from its surface but for the gravel and dreikanter areas of the gibber plains, in my experience still remains preserved in the source area of Wooroona Creek at an altitude of 20 – 30 m, and further to the east may form the divide between the waters flowing to the Georgina and Gregory Rivers. This experience and

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[19] Geological map of the Northern Territory of South Australia, by H.Y.L. Brown, F.G.S., Government Geologist. Physical geography compiled by C. Winnecke, F.R.G.S. from private and official Records. Adelaide 1898. Scale 20 miles = 1 inch.

[20] *Northern Territory of South Australia. North-western district. Reports (geological and general) resulting from the explorations made by the government geologist and staff during 1905.* Adelaide, 1906. pp. 5 – 20. General Geology H.Y.L. Brown and H. Basedow. p. 14. *"In lithological characters this formation is similar to the [sic] covering large areas between the Katherine Station and Flora Falls, also to that at Jasper and Timber Creeks, off the Victoria River, between the Elsey and Daly Waters Stations on the Transcontinental Telegraph Line, at Anthony's Lagoon, Brunette Downs, Alexandria Station, and other places. It is most probably continuous beneath the basalt, sandstone and other later formations. The occurrence of Cambrian fossils near the Daly River and Alexandria Station (Alexandra Downs) prove that these widely separated expanses of limestone are identical in age."*

the nature of the landscape, the penetration of the old mountains by embayments brings me to the firm assumption that these tableland limestones are of the same age as the Rolling Downs Formation and that they are only differentiated in so far as here the porous, pure limestones dominate, whereas in the Artesian Basin the Rolling Downs [Formation] is principally represented by impervious limy shales and marls.

The “Olenellus” from Alexandra Downs Station was found on the dump heap of a borehole, and probably in shaly marls, whose relationship to the limestones is still not explained. That Cambrian fossils have been found on the Daly River is no certain proof that the enormous limestone area must be of the same age. On the contrary, on the MacArthur River probably Permo-Carboniferous coaly shale has been found below the limestones, and by all accounts usually lies directly on the limestone of the Desert Sandstone Formation!

It is easily possible that by chance the Cambrian limestones are connected to the much larger area of the younger Lower Cretaceous limestones, and demonstrate no obvious discordance nor any other obvious differences. Altogether it is almost certain, that in Western and Central Australia much older mountain areas are present, that in the so-called Australian Anticordillera and Cordillera; it is thus easily explainable that the Daly River Cambrian still rests horizontally on the disturbed Precambrian, while further east even the formations of the later Palaeozoic have undergone tectonic disturbance.

It is much easier to explain the error, that the same limestones in Queensland are considered post-Tertiary and freshwater. Is there anywhere at all where freshwater limestones occur over an area of many thousands of km^2, with a thickness of hundreds of metres or more? This observation fits only for the superficial beds and cavity fills, i.e. for purely secondary formations, which fill the older cavities and joints in varying thickness, and were also deposited in greater or lesser thickness in pooled freshwater, which formed on the surface of the Tableland, particularly on its northern edge, for morphological or climatic reasons. These deposits and those fossils found in them are most certainly secondary, and the great mass of the tableland limestone is older, *older than the Desert Sandstone Formation and younger that the disturbed Palaeozoic!*

Unfortunately, I have no palaeontological evidence for this conviction; I have not succeeded in finding clear evidence of fossils in the complex of limy strata, although at Camooweal at a depth of over 60 m in one cave the individual beds could be perused: I hope however, that with a more thorough examination primary fossils will be found, that will substantiate the opinion expressed here.

My Journey on the Tableland

The track from Cloncurry to Camooweal leads in its eastern half through the old mountainous area, in its western half over the Barkly Tableland. Cloncurry lies at about 200 m A.S.L., the track climbs to the watershed between the catchments of the Cloncurry and Leichhardt Rivers, which lies at about 400 m,[21] drops to the valley of the West Leichhardt below 300 m, rises again in the Wagga Boonya Range to over 400 m then with a few undulations drops to the valley of the Georgina at Camooweal, at an altitude of about 230 m. The eastern part of the mountainous country, particularly in the area of the Cameron River and Argylla Creek, is a wild, desert and geologically very complicated area, whose highest peaks do not rise above 700 m a.s.l.; crystalline schists, marble, quartzites alternate in colourful confusion with stocks of plutonic rocks.[22] The mountainous area was reduced to a peneplain and is at least partly covered with Desert Sandstone, but was however apparently uplifted again in the Late Tertiary and ripely dissected by valleys; the valleys of not only the main streams, but also of their tributaries, are exceptionally wide, although the actual river- and creek-beds are for the most part dry: but the rare mighty downpours, which often make the post-road quite impassable for weeks in the rainy season, cause mighty powerfully rivers to arise, and which clear weathered debris almost completely and transport it into the broad valleys with little gradient. The population is extremely sparse because of inhospitability and lack of water. Miners seeking gold and mainly copper scratch, and in recent years hunters as well, who are after the very numerous large mountain kangaroos (Wallaroo).

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[21] Interesting cross-sections of the relief on the Cloncurry – Camooweal – Burketown run are contained in Report by Mr. George Phillips, C.E. upon the advisability of constructing Railways, and ports connected therewith, in the Gulf of Carpentaria. Brisbane 1909.

[22] Lionel C. Ball, Cloncurry Copper Mining District. Part 1 & 2. *Queensland Geological Survey Publ.* No. 215. Brisbane 1908. is the best geological monograph on the greater area of Cloncurry.

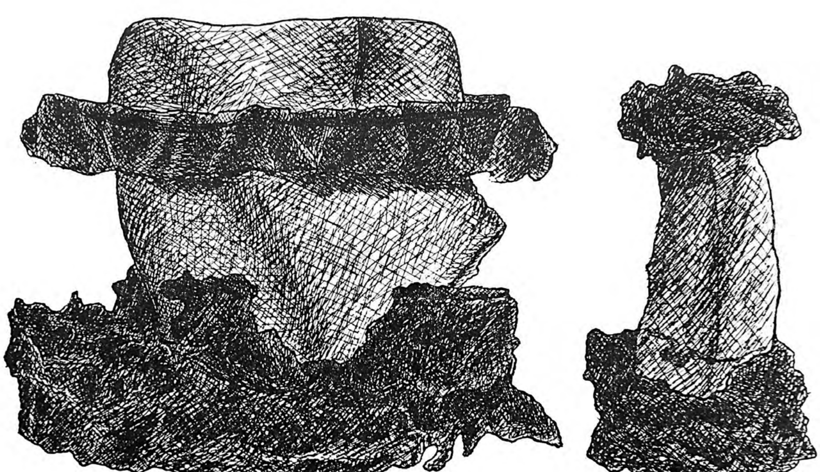
The natives, apart from a few who serve the whites, have died out; mostly they have fallen victims of formal hunts, which were carried out on them in the eighties. Beyond the West Leichhardt River the track leads almost north-north-west, winding through broad waterless valleys and between low and jagged quartzite ridges. The divide between the tributaries of the Leichhardt River and the Georgina is crossed either in Kennedy's Gap or in a pass on the Wagga-Boonya Ridge. The dividing ridge only rises insignificantly above its surroundings, particularly to the west the drop is very slow. The ground is mostly covered with loose, angular quartz debris and coarse sand, which bears an impoverished gidya [*sic* – presumably gidgee] scrub and Triodia grass [spinifex]. Only at some distance from the divide do small strips of open downs country begin to appear, which have a rich, dark soil that is covered with very luxuriant and juicy grass. These strips of good pasture have attracted a settler, a selector, who has established himself in the Gundaria Quadrangle on Johnsons Creek; an almost complete paucity of water threatens his enterprise greatly, as the waterholes in the bed of the creek are mostly not permanent and a well, dug almost 100 feet deep, passed through sand and gravel into the quartzite, without reaching a continuous supply of groundwater. Near the earlier Post and Telegraph station Yelvertoft, now burnt down, the grassy areas become broader, but the limestone cannot be seen cropping out anywhere; then the track climbs again, covering mostly real gibber plains of angular debris of jasper, chalcedony, agate and other varieties of quartz, miserable wattle scrub and tussocks of Triodia grass, and are especially remarkable for the numerous termite mounds, up to 3 m high. On the black soil there are no obvious termite mounds.

The gibber plains are the last denudational remains of the Desert Sandstone Beds, which covered the Tableland. About 50 km east of Camooweal in the catchment of Wooroona Creek the track approaches within ½ km of the low remains of the Desert Sandstone plateau, which rises, with steep slopes, 30 – 40 m above its base, and apparently becomes higher and broader to the east.

Wooroona or Warona Creek is cut into limestone south of the track, on the left side of its bed there is even a doline, about 4 m deep and 10 m in diameter, its base covered with alluvium. The bed of the creek is cut into horizontal, thin plates of a white, ringing, hard, quartz-like limestone, set through with vertical cracks crossing each other at right angles, which border the deeper parts of the creek bed so sharply that it resembles a water-container chiselled into the limestone. From here on there is an initially steep gradient, then from Nowranie Creek on it is almost flat to Camooweal. Here to the gibber plains with scrub predominate over the open downs country. The bed of Nowranie Creek, where it is crossed by the track, contains an enduring, large, deep pond (waterhole), the water of which apparently cannot seep into the complex of limy beds below. On a broad plain, deforested far and wide, lies Camooweal, a town of about 20 houses, and important shopping and recreation centre for a gigantic district, whose area is almost as large as Germany and has at the most 500 white inhabitants. Towards Camooweal converge not only the cattle stations on the Barkly Tableland in Queensland, but also a much larger area in the Northern Territory. The transports to and from the stations go via Camooweal to Burketown or to Cloncurry, in the local inns the solitary, well-paid drivers, drovers and shepherds are now and then relieved of large sums.

Camooweal lies only about ½ km from the broad, shallow bed of the Georgina River, which to the west of the town flows from NNW to SSE, and forms a shallow lake, Lake Frances, where it is nearest to the town. This is only a perennial pond, through the bottom of which water does not sink to the depths. About 4 km NNW of Camooweal, close to Rocklands Station, there is a much larger perennial waterbody in the bed of the Georgina, this is Landsborough's Lake Mary, he who also named Lake Frances. Usually the river bed is dry outside and between these waterholes, only in the rainy season (December – April) does the river bed become a mighty stream, which in places broadens to a lake. Part of the water flows away at the surface, but much more just evaporates and a large proportion disappears in stream sinks which lead to branching cave passages and finally to the base level of the groundwater in the karst area. In the dry bed of the Georgina River at Camooweal and Rocklands the horizontal limestone beds are exposed as steps, which in places show rudimentary fine karren, the joints and gaps are mostly secondarily filled with cherty deposits, which were apparently at least in part originally clayey and limy, but have been infiltrated by silicic acid carried by the water which seeped through the Desert Sandstone beds. It is known that such cherty infiltration is common in Australia, very often on an unusually large scale. The origin of this free silicic acid is not yet clear. Just at the base of the tableland limestones there are sandstones turned to quartzite, which are widespread, and the Desert Sandstone beds contain enormously much secondarily silicified material as well, which as its last remains forms the "gibber plains".

These cherty deposits are naturally more resistant than the limestone beds, particularly as here, on the quietly flowing Georgina, chemical erosion is more effective than mechanical; because of this miniature ledges and lumps of various kinds are produced, when the primary limestone has already lost a great deal of volume. In some places strange forms are created by this unequal corrosion, of which I have brought two fine samples from Rocklands Station to Prague. These have been examined by Dr Radim Kettner, who has kindly put the results of his examination at my disposal. These are given word for word in the footnote. [23] See illustration also.



Corrosion relics from Rocklands Station. The primary mass of limestone is pale, the cherty deposits are dark. ⅓ natural size.

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[23] The cherts, examined on the basis of two specimens, form lensoidal or irregularly-bounded intercalations, apparently completely concordant; they are of a light bluish or yellowish colour with conchoidal fracture. Under the microscope they appear quite dense, structureless, in places clear and translucent, elsewhere rendered yellowish and opaque by accumulated submicroscopic particles of a chloritic and limonitic substance. Under crossed nicols the chert is a dense mix of tiny quartz grainlets, which are either angularly intergrown and mostly show undulose extinction, or are interwoven with an amorphous, isotropic opaline substance. Often small sphaerocrystals of fibrous chalcedony can be seen. In this dense cherty groundmass dolomite grainlets may be embedded, in places rarely, in others in masses, which stand out strongly from the groundmass because of their strong polarisation colours. Even in normal light and with strong magnification and lowered condenser they can be observed easily. As a rule they are bounded by completely developed rhombohedral faces and almost never twinned. – Traces of organic remains could not be recognised in any of the thin sections. A thin section prepared from a siliceous dreikanter shows quite similar relationships compared to the sample of cherty intercalation described above, only the dolomite spar is more rarely developed in the cherty groundmass. Thus it can be easily maintained that the angular pebbles spread over the surface are derived from similar cherty layers in the limestone beds. As far as the *origin* of the cherts which interest us is concerned, I am of the opinion, that they have originated from *dolomitic limestones* by a gradual metasomatic replacement of the $CaCO_3$ by silica. This is evidenced by the presence of dolomite crystallites in the siliceous groundmass of the cherts. Seeping vadose waters bringing colloidal silica dissolved from above, dissolved and removed the more soluble $CaCO_3$ of the originally dolomitic limestones and replaced it with silica; the less soluble $MgCO_3$ did not enter solution and thus remained in the rock. The limestones were shown to be dolomite-bearing by microscopic examination as well as testing one of the thin sections prepared from the cherty limestone with dilute hydrochloric acid. The aspect of the thin section appears to be the same as described by e.g. J.H.L. Vogt from Norwegian dolomitic limestones* or Fran Tučan from those of the Croatian karst area.** Whereas the dolomite grains, when closely crowded, show the characteristicsaccharoidal structure and appear as polygonal, straight- or curved-sided individuals, the calcite can be recognised by its zigzag outlines and frequent twinning. Another explanation of the origin of the cherts under consideration does not appear plausible to me. Contrary to the assumption of an organic origin for the chert intercalations, which their concordant relation to the limestone beds might support, there is the absolute absence of any organic remains in the cherty material. One can hardly accept the opinion that the chert filled pre-existing voids in the limestone, because of the complete absence of structure in the chert. If this last opinion were correct, the chert deposits should show the concentric structure of agate formation. The chert nodules (a hand-specimen from Glissan Caves) from the lower Cretaceous limestones are composed of a mix of grains of quartz, chalcedony and opal, and also contain numerous remains of foraminifera, the shells of which consist of lime. The following genera of foraminifera could be determined: *Operculina, Globigerina, Nodosaria, Haplophragmium, Cristellaria* and *Textularia*. I do not venture to decide the source of the siliceous material forming the nodules, am however of the opinion that is probably not of organic origin, since foraminifera, as is well known, deposit limy shells.

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*) *Norsk marmor, Norges Geologiske Undersögelse,* Kristiania 1897.

**) Die Kalksteine und Dolomite des kroatischen Karstgebietes, *Annales géologiques de la Péninsule balkanique*, vol. VI, Part 2, Belgrade 1911.

Keys In the neighbourhood of Camooweal as well, the plains covered by siliceous gravel take up a much greater area than those on which the limestone is only covered by its own eluvial clay.

The surface is only very rarely exposed, and where one really sees the bare banks in a total thickness of several metres, as already said, the joints and furrows are mostly infilled. The surface of the limestones can thus not function as a sieve, the gaps which might lead the seepage water to depth, are surely mostly blocked. Were this not so, Lake Frances and Lake Mary could not be maintained as perennial waterbodies. It is also quite possible that their lakebed is made up of the siliceous, thinly bedded limestones which are almost impervious to water.

With the exception of the rudimentary karren which can be seen on the exposed limestone banks, there are no other karst phenomena far and wide, and one could travel extensively back and forth without any impression of the karstic nature of the tableland limetones. The cause is naturally only that the tableland was previously covered by Desert Sandstone, that the limestone surface is only occasionally truly exposed, and that the free action of seeping water is hindered by secondary deposits.

Groups of dolines, chimneys and collapse shafts occur only widely separated from one another, mostly they lie near the river bed, and great masses of water disappear through them during high water. With the co-operation of the Camooweal citizens and especially of the Manager of Rocklands, Mr H.A. Glissan, it was made possible for me to get to know all cave groups in the nearer vicinity.

In so far as the Tableland can still be regarded as virtually a terra incognita, so also is knowledge of caves in the vicinity of Camooweal not widespread. In his diary Landsborough mentions only a single locality about 5 km north of Lake Mary, near to Hervey's Creek, "a strange deep rocky pit". Apparently from Landsborough's indications this shaft was taken into the official "Queensland Four-Mile Map" (Sheet 16 D) as "cavern". In his Geographic History of Queensland (issued in the year 1895) A. Meston has the following note (p. 161) on the caves on the Tableland: "Far north-west, in the Camooweal district, on the Georgina River, are peculiar underground limestone caves representing irregular chasms over 100 feet in depth, the walls formed by large limestone boulders, and the floor covered by limestone slabs resembling tombstones. There are side passages, and small caves, some adorned by beautiful stalactites covering the roof." A further remark probably relates to the caves in general "Bones of animals and aboriginals, and heaps of drift, are found on the floors of these remarkable subterranean caverns", for the inhabitants of Camooweal could tell me of such sensational discoveries. The only comprehensive description, of the so-called Nowranie Caves, was given by T.P. Keys,[24] and which was printed only in brief excerpts. Mr Keys was occupied as a teacher in Camooweal for several years, and is still famous as having the best knowledge of the caves and as an exceptionally good climber.

From Rocklands Station I first saw the group of caves on Little Harvey's Creek, which lie near its confluence with the Georgina. It consists of a large shallow asymmetrical doline which is deepest on the north-eastern side and opens beneath a steep wall in a stream sink about 8 m below the upper margin. In the wet season part of the water of the Georgina and Harvey Creek flow to depth through this doline, in the dry season it was quite dry, and it was possible to enter the cave passage which is illuminated from above by an open chimney about 25 m from the entrance. According to Mr Glissan's description the passage was almost horizontal, almost completely lacking in cave deposits, a partly blocked secondary passage led to the collapsed cave entrance somewhat further south. This year the water remained in the doline, although the river beds has been dry for a long while; the stream sink was quite firmly blocked by material washed in and perhaps also through collapse of part of the roof, so that the water could not flow away. In this way Rocklands Station was enriched by a fine "waterhole", most welcome to the management, as on the upper Georgina there are only three waterholes (Grassmere waterhole, Keribobla waterhole and Redford waterhole,[25] which however exceptionally, during long-lasting quite rainless dry seasons, also dry up.

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[24] Description of some caves near Camooweal. (Read before the Royal Society of Queensland, August 19, 1899. *Proceedings of the Royal Society of Queensland.* Vol. XV. 1900. Pp. 87 – 88.

[25] On the map in STIELER's *Handatlas* Redford and Grassmere are denoted as small settlements. Presumably the abbreviation W.H. caused an error. On German maps W.H. indicates an inn [Wirtshaus], but in Australia merely a pond, sometimes with bad and stinking water.

The eastern rocky margin of this doline runs almost N – S, and about 25 m further east the chimney and the collapsed cave lie in the same direction. The debris does not permit access to the cave passage. The freshly broken off beds of the former cave roof are mostly quite thin and siliceous, only deeper in the cave are there thicker beds. The siliceous beds here and there also contain chert nodules and the joints are partly filled by cherty, hard intermediate layers. I gave the name H.A. Glissan's Group to these caves, to acknowledge the great merit that gentleman earned for the exploration of the hydrographic relationships of the area during the quarter-century of his sojourn on the Tableland, and for their economic opening.

Approximately 2 km further north-west lies another doline, arisen by collapse. On the north side it is enclosed by a steep wall about 13 m high, on the other sides the ground rises step-like, below the wall lies the rather blocked stream sink opening, to judge by quite fresh traces the water stood at about 2.5 m below the upper edge. On the return journey we saw about a further 1½ km NW of Lake Mary a doline with oval outline, originating by collapse, whose longer axis runs WNW – ESE and is about 14 m long, 10 m wide and 10 m deep.

The next day we saw the caves on Emu Creek, about 15 km north of Redlands. Here, in flat-lying exposed limestone beds are a few rudimentary dolines, then further east a large basin-doline about 5 m deep, with a small stream sink at its deepest point, and close by a large half-uncovered cave, which occupies a space about 50 m long N – S, and 30 m wide; only less than half of it remains as a cave, while the roof has collapsed over the remainder. Two small chimney openings lead vertically through the about 5 m thick roof into the cave. The debris of the collapsed roof lies in chaos on the floor of the free space, it is still only slightly affected by corrosion, so the collapse can be considered relatively recent, the step-like slopes and the bared surfaces of beds in the vicinity are weakly karstified. The roof of the cave is completely without cave deposits, its floor is covered with dry dusty loam, the stream sink is covered by debris. On the western side of the covered section, part of the roof remaining, 3 beds thick, is broken off at a thickness of over 1 m and forms a continuous terrace rising above the cave floor. About 50 paces east of the basin-doline is another of oval outline, with steep, rocky edges, and still partly filled by water. The depth of the uncovered slopes is 3 m, the depth of the water still more than 1 m. This is the collapse doline, much filled by material which has been washed in.

About 8 km north-west of this group is another so-called Hassel's caves on Elizabeth Creek, which are very deep and accommodate a large number of bats.

In a southerly direction from Lake Frances the Georgina forms another "lake", Lake Canellan, which dries up in very dry years. About 1 km west of this pond lies a collapse doline in the process of formation. A slightly elliptical almost round space about 30 m in diameter is filled by a confusion of broken, thick beds, broken into large and small plates, which sink concentrically towards the centre; here however there remains a stable bridge, beneath which there is a narrow, partly collapsed but still 5 m long cave entrance leads, from which several very low horizontal passages branch, and are almost completely filled with loam. A few 3 – 5 cm long stalactites hang from the roof of this passage. Some rocks at depth show the effect of sand carried in eddies well. Fifty metres in an easterly direction from this big collapse doline lies a small, shallow basin-like round doline, whose floor lies only about 30 cm below its margin. Small, shallow karren are eaten into the surfaces of the beds, even the corners of the disturbed, lying debris have been attacked. During high water an arm of the Georgina River disappears through this cave.

The western bank of the bed of the Georgina and that of the lakes in it as well is less steep and high than the eastern bank, this same phenomenon is apparent on other N – S flowing waters on the Tableland.

About 2 km north-east of Camooweal in the immediate vicinity of the track now used by the Cloncurry coach there lies a group of depressions. North of the track there is an irregular doline with branching margins, which harbours a waterhole; its diameter reaches about 30 m, the depth 5 m, it is filled with soil and other material washed in. South of the track there is an even more irregular depression, actually a group of stream sinks with a common outer margin. The depression has partly arisen by sinking of the thick plates, which are partly covered by hard, silicified, red secondary deposits. Water flows into one of these stream sink openings, now partly filled with mud, into another a sharp cutting leads from the southern side. The cuttings are mostly joints, broadened by the swirling motion of the water, one can clearly see how the water partly disappears sideways beneath the beds, but how, after heavy rain, the greater part of the water reaches the stream sinks and has great evorsive power, as it takes quartz gravel and sand from the surroundings with it. About 400 metres to the SW lies another depression, whose centre is taken up by a gorge with vertical walls, which arose by collapse of the roof over a cave which formed a regular parallelogram. The eastern and western sides are about 30 m long, the others about 10 m; one can climb in through deep water-made cuttings from the northern side, the depth from the base to the margin of the depression measures about 25 m. In the southernmost part of the space a section of the roof remains preserved; on the floor lie the remains of the roof with broken, short stalactites, partly covered by damp, dark red mud. The deepest part lies in the south-western corner, where there is a blocked stream sink. A sharp water cutting also leads into the space from the southern side.

About 6 km east of Camooweal lies another group of stream sinks, which are almost regularly four-cornered depressions with somewhat abraded margins, lying two together. The floors are covered with sandy clay. Two are larger, with about 5 m length of their sides and 2 – 3 m deep, two smaller, about 1½ m wide and 1 m deep. In a northerly direction from these sinks near the telegraph line there is a doline originating through collapse, which is connected with a still-covered cave on the western side. The diameter of the pentagonal doline measures over 20 m, the depth about 15 m, the entrance to the cave is 13 m wide. The roof is penetrated by two round chimney openings, in the south-western corner there is a stream sink, blocked with mud. The eastern part of the cave has gentle slopes to about 6 m depth, but in the lower half they are almost vertical; there was apparently a funnel-doline, which then was deepened by collapse of the roof. Karstification only weak, no speleothems.

The Nowranie Caves,[26] which the "servile" portion of the local population refers to as the "Lamington Caves" (after the Governor, Lord Lamington, who visited the caves) lie about 20 km south-east of Camooweal, near the shallow bed of Nowranie Creek, some of whose waters flow into the cave at high water. A spacious natural shaft occurs in the middle of an oval room which descends in step-like fashion, with a narrow base on the ENE side, with two walls about 40 m long, which intersect at an acute angle in the SW. The depth below the short base wall is about 40 m, here a high cave-gate opens, to the SW rises a big debris pile, so that in the sharp corner the depth of the floor is less than 20 m and divided by a great rock jammed in it. From the two corners of the base wall two sharp cuttings lead into the shaft, through which floodwaters in part reach depth. P.T. Keys describes three storeys in this cave; we were only in a position to visit two of them, in the third, deepest, there was still water remaining. Two kinds of cave entrance can be differentiated, the high and broad passages which run in sharply determined directions, and then the adjacent caves and low lateral passages, which in the upper storey only are more widespread. The upper storey communicates with the lower through a broad hole, hollowed out in the hard, siliceous, ca. 1½ m thick layer between by the swirling motion of water. At the end of the accessible passage of the upper storey beneath the debris there are other holes, now inaccessible. A narrower, chimney-like hole leads from the lower storey to the water level, which lies more than 73 m below the surface. The upper storey lies more than 40 m, the lower about 55 m below the edge of the natural shaft. Different directions become apparent in the course of the main passages, mostly WSW – ENE dominates, then come WNW – ESE, SSW – NNE and SSE – NNW. The length of the main passages of the upper storey that we walked measures about 160 m, those of the lower storey about 60 m. The floor is formed of flat bedding planes, is covered in places with fallen debris from the roof, introduced clay and gravel fill the joints between the flat, tombstone-like plates. As already indicated, the floor of the upper and also the lower storey are formed of these thin, cherty limestone beds, which have been eroded through mechanically at distant points. Secondary lime deposits are extremely sparse, stalactites are rare and short, stalagmites only rudimentary and even rarer, only below some narrow chimney pipes are there thick travertine columns and shallow terraced overflows on the floor. The air is very cool and at a few places in the upper main passage there is an eddying, strong draft of wind, which is apparently caused by openings in the roof; the poor lighting with torches did not permit a closer examination of the upper parts of the high passages.

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[26] It is the great natural shaft and the cave leading from it that T.P. Keys described in the Queensland Royal Society Proceedings.

About 100 m WSW of the natural shaft there is an oval depression, in the middle of which a chimney of about 3 m diameter is situated. The chimney is at least 50 m deep, but appears not to communicate with the other caves at present, since burning bundles of straw we threw down were suddenly extinguished at a certain depth.

I have asked about other caves in the more distant surroundings and obtained information about only three; one, which is shown as Jopp's Cave on the map, about 30 km south of Camooweal on the Georgina River, and takes up part of the high water; about 20 km west of the Georgina Happy Creek flows almost parallel with it, and is formed from its tributaries Kiama, Bustard Creek and Cattle Creek. On Bustard Creek there is also a cave and an arm of Happy Creek disappears into another about 10 km further south.

In the territory of Avon Downs Station (the only sheep-raising station in the Northern Territory) there are no known caves.

If all these cave groups enumerated here are marked on the map even approximately correctly, they are aligned quite obviously in three approximately N – S zones; the eastern one with Nowranie Caves and the stream sink group and the doline on the Telegraph line east of Camooweal, the middle one along the course of the Georgina and the third, western one, on Happy Creek. It appears that in these zones there are lines of weakness affected by faulting, perhaps the asymmetry of the river beds, already discussed also has a tectonic cause.

From Camooweal towards the north-east the track leads mostly over gibber plains with large quartzite and chert blocks, numerous gravels of jasper and agate, often with typical dreikanter or multi-sided forms; the limestone beds rarely rise above the surface in more or less karstified form. The scrub is rare, but the rich areas of grass are reduced in relation to the sparsely grassed gravel surfaces. About 13 km from Camooweal one passes Bullring Waterhole on Chester Creek, a tributary of the Georgina. The water reserves do not suffice in dry years, and so a subartesian borehole not far to the east must help out, to water the cattle. Even further to the NE the track crosses another creek, now of course dry, which purportedly ends in a waterhole, probably a doline.

On the banks of the dry bed of the O'Shanassy River the thin-bedded, cherty limestones are exposed, and only let very little water through to depth and show no inclination to karstification. About 6 km further there is a zone in which very slightly karstified limestone forms the surface, the karren are common, but mostly not deep, and a large number of rudimentary dolines is present. Towards Old Morstone these beds are covered over rather large areas by a quite thin layer of conglomerate, which includes gravel and angular fragments as well as sand, cemented by calcareous sinter. These are doubtless secondary deposits, such as are known elsewhere in tropical, subarid climates. [27] Further east the matrix of the conglomerates becomes more siliceous.

Morstone sheep station is situated on the O'Shanassy River, whose bed is marked by abundant gallery-forest. Only in recent years has the river dried out complexly, it supposedly always had water before; water is obtained mostly from the waterholes and from shallow and not very productive wells. Deep bores have not yielded good results, although water was reached at several levels, but never in sufficient quantity to justify pumping it out.

Conditions on the adjacent Beaumont Station are similar. The limestone high country continues without break along the track to the Thornton River, but on the right bank of the broad, currently dry river bed, sharp quartzite ridges alternate with limestone rocks, and on the Seymour River one is among the strongly folded metamorphosed schists of the old mountain country, through which towards the north follows the valley of Police Creek. The mountain country is very much desert and waterless, but still strongly coursed by valleys, the relative height of the highest points is small. The area has no owner, belongs to no station, and the only large waterhole – Lilly – on Police Creek serves only the post horses and the camping area for transports between Camooweal and Burketown.

The valley of Police Creek becomes ever broader, the last spurs of the old mountain are held back and a flat, unforested area with sparse grass continues as far as the green strip of the gallery-forest accompanying the bed of the Gregory River. The Gregory River is perennial and flows between banks 15 – 20 m high, has a broad high-water bed and several "anabranches" and "billabongs", but for most

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[27] Branner J.C., Aggraded limestone plains of the interior of Bahia and the climatic changes suggested by them. *Bulletin of the Geological Society of America,* vol. 22, pp 187 – 206. 1911.

of the year only forms a 10 – 15 m wide, quite deep, clear stream. The whole inundation area is wooded with semitropical scrub, the actual river bed is often accompanied by an impenetrable Pandanus thicket.

From the Gregory Downs Hotel I undertook a six-day excursion, which led me to the west into the Burketown mineral field, from where, in a south-easterly direction, I reached Riversleigh Station via the Lillydale ford on the Gregory River, and then in an easterly direction to Lilly waterhole to arrive at a familiar track back to Gregory Downs Hotel. This area has been dealt with in some detail in the oft-quoted report of W.E. Cameron and the monograph of L.C. Ball, and in travelling through briefly I could not gain more than a general impression. From Gregory Downs westward one travels first through a gently undulation landscape, dominated by the Desert Sandstone. Only about 40 – 50 km further one travels between short, low ridges, mostly formed of old metamorphosed schists, limestones and quartzites. The limestones are different from the Tableland limestones, are almost marble-like and decidedly much older. A little-disturbed, locally very hard quartzitic sandstone appears to overlie this old succession, and in places where the tableland limestone succession is preserved, forms its immediate bedrock. This can be seen in different places further south near Riversleigh and on the Thornton River, and I believe that W.E. Cameron is correct in describing this sandstone succession as younger and tectonically less disturbed than the old complex of beds immediately underlying it. Here two different quartzites and two different limestones must be differentiated; the older ones belong to the old succession and form only zones or lenses within it, the younger ones lie discordantly on the old metamorphosed succession, the quartzite-sandstones domed and the limestones almost horizontal. These however are only present in compact [!] form in the west of the area forming the edge of the tableland, in the Burketown mineral field they are only preserved as “témoins” or witness-hills, among which the hill at Lawn Hill Station is best-known.

The tectonic evolution of the area is interpreted by me, much in agreement with L.C. Ball, as follows. The sandstone series was only formed, as the old Palaeozoic mountains were already deeply eroded, but underwent its last reverberating movements as well. Later however, after the Cretaceous transgression, which left the tableland limestone and at least partly the Desert Sandstone series behind, a new, shallow arching in the nature of a large fold arose, which was connected with another, much higher arching of the mountain country of Cloncurry. In the up-arched area the Cretaceous cover was removed, apart from small, perhaps somewhat sunken plates. The present border of the tableland also approximately marks the boundary of this anticlinal structure, there the Cretaceous beds remain almost undisturbed. At the same time as the up-arching of the large anticlinal structure or later, the area of the Gulf of Carpentaria sank, and the activity of the rivers flowing through it was rejuvenated. A later stage of the falling sea-level can also be determined, since the rivers are altogether deeply cut into the alluvial plain, and some of them must adjust to the jump in levels by a waterfall in their lower courses (e.g. Leichhardt River). This renewed erosional activity has enlivened the battle between the individual rivers. A broad valley runs through the Burketown mineral field from south to north, in which there are now low divides. The northern part is drained by Louie Creek, the southern by Little Creek, to the Gregory River. This old valley, whose southern part was named Daneš Valley by L.C. Ball, lies in the continuation of a similar dry valley, which separated Verdon Rock south of Verdon Creek from the tableland, and this again is only an extension of the O’Shanassy River valley. Apparently the changes of balance benefitted the Gregory River so that it could deepen its valley backwards faster, and turned the O’Shanassy to its tributary.

I have already mentioned how I found secondary fossils in the limestone at approximately the same places as W.E. Cameron and his informants. It remains to remark that the Gregory River below the Lillydale ford has deposited much travertine and lime-cemented conglomerate, which has diverted an arm of the river as Carl Creek. The bed of this, as is that of the main river, divided by travertine barriers into several deep reservoirs, between which the water flows as rapids or cataracts. The highest of the waterfalls lies about 4 km downstream of the ford, where the river, as two mighty streams and numerous small ones, forces a way through an almost impenetrable pandanus thicket, and from about a height of 5 m drops into a long, little moving channel. Above the ford there are also “rapids”, and near the main sources of the karst river also some reported by Landsborough. Thus, much travertine is deposited by the river, and even near Gregory Downs the gravels are rapidly cemented and tree-trunks encrusted.

Hydrographic Relationships of the Tableland

A large part of the Tableland is drained towards the outflow-free area of central Australia. The Georgina River with its tributaries belongs to the catchment of Lake Eyre, north-west of it there is a myriad of small watercourses, which supply the so-called polygonum swamps, broad, morphologically expressionless shallow basins, which are sometimes dry. The Georgina has a greater gradient and spreads its area at the cost of these periodic lakes. The entire enclosed area however is mightily attacked from the north-eastern side, the rivers hurrying to the Gulf of Carpentaria forever cut more into the edge of the Tableland, and move the watershed further inland. Almost all rivers, and in their headwaters all of them, only carry water periodically, and that only in the wet season, which often begins as early as December and often continues until April. The amount of rain falling in this area is rather irregular, it is subject to such gross variations as that further south-east, where periodically very devastating, long-lasting droughts occur, caused by an almost complete failure of the wet season. The Tableland does not suffer such devastating droughts, and this advantage of the climate is greatly valued by the cattle-breeders, and praised in all printed matter seeking the attention of settlers to this area.

The average annual rainfall in Camooweal is about 300 mm, to the south and south-west it is certainly less, to the north-west however, greater. On the Roper and Daly Rivers it measures on average almost 1000 mm. In the wet season the flat area often is several times turned into wide expanses of water by continuing rain; the rivers and creeks all overflow their banks and flood their surroundings far and wide. The higher gibber plains then form islands of different size and extent, on which the cattle and all the mammalian fauna seeks refuge. If however the flood comes suddenly, it is not uncommon for the sheep stations to suffer significant losses of the unprepared sheep herds by drowning.

The water flows quite slowly away in the shallow river beds, a large proportion is lost to evaporation and part of it enters the joints and particularly the sinks, and feeds the groundwater. Those rivers which flow the entire year are generously supplied by this groundwater. No stream flowing inland taps the groundwater, only those perennial rivers flowing to the Gulf of Carpentaria and the Timor Sea, which represent an anomaly for their climatic zone.

Landsborough has already noticed the great difference between the ever-flowing Gregory River, which arises suddenly from springs, and the O'Shanassy River, which, although it shows higher water levels, is otherwise often dry. A.C. Gregory correctly held the springs rising from the limestone area as the source of the continuous supply of water to the Victoria and Roper Rivers. W.E. Cameron correctly recognised that the great permeability of the limestone complex is the cause of this phenomenon, already knew the results from the subartesian bores, and drew the right conclusion that water can be reached at a particular level by boring everywhere on the limestone plateau.

Naturally, in economic circles, people were not satisfied that only subartesian water, which had to be pumped artificially to the surface at significant cost, was reached, and there were also experiments to see if it was possible to drill to a level, from which the water would reach the surface under its own pressure. In this way subartesian water was obtained in several boreholes in the area of Rocklands Station at a depth of 60 – 80 m, but two boreholes were sunk deeper (bore no. VI, 190 m, bore no. VII, 250 m), but naturally no water under artesian pressure was reached, since boring was carried out only in limestone. On Alexandra Downs station in the Northern Territory a borehole was in fact sunk to a depth of 1700 feet (more than 520 m), still in limestone, and that happened, although the groundwater level was reached at about 100 m. As the Great Artesian Basin of Australia lies under the superficially similar downs country of Queensland, it was reckoned with certainty that under the "downs country" of the Tableland artesian water would also be found. After several unsuccessful experiments to find an artesian source below the subartesian one, the results were finally accepted. Even the representatives of science accepted this fact, but could not find an explanation of it anywhere. It would have been very appropriate however, to explain to the cattlemen who didn't spare money or effort to obtain a reliable water supply, that in the porous and much-jointed limestones the extraordinary pressure regimes that cause the water to rise to the surface, are not to be reckoned with.

It has been determined in numerous bores that over the whole Tableland, insofar as it is made up of limestone (with the exception of the eastern part, where the impervious siliceous and dolomitic limestones dominate), water can be reached, but which only rises to a certain level, or can only be reached at this level by boring. According to the assumption of the most knowledgeable persons of the conditions, the results of all bores so far suggest a common level for the groundwater, which apparently drops slowly from south to north. A direct proof cannot yet be given, as our knowledge of the absolute and relative heights of the individual boreholes is only superficial, and cannot be obtained with the necessary approximate surety using available means.

Mr H.A. Glissan of Rocklands has made available to me the complete data on bores made on this cattle station, I have only been able to obtain general information on the depth of the underground water levels orally and from literature for the remaining region. At the time of my stay on Rocklands Station in 1910 there were already seventeen functional subartesian wells: No. I. 405 feet deep, water is pumped from a depth of 312 feet; No. II. 300 feet, pumped from 250 feet; No. III. 320 – 250 feet, No. IV. 300 – 200 feet, No. V. 320 – 270 feet, No VI. 610 – 280 feet, No. VII. 800 – 185 feet, No. VIII. 406 – 320 feet, No. IX. 380 – 280 feet, No. X. 300 – 260 feet, No. XI. 380 – 260 feet, No. XII. 300 – 260 feet, No. XIII. 380 – 260 feet, No. XIV. 380 – 260 feet, No. XV. 360 – 260 feet, No. XVI. 340 – 280 feet, No. XVII. 300 – 260 feet, No XVIII. Water level not yet reached.

Even if all these data cannot be exactly compared, and one has to be satisfied that they all point to a uniform groundwater level, two at least can be considered separately, namely bore No. VII, which is situated about 15 km south of Camooweal in the bed of the Georgina River and bore No. IV, which lies about 7 km further to the SE on Don Creek. In both of these bores the water is pumped from an exceptionally small depth. This fact surely indicates that the water level drops from south to north, which is supported by data from other stations further south.

On Morstone Station in the north-western corner near the O'Shanassy River two boreholes were sunk to a depth of about 300 feet with good result; further east and south-east however all attempts at finding artesian water failed; one borehole was sunk to 500 feet, but no water was reached. My informant (the manager in Morstone) told me that only limestone was penetrated; apparently there near the old mountains the more impervious quartz-rich beds predominate, of there is even a tectonic fault, which cut off the connection of this eastern part of the Tableland with the uniform groundwater level.

There are boreholes with subartesian water on Flora Downs station, Lake Nash station, Hervert Vale, Avon Downs, etc., mostly the water is pumped from 60 – 100 m. May I be permitted to quote here just one section from the "Report" of the explorer David Lindsay,[28] which refers

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[28] Land-Grant Railway across Central Australia. The North Territory of the State of South Australia as a field for Enterprise and Capital. S. so. (D. Lindsay, Report on "The Tableland" 25th July 1898.)
Large supplies of good fresh water have been obtained at varying depths up to 200 feet, and no doubt exists that water can be obtained any where [sic] by sinking. It is just possible that artesian water may be found. A trial bore on the Alexandria station, put down to a depth of 1664 feet, failed to strike artesian water, although at 238 feet water was met with, which rose 19 feet and yielded 24,000 gallons per day, the utmost capacity of the pump, without diminishing the flow. By means of windmills the water from wells can be very cheaply raised and pumped into tanks. During the dry season – the winter – strong winds blow regularly, ensuring the satisfactory working of these mills. Owing to the absorption of the immense bodies of water which find their way on the western portion of this tract of country, and the rock formation of the ranges near the telegraph line, artesian water should be found over a considerable are, but here the grasses are not nearly so good as on the eastern portion of the Tableland. Throughout the whole of this area all the surface water is fresh. Soil. – For the most part the soil is of a rich black or red loam mixed with clay. On the bluebush flats and part liable to inundation the soil is loose and very porous, and in the dry season full of cracks, through which immense quantities of water flow to the subterranean reservoirs and channels. This is specially noticeable on the western half of the Tableland.
Equally important is the evidence of Mr John Costello from Lake Nash station, before the Royal Commission, who wrote (*The Northern Territory of South Australia. Papers read before the Royal Geographical Society of Australasia, South Australian Branch.* Adelaide 1901, p. 11.): *"There is a large area of country from Newcastle Waters and the head of the Roper to the Queensland border at Camooweal. This magnificent belt of country known as the tableland may be said to be the cream of the pastoral land of the Territory. I have the fullest and greatest faith in the future of squatting in it. I have travelled over most sheep raising country in Queensland, and I can safely say that in no part of that Colony have I seen country better adapted for wool growing than this splendid table-land. A permanent supply of water can be obtained in this country at a depth varying from 150 to 250 feet. It would not require an expensive boring plant to put down a 7-inch tubed well that depth. At each such well, 6000 to 8000 head of cattle could be watered.*

to that part of the Tableland stretching between the Queensland border and the transcontinental telegraph line.

On Milne River station an inexhaustible supply of water was reached by boring at a depth of 40 m. In the opinion of the owner (in the year 1885) it was possible to reach water at the most 45 m deep over much of the surroundings. In Carrandotta and Hedingley somewhat further to the south fresh water was reached at different depths between 15 – 20 m and each bore had a boundless supply of water. *"I take it to be a general underflow of water all through this country and no local soakage"* says the informant Mr J.S. Little.[29]

Somewhat south of Carrandotta (22° S) is the southern end of the Tableland to be sought. This accords with the information given by W.O. Hodgkinson in his report on the nature of this region.

The western and south-western boundaries are still not known, since no drilling at any scale has been undertaken further west of Brunette Downs; as however shines out from the report of the cattle inspectors, it is much in the interest of the cattle-growers and particularly for the maintenance of the cattle droving tracks (stockroutes), for the government to take the initiative and begin drilling in the area east and west of the telegraph line.[30] In the northernportions of the Tableland however, artificially obtained water is no longer so necessary, since the catchments of the Daly and Roper Rivers receive a high annual precipitation and the number of perennial "waterholes" and natural springs is large. There remain only the lasting, unceasing springs that arise on the limestone terrain, and the perennial rivers continuously nourished by, it as natural proof of the inexhaustibility of the amount of water stored in the limestone complex.[31]

[28 [cont.]] *It would be a certain reserve store in case of drought. I think I might safely say that (with sufficient wells) the stations from Lake Nash to the head of the MacArthur would be equal to supporting 10,000,000 sheep."*

[29] The land-grant Railway across Central Australia etc. p. 72. (Extracts from three reports to the Government Resident by Mr J.S. Little.)

[30] *Government Resident's Report on the Northern Territory 1909*. Adelaide, 1910, p. 7.

[31] In this context A.H. Glissan expressed himself very clearly in his excellent letter to Mr George Phillips, which I give here in extensor (Report by Mr George

[31 [cont.]] Phillips C.E. upon the Advisability of constructing Railways etc. in the Gulf of Carpentaria. pp. 38 – 9.) *Following up my promise to you when here to commit some of my experiences on the question of the Gregory River and our sub-artesian water supply to paper, I will now do so. In a conversation I had with you, you gave me to understand that some of the residents on or about the Gregory River were of opinion that the flow of water down that magnificent stream had to some extent given out. I certainly cannot confirm this, as after twenty-three years living in this part, and seeing the Gregory on many occasions (where I have spent many pleasant days fishing), I cannot think for one moment that the normal supply of water has decreased. I fancy that the idea of the flow having decreased in this way (and no doubt rightly too) has its origin in the fact that the rainfall at the heads of the river in some years is very much heavier than in others, so that the surface drainage is greater and continues longer in some years than in others. Beyond all doubt the Gregory is fed from the enormous supplies of water stored under the surface, and contained in the limestone formation of the Barkly Tableland. I feel sure that if careful measurements were made of the supply of water passing a given point in the Gregory River, in dry or very dry years, that the supply would vary very little if any. Once the surface drainage is exhausted then the subterranean flow would, I feel sure, be very regular. I would here staet that I have had put down on Rocklands eighteen sub-artesian bore wells, which have been in use for over fifteen years, and in no single instance have I had to lengthen my pump casing to reach the water; all have stood at the same levels as when first struck. One pump, the working barrel of which is only 6 feet in the water, has been running with engine-power for weeks and months (double shifts), and has never exhausted the water or necessitated the lowering of the pump. I would here mention that I had one bore tested very severely with large engine and 4¼ inch pump, and the pump run at barely a safe speed, which gave the splendid result of 120,000 gallons in twenty-four hours, and never reduced the supply as far as we could tell. This will show you enormous supply of splendid water under the surface of the Barkly Tableland. You have seen a little of our rolling downs, and I will say that God gave us splendid country, superficially dry, but with an unlimited supply of the best water beneath our feet. I was sorry that your time would not permit of my showing you round. I mentioned to you the numbers of caverns and places where water gets beneath the surface. There are several places on the property where the river and other large creeks run into for weeks, some years, and the water is going away into the interior of the ground all the time, the cavern never standing full. At the Nowranie Caves we can go down with ropes for about 240 feet till you come to the standing water, which, so far, though known for years, has never been dry, having been visited on many occasions. I will here mention that there are no doubt, subterranean air passages extending for miles. In some bores the current of air is so strong, when the wind is in a certain direction, that it would blow your hat away if held over the hole. I have seen the*

Thus the water stored in the limestone complexes becomes an inexhaustible source of life in the entire gigantic region, by creating permanent rivers and springs on the one hand, on the other, providing boreholes with the necessary water for the extensive exploitation of the higher areas, which without this reachable underground water supply would be almost unsuitable for exploitation. It can be considered quite certain that only after many years will we learn to properly appreciate the economic importance of this underground water supply, until even in the Northern Territory people have outgrown the baby-shoes of attempts at settlement.

It cannot be doubted that here we are dealing with a uniform groundwater level in a very large and deep karst area. Naturally the rock is not so jointed, that water can be expected at the specified level at every place, but if one bores somewhat deeper one does obtain water, which then rises to an almost stable level. Such local differences can also be brought about by intercalations of impermeable beds or by secondary intercalations.

In the karst area of the north Australian tableland there lies a young, tectonically very little disturbed karst area. The morphological exploration of this has only just begun. With the exception of a portion of the eastern spurs of this area, the region around Camooweal on the Barkly Tableland, the description of which is attempted in this article, we have only a few older data from other areas lying far to the north, which report the karstified nature of individual landscapes or limestone complexes. References to these from J.E. Tenison Woods[32], A.C. Gregory[33] and H.Y.L. Brown[34] may be cited here. I am however convinced that dolines and

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31 [cont.] *Georgina River in very big flood, and 4 feet over the 8-inch bore-hole for ten days, and the hole could not be filled. I went to see how things were at the bore, in my boat; the swirl of water was over the hole all the time. This shows you the enormous intake of water there is, and that there is very little chance of the Gregory River ever failing.* It is very significant that the water level in the boreholes moves so little; because of the decided character of the wet and dry seasons one would expect something quite different. This circumstance is probably to some extent explained by the enormous areas over which the groundwater spreads. Locally the level of the water is probably raised strongly by the intensive inflow in the rainy season and the increased pressure would also raise the outflow rate of the karst rivers at their springs, but during the dry season the water level never sinks below a certain minimum.

32 J.E. Tenison Woods, *Report on the Geology and Mineralogy of the Territory*. The Northern Territory of South Australia. Adelaide 1888. *"Next in succession to the granite and the folded and contorted slate strata comes a small outlier of ancient crystalline limestone, which occupies a small area of a few hundred acres at the Eveleen mine. The strata are contorted and even bent and folded into rude circles. Besides presenting the usual appearance of limestone, of fantastic pinnacles etc., this formation has a most peculiar aspect from the nature of the rock."* Eveleen mine lies north of the tableland near the upper reaches of the Mary River. Tenison Woods compares this limestone with similar ones in Queensland, in the Malayan Peninsula, on Borneo, in China and in the Philippines; these are Devonian or lower Carboniferous. The limestone at Eveleen may perhaps be of the same age. – That refers to the series considered by Brown – Basedow to be Precambrian.

33 Journal of the North Australian Exploring Expedition under the commando of Augustus C. Gregory Esq. *The Journal of the Royal Geographical Society, Lond.* Vol XXVIII. 1858. p. 82. July 4, 1857. *"At 15° S near Dry Creek "limestone was frequent and rendered the surface very rough and frequent depressions of the surface appeared to result from the falling in of the roofs of caverns beneath, the existence of which was also indicated by deep clefts and holes in the rock, into which the surface water flow during the rains."* p. 83. July 10. *"limestone appeared, deep isolated hollows were frequent. In one of these hollows which was 30 yards in diameter and 19 ft. deep there was in the centre a chasm in the rock 15 ft. deep and 3 ft. wide extending to E and W."* p. 84. July 12. *"This sandstone rests on a hard cherty limestone similar to that of the Victoria. In this rock many depressions occur, apparently caused by the falling of the roofs of caverns, as there are usually deep fissures in the rock at the bottom of these hollows, into which the surface water runs during rain. In some places the sandstone resting on the limestone have sunk many feet below the general level, with areas varying from 1 – 10 acres, sometimes sloping towards a central point of depression 10 – 30 ft. below the plain, and in other cases they have abrupt rocky banks 3 to 8 feet high, and the bottom perfectly level. The level character of the country is unfavourable for investigations of this nature and the thickness of the strata not easily determined; but the collective thickness of the strata above the limestone may be assumed as less than 100 ft. The porous nature of the limestone precludes the existence of surface water by draining the whole of the upper part of the tableland, while it causes strong springs in the lower ground to the E., where the limestone is exposed on the banks of Elsey Creek and the Roper River."*

34 *Northern Territory of South Australia. North-Western District. Reports on the explorations made by the government geologist and staff during 1905.* p. 14. Limestone beds E of Mt Litchfield to the Katherine River (2 miles north of Noltenius Billabong and c. 9 miles from Daly River) *"beds of a compact blue-grey and yellow sub-crystalline limestone are horizontal ... The exposed surfaces have been eroded in*

stream sinks in particular will be found scattered in many other places. What is the cause of this weak development of karst phenomena on the surface? Probably the main reason for the fact is to be sought in that the whole area of these complexes was covered by the Desert Sandstone, and is still largely covered by it. The secondary infiltration of silicic acid in the limestone beds beneath, along the joints and bedding planes, has also made the uppermost beds of the limestone more resistant to chemical corrosion and greatly reduced the natural porosity of the rock, so that the corrosive activity of the surface water could only be developed at favourable sites. However, where the occasionally flowing water has succeeded in widening access to depth, it has also succeeded in creating a wide stream sink and cave passages as well, both chemically and mechanically, as far as the groundwater level. The high waters always carry very much gravel and sand and have great erosive power. To this chiefly erosive power of the swirling water is due that the hard impervious quartz-rich interbeds are broken through in places and so the development of the various storeys of the caverns could arise.

There we have before us an entire youthful karst, but a covered karst, whose surface development is dependent not only from chemically corroding forces, but to a great extent also from mechanical effects. There are only rarely karren and those only on longer-exposed limestone beds, there are rarely genuine solution dolines, instead there are mostly mechanically potholed stream sinks, and caves that are broken in or collapsed. The relationships are much complicated by the impervious interbeds.

Some remarks on the development of karst phenomena, on karst hydrography and on the geographic cycle in karst.

As already outlined in the first part of my karst studies in the tropics, a certain dissatisfaction with the results of karst study in the tectonically strongly disturbed mountains of Europe drove me to seek less-disturbed karst areas beyond Europe and in other climatic regimes. Whether I have been successful in this can be judged from the three parts in which my karst studies in the tropics are contained in extenso.

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[34] [cont.] *a remarkable manner by the atmosphere, and appear in the form of sharp, confluent, serrated ridges, grading downwards on all sides; the whole giving the effect of a model of mountain chains on a small scale.”*

I saw there many new forms and needed to change my opinions on the origin of others to a certain extent. It would be superfluous to go into detail and deal with the different karst researchers and spelaeologists whose opinions I either share or must counter.

In Goenoeng Sewoe and in the karst plateau of the Barkly Tableland I was particularly surprised by the multitude of forms due to collapse. The true corrosion forms of the surface, real dolines, are here in the background. Whereas, for example in the Dinaric karst, one can reckon with such a great preponderance of true corrosion forms, that e.g. B. Cvijić and Grund considered forms derived by collapse to be exceptions and devoted little attention to them, one can consider these collapse forms to be typical of the areas visited by me. It can certainly be suggested that “cockpit country” or “Goenoeng Sewoe” might represent a very advanced style of karst, that thus perhaps the numerous collapse forms are characteristic of the old stages of the geographic cycle in karst. Contrary to this I can suggest that in a karst area as young as the northern Australian tableland, these forms dominate completely; that, however, I have not encountered a greater number of typical collapse structures in a region very similar to a typical “cockpit country” north of the lower Narenta and in other approximately similarly developed areas of the Dinaric karst. I am obliged to think of other causes of such a frequent occurrence of collapse structures. As emerges from the descriptions of other very little disturbed karst region, collapse structures are also widespread there, as e.g. in Florida, in Yucatan, in the South Australian karst area of Eucla; the corrosion dolines so common in Europe are scarcely mentioned. I am strongly inclined to suppose that the tectonic element plays a big role. It can indeed be supposed that the limestones that show relatively more collapse forms have a much lesser degree of solidity than the others that do not collapse so easily. Three elements are of importance here: 1. the origin of the limestones could be very different, 2. their geological age ditto, or 3. the influences by which the rock becomes firmer and tougher. The first element can be excluded, since we must suppose a process in the ocean which is overall similar for the great masses of limestone, but different in detail; the second cannot weigh very heavily, since Cretaceous and older Tertiary limestones are found among the less solid ones as well as among the solid ones, that show little collapse; but really, the third element can be decisive for the most part. It cannot be denied that the strong mountain pressure developed particularly during the folding, mountain-building processes, must increase the toughness of the rocks exposed to it enormously. The mass of these must become denser and heavier under the pressure, many local differences in solidity become equalised, in short, that rock once exposed to folding is better able to resist the influences of gravity. It would certainly be very interesting to verify this assumption empirically in the laboratory, but the number of quoted examples alone seems to be convincing enough.

This difference between the folded and the tectonically little disturbed limestones also finds a strong expression in the detail of the morphological forms. There is however another difference, namely the arrangement of the karst phenomena is much more natural, freer in the flat-lying, unfolded limestones, as there are fewer tectonically pre-disposed lines and zones. The influence of tectonic conditions on the development of the karst phenomenon in folded mountains is great; it can of course not change the basic provisos of karst phenomena and karst hydrography, but the frequency, the arrangement, larger or smaller karst phenomena in certain tectonically pre-disposed zones or along certain lines, are quite important and interesting problems which greatly complicate questions about the nature, the distribution and the causes of the individual phenomena. The chaos brought about by erosion is, in tectonically very disturbed areas, seldom so irregular as in the flat-lying limestones, one can easily find out more and less favoured zones, areas and lines on a map; this cannot be said for a karst landscape such as typically occurs on Jamaica or in Goenoeng Sewoe.

In reference to those forces working on karst I must accentuate that the mechanical erosion of permanent watercourses and its washing away play a greater role in the formation of karst phenomena than is usually accepted. Not only the cave rivers, but also the seepage waters that penetrate the joints and widen them to pipes and chimneys bring much gravel and sand with them, thus calling forth strong eversion activity with the swirling action of the water. Young cave passages and chimneys that are scarcely changed by secondary deposits show extremely common and obvious forms that are only explicable by eversion. Mechanical action then aids the chemical, particularly where there are either primary or secondary impervious layers. Less porous or impervious layers are probably more common than so far accepted, and with the different complications of the karst cycle and the karst hydrography can be explained.

I am inclined to ascribe an important role to the impact of the strongly flowing water even in the case of karren formation; arid or subarid climatic zones and also the surf zone at the seacoast really appear to be the most advantageous for true karren forms; almost complete lack of vegetation, rapid washing away of decomposition products, unhindered impact of large masses of water are probably the most important conditions for development of true karren. Concentrated mechanical power of draining water has created the larger karren-holes, karren-springs and chimneys, chemical erosion in the case of such formations can perhaps only be regarded as the second most important factor, which competes for the position with density and the collapses.

With the true, corrosive dolines the chemical activity of the water is probably expressed most purely; it occurs most frequently where no short watercourses, not even very short ones, can form, where no gravel and little sand is present and mechanical erosion has to remain at a minimum. The share of mechanical erosion on the morphological shaping of a karst area is very important, for the rate of progress of the geographic cycle in karst depends to a great extent on the participation of mechanically functioning forces. The more water carrying gravel and sand is involved in the destruction of limestone areas, the faster the tempo of the course of the geographic cycle. Where the karst reaches as far as the watershed, where it receives no water from an area of impervious rock, is where the true corrosion forms reign; the more water laden with gravel and sand enters the karst, the more vigorous the work of destruction. Connected cave passages occur in just these areas in large numbers and great length, where rivers from impervious rock areas enter the karst. That is also where the rate of development of the caves is fastest, the level is lowered rapidly and cave systems with several storeys occur.

According to A. Grund and A. Penck the true polyas are senkungsfelder, which are only considered karst phenomena because of their peculiar hydrographic relationships. I advanced justified objections to this narrow concept of polyas ten years ago,[35] which have been recog-

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[35] *Ein Beitrag zur Kenntnis des Karstphänomens. Földrajzi Közlemenyek.* Vol XXXIV Part VIII.

nised at least in part by A. Grund[36]; since I saw Jamaica I can protest such a narrow definition of polyas with even greater justification. Particularly in Jamaica development of polyas can be observed instructively in several cases in which a purely tectonic cause is completely excluded. In the lower Narenta region I have already ascribed a large and important share of the development of polyas to mechanical erosion, and can only confirm this interpretation after my experiences in Jamaica. In the Narenta area we are dealing with, first of all, mostly a removal of impervious strata from the polya area itself, in Jamaica with the share of the rivers charged with gravel and sand, coming from the impervious terrain in forming the polyas. Where greater involvement of mechanical erosion is excluded, polyas are absent. I can however, try as I might, see no justifiable difference between the polyas of the Dinaric region and those of Jamaica, they are troughs very similar to one another, which cannot be differentiated with reference to their horizontal or vertical dimensions, nor do they show other characteristics which might justify such a separation. The exposed or open basins, drained at the surface, which earlier were karst polyas, are no longer true polyas, since they lack an important feature, namely internal hydrographic unity, but can be considered, just like the canyons in karst, as a late stage in the development of caves. And mostly it is canyons which have originated by the continued collapse of the cave roofs above the originally underground watercourses, which have broken through the formerly closed edge of such an exposed polya.

Concerning karst hydrography, I have found my opinions developed in the year 1905 to be correct, and have had opportunity to test them in many cases. At that time I considered the various forms of subterranean hydrography in karst as stages of a geographical cycle, and still do so today. In young karst areas the reigning hydrographic element is groundwater, only later do subterranean rivers develop. The larger and deeper the karst area, the smaller the effect of tectonic disturbance and mechanical erosion, and the longer the original conditions can remain, the slower do connected caves systems develop. In small karst areas which stand in the way of surface watercourses, development proceeds rapidly; a tunnel cave several hundred metres in length can be eroded out by a river in a relatively short time. This is particularly true of small ribbon- or lens-like shallow karst areas, whose hydrographic relationships develop simply and clearly. I cannot understand why F. Katzer gives a greater importance to groundwater for just these areas – in my opinion it may be merely a special incidence, namely a shallow karst area filling a synclinal depression.

In the great tableland area of northern Australia, of which I have only been able to examine a small part personally, I see a good example of a morphologically young, deep karst, in which a uniform groundwater level exists, and which has been established by numerous bores. In that area a more or less closed karst channel system is quite excluded, rather, all joints are filled with water up to a certain level and this level drops gently towards the north. Only one question can complicate this set of facts; can there be one or more cave rivers, perhaps at the edge of the karst area, that reach the daylight, independent of and higher than those springs arising from the groundwater? That appears to me the salient point of the heated discussion of Grund-Katzer and others and I think that the solution of this problem is very simple. When there are one or more less porous layers in the limestone complex forming the karst area, such a situation can arise and preserve independent karst channels, even high above the level of the groundwater or the lower storey of the karst channel. Whether or not they are actually independent or the water at least partly flows or seeps to the lower level one cannot say without a detailed examination of each individual case. So I consider conditions such as those that Katzer draws in his section and also explains, to be quite possible, but not at all general. Wherever such conditions exist they are but to be considered exceptions, complications, that have been caused by the dissimilar nature of the different layers in the complex of limestone beds. Approximately the same is valid for that secondary blurring [lack of clarity] assumed by Sawicki,[37] which can occur just below the surface as well as on the floor of a cave storey. Sawicki has certainly made correct observations, but has made the so modern generalised conclusions that are rather exaggerated. If Grund[38] expresses opposition to

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[36] *Beiträge zur Morphologie des Dinarischen Gebirges.* Leipzig – Berlin. 1910, pl. 226.

[37] Ein Beitrag zum geographischen Zyklus im Karst. *Geographische Zeitschrift.* Vol. XV, pl. 185 et seq.

[38] Der geographische Zyklus im Karst. *Zeitschrift der Gesellschaft für Erdkunde zu Berlin.* 1914, p. 627. [The number for this footnote is missing from the original text. Its author is Alfred Grund.]

Sawicki's conclusions, he is actually fighting against his own method, against unjustified generalisations, which, particularly in the development of our knowledge of karst, has caused such unnecessary difficulties. If Sawicki imagines that the surface of a karst area can be so thoroughly blurred [lacking in clarity] that there should be no communication at all between groundwater in the karst and that flowing on the surface, then he is only assuming the most extreme case, which is but theoretically possible, but in reality certainly does not occur. That blurring can be a very important factor, that it can produce the existence of a large number of small, hydrographically quite independent catchment areas on the surface of a true karst area, is indicated by the superb example of the "Goenoeng Sewoe" area with its numerous telagas.

The foregoing considerations of karst phenomena and particularly of karst hydrography have all proceeded from the assumption that one had before one a karst area of a complex of limestone beds, in which all beds were similarly "pure", similar in solubility, similarly jointed, equally porous. An ideal case has been constructed, one has made observations referring to such an ideal situation and then drawn generalised conclusions, without worrying about whether such ideal conditions actually exist in reality, or where. We must still be content with only general data on the chemical nature in particular and on the relationship of chemical composition to the solubility of limestone, and in studying karst one has still devoted very little attention to differences which individual beds or layers of limestone can show, which can occasionally however have an important role in the development of cave phenomena and for the hydrography of the particular area. The more one pays attention to such differences in chemical composition, in solubility and porosity of the individual rock layers, the more complications and deviations from the ideal case appear in the realities of karst hydrography. Every karst area certainly shows great deviations from the theoretically postulated conditions. The reality is seldom so simple as it ought to be according to a generally conceived theory, such as that of Grund's karst water theory.

In his, regrettably final, essay "the geographic cycle in karst" Alfred Grund regarded the "cockpit country" described by me as the mature and old stages of the geographical cycle of a karst landscape, and presented his interpretation very graphically. I can only agree with him that I knew from the beginning that such forms as occur in cockpit country can only be characteristic of a landscape already well advanced in its morphological development, but cannot avoid saying once again, however, that a truly irregular "cockpit country" can only be found in tectonically little-disturbed regions, and that the examples from the Dinaric karst area quoted by Grund himself therefore differ quite significantly from those examined in the first and second parts of these studies.

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The Australian travels of Jiří Viktor Daneš: Geographer, speleologist and world traveller

John Dunkley[1] and Bruce Welch[2]

[1] Highland Caving Group and Australian Speleological Federation, deceased.

[2] Linnean Society of New South Wales. 21 Thompson St, Marrickville NSW. bruce@bookproduction.org

Preface

This issue of *Helictite* includes an account of the major expedition to Australia in 1909-10 of Dr Jiří Daneš (Figure 1), Associate Professor at Charles University in Prague, which was then part of the Austrian-Hungarian Empire (later Republic of Czechoslovakia, now Czech Republic or Czechia). Jiří Daneš (pronounced "Yee-zhi Dah-nesh") was what we would now call a geomorphologist. He was accompanied by Dr Karel Domin, also an Associate Professor at Charles University in Prague, who was a botanist.

Figure 1. Jiří Viktor Daneš.

The key documents discussed here are a 76-page professional paper "Karststudien in Australien" written in German and published in Prague in 1916, a large 2-volume book *Dvojím Rájem* (*Through a Double Paradise*) in Czech (Figure 2), and some shorter articles by Daneš on Australian karst, lime-

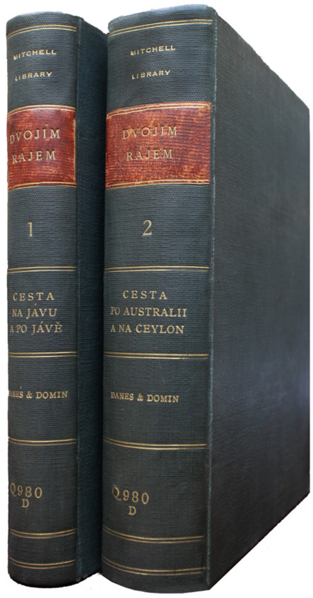


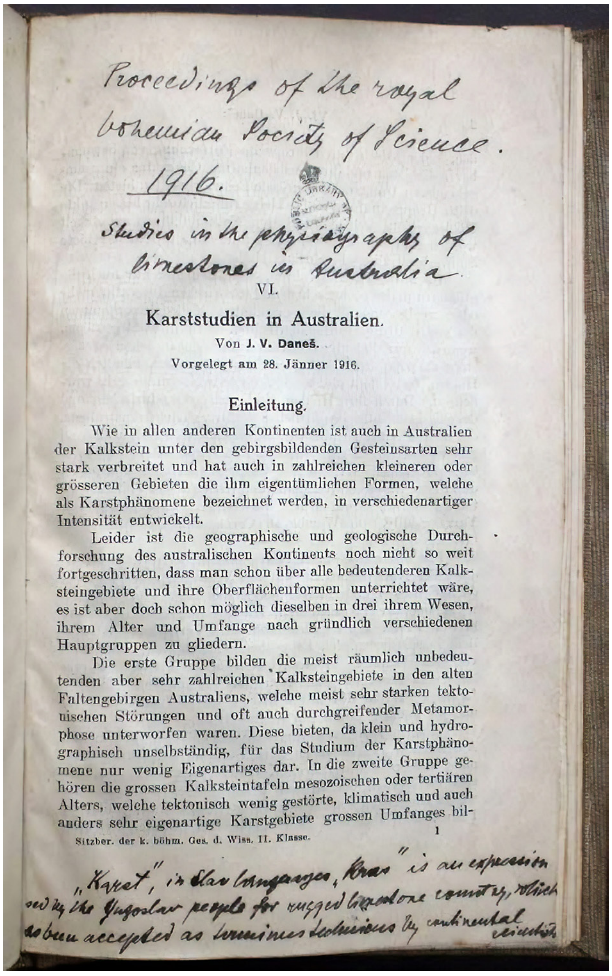
Figure 2. The two-volume set of *Dvojím Rájem*, "Through a Double Paradise" held in the Mitchell Library, State Library of New South Wales. Photo Bruce Welch.

stone and other physiography, in English, German and Czech.

Dvojím Rájem "Through a Double Paradise", is more comprehensive and less technical than "Karststudien", though a better description of the remote parts of Australia the two Czechs visited just nine years after the nation was established. A coffee-table travelogue, it was jointly written by Dr J. V. Daneš and Dr K. Domin (1911) and was a profusely illustrated (mostly with photographs taken by Daneš), highly professionally produced, large two-volume set of over 1,100 pages aimed at an educated public. It contains some speleological descriptions, along with accounts of the places and people encountered *en route*.

Karststudien in Australien (Daneš 1916) has, to our knowledge, not previously been fully translated into English from the original German, a task now carried out by geologist John Pickett for publication here.

A photocopy of the paper "Karststudien in Australien" was in the possession of Professor J.N. Jennings (1916-1984) in Canberra. It probably formed the basis of both his paper on Daneš at Chillagoe (Jennings 1966) and his detailed paper on Daneš's work (Jennings 1980). Much later an original reprint, annotated by Daneš, was located by the authors in the State Library of NSW (Figure 3). Over the years several Australian speleologists attempted to translate small sections of the paper, with varying success. Copies passed among Andy Spate, Dave Gillieson, John and Jeanette Dunkley, Colin Tyrrell, Ken Grimes and possibly others – all using a poor copy of the original, which was difficult to scan – but the real problem was accurate translation of the 25,000 words. Using Google translate, Colin Tyrrell produced the first working version in English, and the late Ken Grimes, who had conducted geological field work in North-West Queensland (Grimes 1974, 1988), considered publication was warranted. However in 2016 fluent German speaker and geologist Dr John Pickett offered to convert the original into modern English.


Proceedings of the royal bohemian Society of Science. 1916.

Studies in the physiography of limestones in Australia

VI.

Karststudien in Australien.

Von J. V. Daneš.

Vorgelegt am 28. Jänner 1916.

Einleitung.

Wie in allen anderen Kontinenten ist auch in Australien der Kalkstein unter den gebirgsbildenden Gesteinsarten sehr stark verbreitet und hat auch in zahlreichen kleineren oder grösseren Gebieten die ihm eigentümlichen Formen, welche als Karstphänomene bezeichnet werden, in verschiedenartiger Intensität entwickelt.

Leider ist die geographische und geologische Durchforschung des australischen Kontinents noch nicht so weit fortgeschritten, dass man schon über alle bedeutenderen Kalksteingebiete und ihre Oberflächenformen unterrichtet wäre, es ist aber doch schon möglich dieselben in drei ihrem Wesen, ihrem Alter und Umfange nach gründlich verschiedenen Hauptgruppen zu gliedern.

Die erste Gruppe bilden die meist räumlich unbedeutenden aber sehr zahlreichen Kalksteingebiete in den alten Faltengebirgen Australiens, welche meist sehr starken tektonischen Störungen und oft auch durchgreifender Metamorphose unterworfen waren. Diese bieten, da klein und hydrographisch unselbständig, für das Studium der Karstphänomene nur wenig Eigenartiges dar. In die zweite Gruppe gehören die grossen Kalksteintafeln mesozoischen oder tertiären Alters, welche tektonisch wenig gestörte, klimatisch und auch anders sehr eigenartige Karstgebiete grossen Umfanges bil-

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Sitzber. der k. böhm. Ges. d. Wiss. II. Klasse.

„Karst", in Slav languages „Kras" is an expression used by the Yugoslav people for rugged limestone country, which has been accepted as terminus technicus by continental scientists

Figure 3. First page from "Karststudien in Australien" showing Daneš handwritten notes. Photo Bruce Welch.

It is interesting that Daneš suggested the translation "Studies in the physiography of limestones in Australia" for the paper's title, presumably aware that 'karst' would not have been understood by most Australians at the time – Ed.

Serendipitously, in early 2017 we stumbled across "Through a Double Paradise", in the Mitchell Library of the State Library of NSW. The Mitchell Library bookplate states that it was donated on 4 January 1921 by Daneš, then Consul-General for Czechoslovakia. It is believed that the inscription is in the hand of the Mitchell Librarian, Hugh Wright, great-grandfather of Bruce Welch (Figure 4). Jeanette Dunkley began working on a Google translation of parts of this from Czech, and Karel Petrasek continued the project.

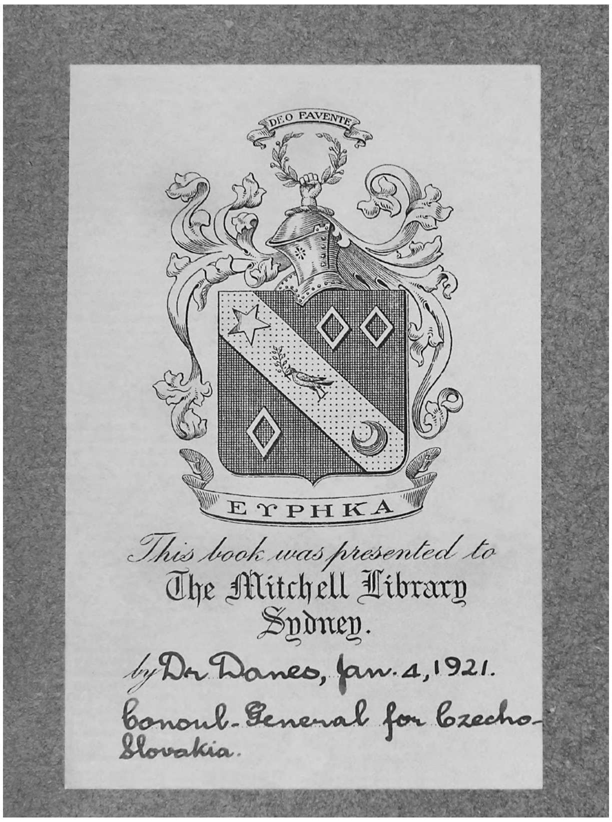

Figure 4. Mitchell Library bookplate showing donation details in the handwriting of the Mitchell Librarian, Hugh Wright. Photo Bruce Welch.

Because many of Daneš's other works are in Czech and/or unpublished, or not readily accessible to readers, we have expanded his background a little to emphasise how karst became his life's focus, in a life full of remarkable journeys. In Australia he visited caves and karst in every state (except South Australia) and territory (including the nascent Canberra) and produced probably the earliest map of limestone physiography for all of Australia (Figure 5).

As this paper was being researched, a biographical work, *Geograp a cestovatel Jiří Daneš* by Jiří Martínek, was published (2017). While it covers little of Daneš's work in Australia, it has been used as an important reference for this article. Yet another item, describing his anthropological collections, now housed in the Náprstek Museum, Prague, was published in the same year (Jungová 2017).

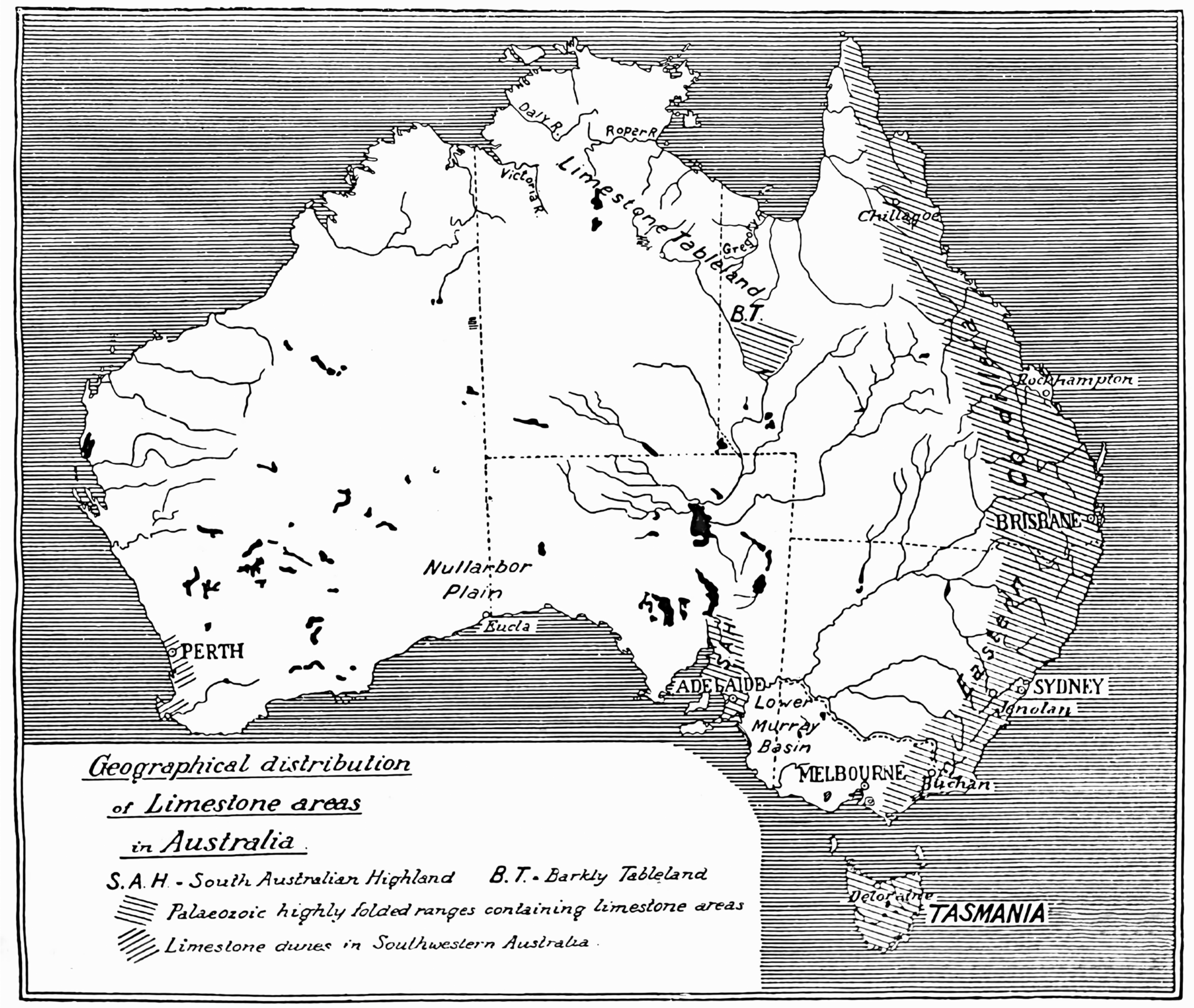

Figure 5. Map drawn by Daneš showing Australian limestone areas, included in his 1924 publication (Daneš 1924a).

Introduction

On 10 April 1928, on a suburban Californian road at Culver City on his way to visit film studios in Hollywood, a motor car collision resulted in the death of Professor Jiří Daneš. This cut short the life of one of the world's foremost karst geomorphologists. The level of respect he commanded in the scientific community is evidenced by his obituary published in *Nature*.

Based in Prague, he was the first karst scientist to both visit and write extensively about karst physiography in Australia (Daneš 1910a, 1910b, 1911a, 1911b, 1914b, 1924a), ranking with our two most distinguished early writers about caves and karst, Thomas Mitchell and Julian Edmund Tenison-Woods, neither of whom was a karst scientist. It was another generation before J.N. Jennings arrived in Australia, later describing Daneš's work at Chillagoe in *Helictite* (Jennings 1966) and his broader travels (Jennings 1980); but little has been written since about Daneš's extraordinary journeys in Australia.

Daneš the man

Jiří Viktor Daneš was an accomplished polymath: curious, persevering and pertinacious, resolute with almost obsessive determination, and an extraordinarily hardy traveller who had a distinguished academic and consular career. Born to a wealthy family in Unhošt, Nový Dvůr (Neuhof in German) (23 August 1880), about 30 km west of Prague in what was then part of the Austro-Hungarian Empire, he studied geography, geology and history in the Faculty of Philosophy at the Charles University in Prague (whose curriculum included a surprising amount of Australian geography), graduating in 1898.

Obtaining a doctorate in 1902, he joined the distinguished Serbian Professor Jovan Cvijić, and together they carried out karst and other geomorphological work in the central Balkans. After post-doctoral studies at the University of Berlin in 1903-04, he returned to karst studies in Herzegovina, soon afterwards presenting a second doctoral thesis in 1905 at Charles University which appointed him Associate Professor, apparently describing his position as 'private lecturer in geography'. In 1904 he attended the 8th International Geological Congress in Washington, afterwards accompanying renowned geomorphologist W.M. Davis and learning his working methods on Congress excursions in the northeast and southwest of the USA and in Mexico. Daneš separately travelled from New York to Boston, Seattle, San Francisco, Los Angeles, Denver and St Louis. Returning to Mexico for the 10th International Geological Congress in 1906, he determined to divert for a month-long study of the distinctive cone karst of Jamaica (Daneš 1914a) and Cuba.

Clearly this training informed his plan to visit Java and Australia.

Planning for Australia

Dated 19 November 1908, a handwritten letter from Prague signed by Karel Domin and Jiří Daneš was addressed to "His Excellency, The Governor-General and Commander-in-Chief of the Commonwealth of Australia, Lord Northcote". The letter proposed "several scientific expeditions and excursions for studying purposes into the interior of Australia. Should, during our time in Australia, an expedition into the interior be arranged by the authorities, may the High Government be pleased to grant us permission to join the same." Accompanying this was a strong recommendation from the President of the Bohemian (i.e. Charles) University of Prague, requesting authorities to promote as far as possible the attainment of these aims.

The following Governor-General (the 2nd Earl of Dudley) laid the letter before Prime Minister Alfred Deakin and the Secretary of State for the Colonies in London. Bureaucratic delays then occurred as the request was referred to the British Ambassador in Vienna and translations obtained of the proponents' credentials. A summary of Daneš's credentials recorded:

"He also studied with a special interest the rock soil [karst] phenomenon, and with this object he made another expedition of research through Jamaica and California in 1907 and also the French rock soil [karst] districts". He planned to undertake "the investigation of the geomorphological conditions of the rock soil [karst] regions in Java and the southern part of Australia (Eucla division), the morphology of the steppes and waste lands as compared with the damp, tropical parts of Northern Queensland…". A formal letter advised that the "Government of Austria strongly recommends and hopes facilities will be granted." By mid-1909 the Prime Minister's office had conveyed these aims and hopes to all state governments, asking them to render assistance in any way possible.

Australian journey 1909-10

In July 1909 Daneš joined Karel Domin, an associate professor in systematic botany at Charles University for their sabbatical. Travelling by train from Berlin and Prague to Trieste, they sailed on the Lloyd Triestino *Austria* to Suez, Aden, Bombay (where they visited the renowned man-made Ellora Caves (Figure 6), then via Penang and Singapore to Batavia (Jakarta). They climbed Mt Gede and Mt Bromo, and visited Semeru volcano (then erupting), while additionally Daneš researched the extensive 2,000 sq km karst of Gunung Sewu on the south coast (Daneš 1915).

Figure 6. Dr Daneš, under the cactus, near the cave temple at Ellora near Bombay, India (Photo Domin).

Continuing by a smaller ship via Port Kennedy (Thursday Island) and stopping briefly at Townsville, they arrived in Brisbane on 16 December 1909. There they visited Stradbroke Island, Mount Tambourine (Figure 7) and scientific institutions such as the Geological Survey, The Royal Society and the Royal Geographical Society of Queensland, as well as researching and arranging expeditions to North Queensland.

Armed with local information, references and contacts, along with a free rail pass from the Queensland government, they entrained to Gladstone, transferred to a coastal steamer to Cairns, and visited and later authored papers on the physiography of the Bellenden-Ker Mountains, the Russell and Barron Rivers and Lake Eacham. They also witnessed Aboriginal corroborees, an important side interest of Daneš. He obtained ethnographic items and later wrote a book detailing these experiences (Daneš 1924b). During much of this stage Domin

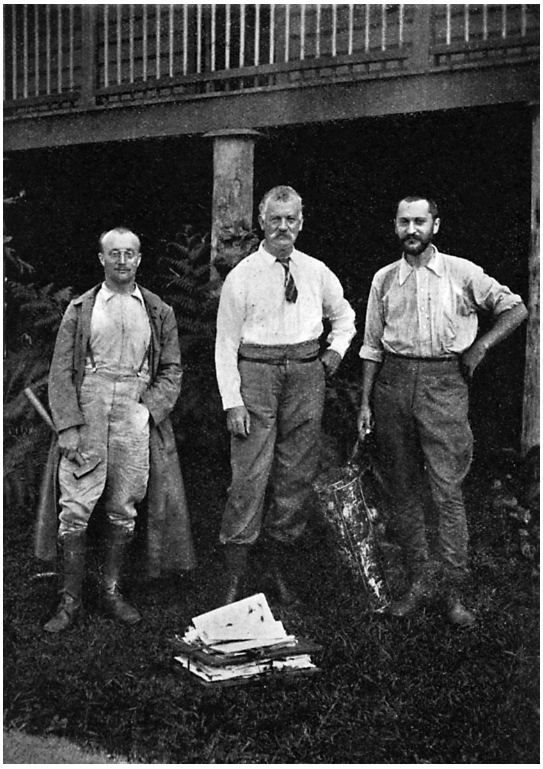

Figure 7. Excursion group at Tambourine Mountain, left to right: Daneš, Inspector J. Shirley, Domin.

was equally active in botanical investigations, later writing an important paper on plant associations in Queensland (Domin 1910).

Daneš probably met his first Australian karst in February 1910, just west of Almaden as they crossed the ranges by rail to Chillagoe (Figures 8-11). He and Domin spent a short time there as guests of Lord McDermott who assigned an assistant for local excursions there and to Mungana (Figures 12, 13). McDermott prevailed on the Queensland State Secretary to provide the Czechs with a free rail pass (Martínek 2017 p. 81).

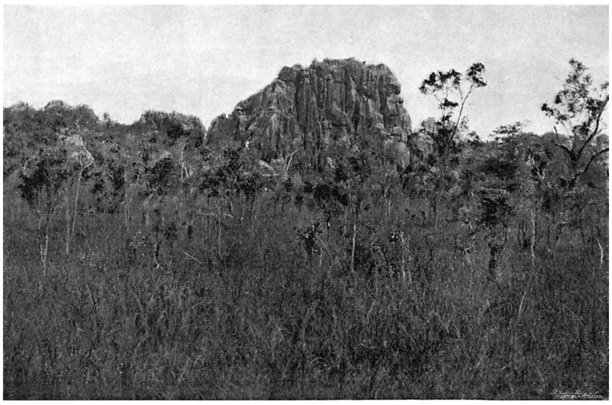

Figure 8. Castle Rock, Chillagoe. Photo Domin.

At the time Townsville was not connected by rail to either Cairns or Brisbane, and most long distance travel was by coastal steamer. Thus, they returned to Cairns, took ship to Townsville, and made inland rail excursions to Charters Towers (from where they

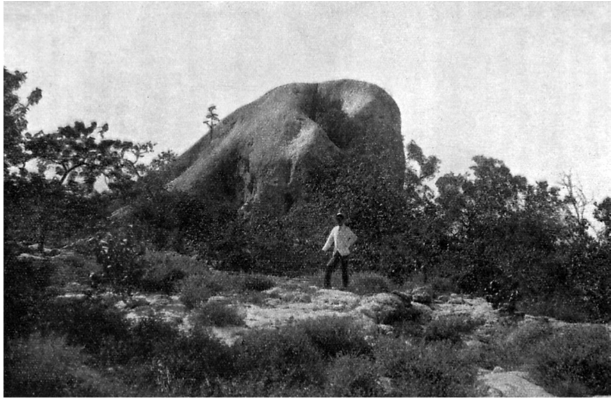

Figure 9. Lions Head, Chillagoe.

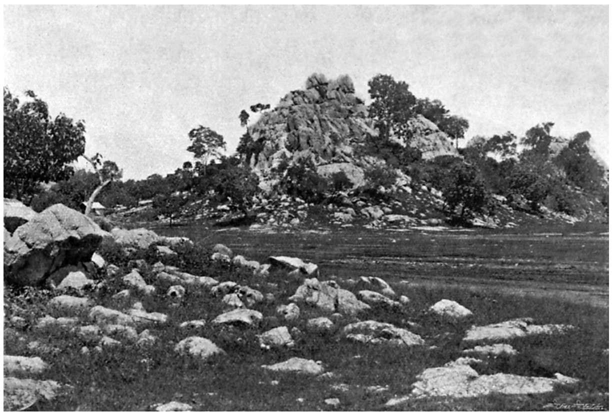

Figure 10. Karst at Chillagoe. Photo Domin.

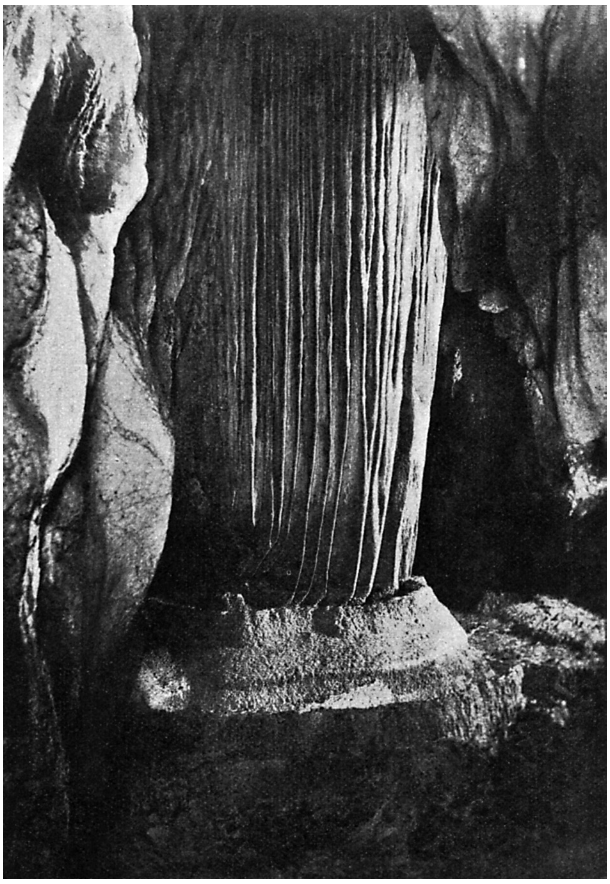

Figure 11. Cave decoration, Chillagoe. Photo Domin.

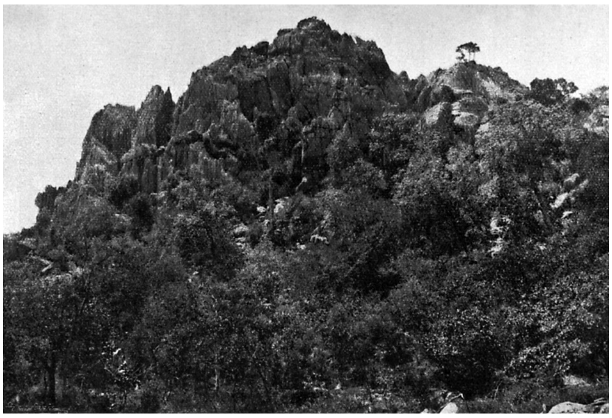

Figure 12. Karst at Mungana.

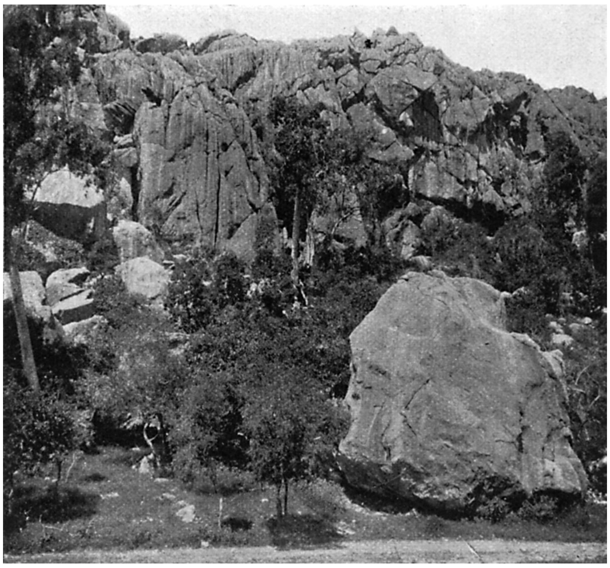

Figure 13. Fallen rocks, Mungana. Photo Domin.

photographed the Burdekin River), Hughenden and Cloncurry. In retrospect it's not clear why the pair travelled all the way to Cloncurry on that first occasion without enquiring about onward transport to the Barkly Tableland. Martínek (2017) suggests they wanted "to continue to the little-known West Queensland; but in these plans they were (deterred) from continuing". Daneš had researched the subject in Brisbane and was certainly more determined on reaching the Barkly, partly to compare it with other karsts, partly to examine evidence of its immense subartesian and very deep basin of groundwater, adverted to in government correspondence and about which he later waxed rather enthusiastically to a number of journalists. Rebuffed, they turned south, travelling by horseback or (more likely) coach direct to Winton, or possibly by train via Hughenden. A Cobb & Co. stagecoach conveyed them on to Longreach (Figure 14), from which rail service to Brisbane was available. Diverting briefly en route at Rockhampton, they visited Olsens Caves (Figures 15, 16) to compare its tropical karst, contrasting it with that seen in Java, Jamaica and around Chillagoe.

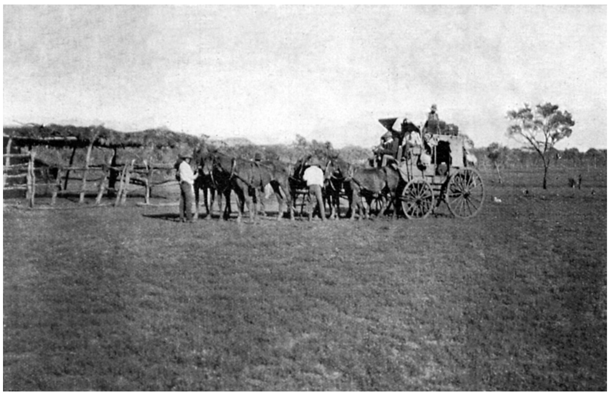

Figure 14. Large coach between Winton and Longreach.

Figure 15. Entrance to Olsens Cave.

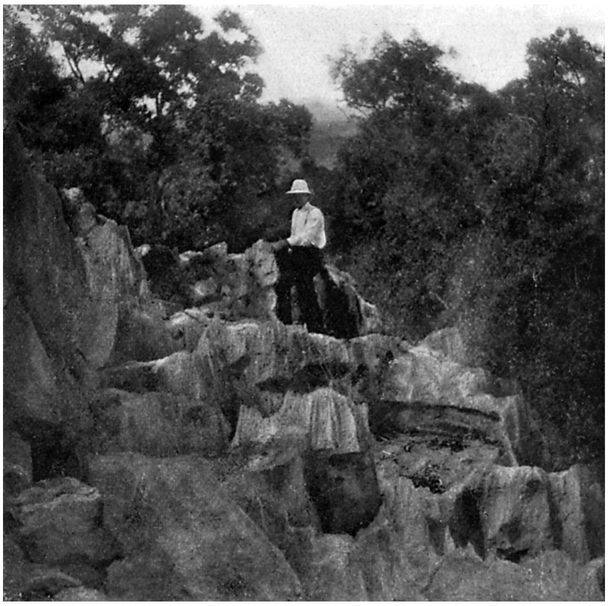

Figure 16. Karst over the Olsens Caves. Domin seated on the rocks.

At Brisbane Karel Domin parted company with Daneš, travelling on to Melbourne and in time built a distinguished academic career. Domin became Professor of Botany and Rector at Charles University and a Deputy of the National Assembly. From various sources Domin published a number of important works on Australian taxonomy and phytogeography, over 4,000 specimens now being lodged in the Botany Department of the National Museum in Prague, and he is regarded as the person primarily responsible for establishing the Tatra National Park in the mountains of southern Poland.

Now travelling alone but undeterred, Daneš returned to the north later in 1910, went by rail to Rockhampton and Barcaldine, then north to Aramac, the last stretch being by stagecoach as the Aramac branch line was not commenced until 1911. Of Aramac he wrote:

"On the coach on which we arrived I had found details of a trader and horse and cattle catcher who had many horses for sale. With the assistance of the police constable, I visited him and picked up two horses and saddles. I did not buy the horses for a parade, and I knew very well that I would not be able to sell them for a decent penny. I bought both of them and a harness for 20 pound sterling, finding out on a report that they had no mistakes that would *a priori* cast doubt on the journey" (Daneš 1910a).

From Aramac he journeyed 340 miles on horseback in three weeks. The plan was to continue north-east to a series of salt lakes (Lakes Mueller, Barcoorah, Dunn, Galilee and Buchanan) located on the continental divide; his interest being primarily physiographic and hydrographic as questions arose about whether some had originally drained to the east (Daneš 1910a).

As an indication of the trouble Daneš took to investigate caves he visited some so-called salt caves near Cauckinburra Swamps in a rather desolate area only to discover that these were merely overhangs formed by erosion of a bank where the overcapping of a hard conglomerate resulted in overhangs.

From Pentland he travelled west by rail via Hughenden to Cloncurry again. From there he at last set out for the Barkly Tableland, journeying the next 300 km by stagecoach, crossing the divide between the Leichhardt River and the internal drainage of the Georgina River, probably north of the site of what is now Mt Isa (Figure 17).

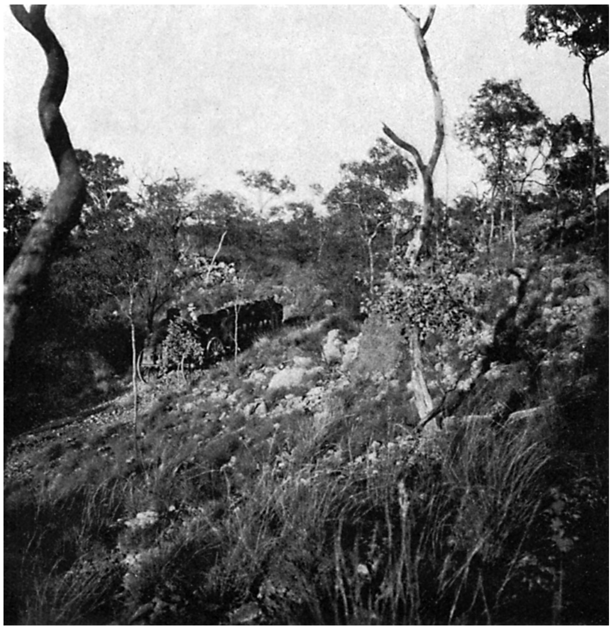

Figure 17. The coach rises over a quartz hill between the Leichhardt and Georgina Rivers north of Mt Isa.

"It was a long and fairly monotonous trip from the terminus of the Great Northern Railway of Queensland in Cloncurry through the dry and wild montane country of the northern 'Australian anti-cordillera' to the tableland at Camooweal (Figure 18). From there, after several excursions to the local cave and sinkhole groups, north to the Gregory River and then through the Carpentaria lowlands via Burketown and Normanton, and through the broad southern part of Cape York to Cairns! The excellent coach connections, which even these far-flung regions of Queensland enjoy, made it possible to cover this great stretch of semi-desert of varying kind, within six weeks, including detours, relatively comfortably and quickly."

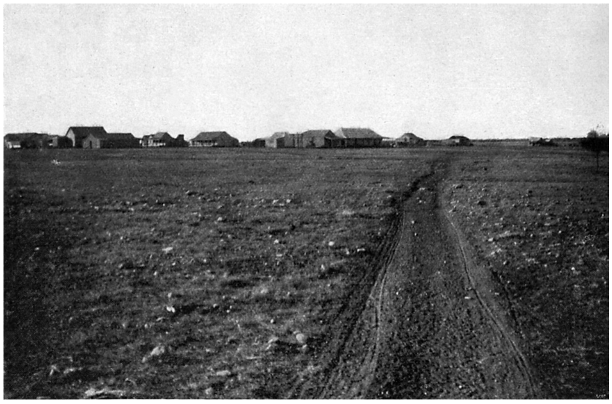

Figure 18. Approaching Camooweal on the coach road from Cloncurry.

This, the main goal of his trip, occupies more than half of his key paper, exceeding 15,000 words and deals with some geology as well as karst geomorphology. Curiously, his biographer (Martínek 2017, p. 82) in an otherwise comprehensive 292-page account of Daneš's life and travels, says little more about the Barkly expedition than that "From Brisbane, in mid-April 1910, he travelled to Rockhampton (in which he visited another karst area), Barcaldine and Aramac, a few hundred kilometres on horseback to Lake Buchanan and Lake Galilee, to the area known as Cloncurry, to the upper Flinders River and to the Barkly Tableland karst region with many caves and chasms at the Queensland and Northern Territory [border] to study the karst relief there."

He arrived in the mining town of Burketown, meeting Queensland geologist Lionel C. Ball (1877-1955), who was performing geological mapping on the border of Queensland and the Northern Territory. Because he assisted with this mapping one of the valleys of this area was named "Danes Valley" in his honour. Martínek (2017) says elsewhere (p. 286) that "unfortunately, today's maps no longer bear this name".

Nowranie, Barwidgee, Hassels, Jopps, Bustard Creek, Wooroona Creek (Figure 19) and other interesting karst and caves near Camooweal demanded his attention.

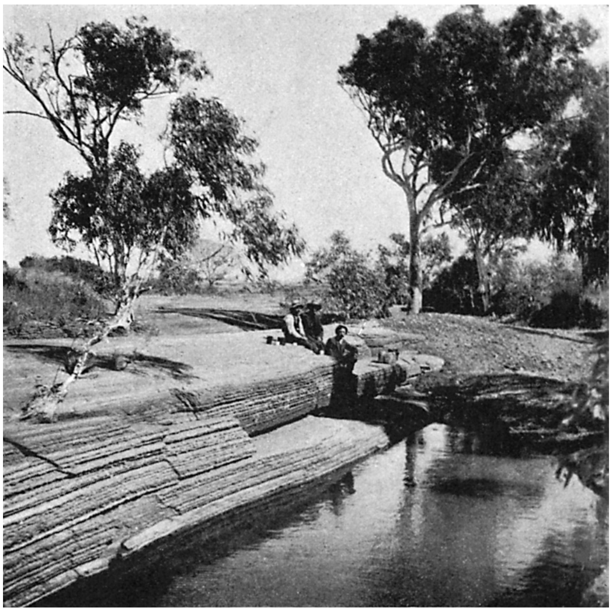

Figure 19. Waterhole in the Wooroona Creek, East from Camooweal. The late Ken Grimes took a photo at this exact spot; he called it Split Rock Waterhole and is a few kilometres north of the Barkly Highway.

Travelling across into what was then the Northern Territory of South Australia, he was able to borrow a horse and guides from the obliging manager of Rocklands Station. Mr Glisssan had lived in the area for 30 years and accompanied him for three days, and was very familiar with the topography and hydrography (Figures 20, 21).

"… We planned a trip and descent into Nowranie Cave, about 19 km southeast of Camooweal (Figures 22-24). We were seven beside two blacks, … and three horsemen … also a postmaster and police sergeant … we tried our luck on ducks and kangaroos. A black arrived late at night in camp with two shot kangaroos. I bought the two tails from him … It was a very delicious roast, the soup then almost did not differ from the good beef …

"We camped at Nowranie Creek, about a quarter of an hour from the cave. [Rocklands station] supplied various preserved delicacies of a well-known selection. Intense cold was also a good way to get

Figure 20. A.H. Glissan's Group of Sink-holes and Caves, Barkly Tableland (caption from Royal Society of Queensland paper by Daneš), otherwise captioned Karst cave near Rocklands, Camooweal.

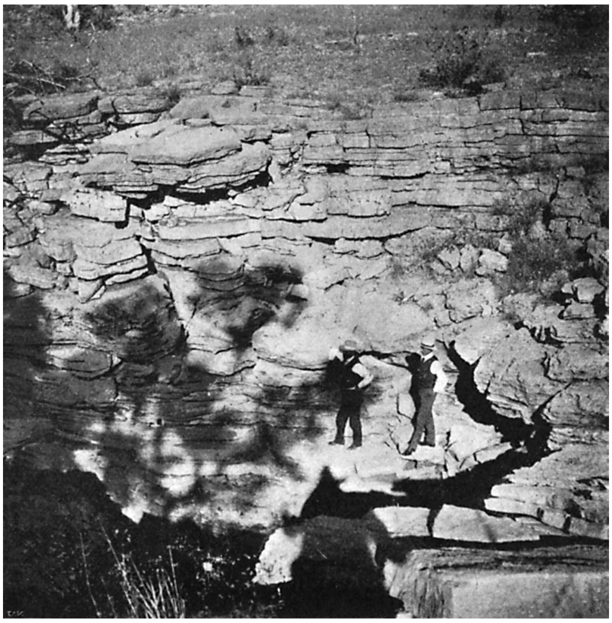

Figure 21. On the edge of the karst in the Glissan group of caves. Probably Barwidgee Cave (4C1) according to a photograph supplied by Ken Grimes.

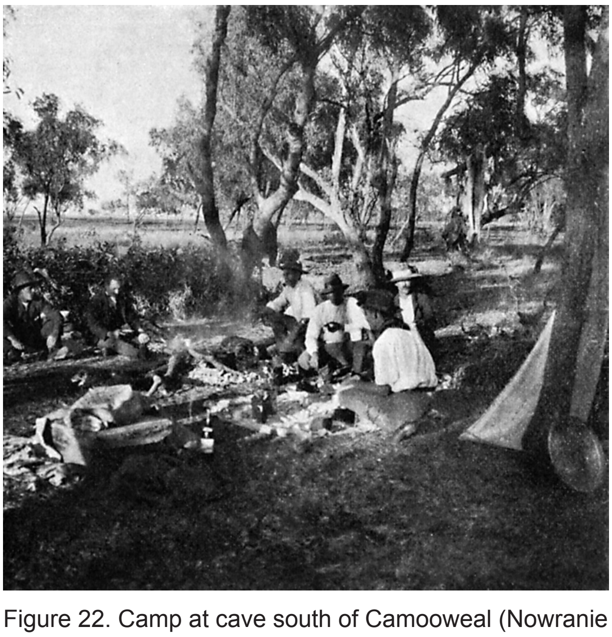

Figure 22. Camp at cave south of Camooweal (Nowranie Cave).

Figure 23. Karst abyss south of Camooweal (Nowranie Cave).

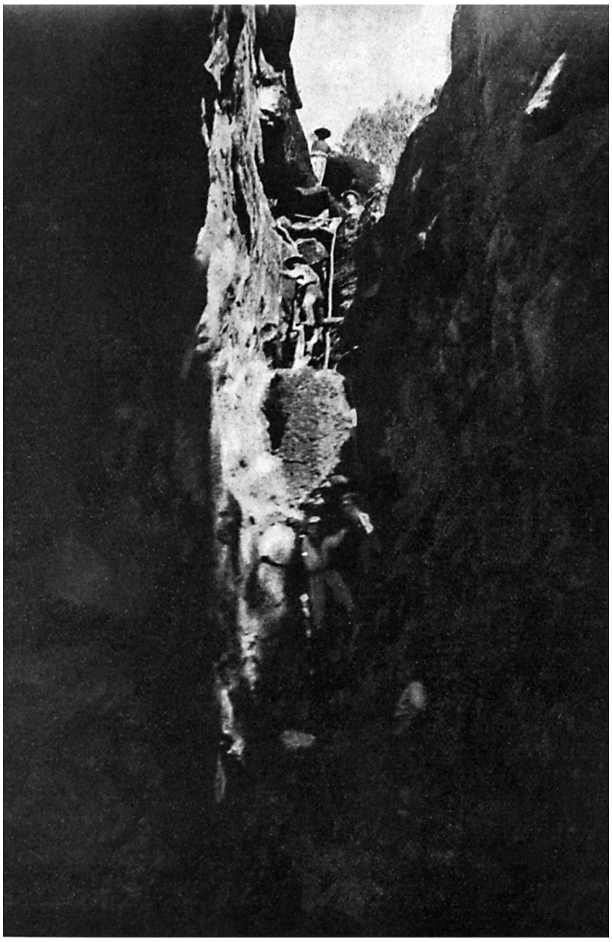

Figure 24. Descent to the abyss near Camooweal (Nowranie Cave).

more frequent drinking with bottles of wine, whiskey and brandy … we slept well and did not feel the winter although this night was a minimum of almost zero in Camooweal … After a hearty breakfast we went to the caves … I've always had a certain horror of climbing down a rope, and it's too hard for me to get rid of the goose pimples, but it was not a waste… I started, too, very smoothly using the instructions of the Rocklands blacksmith, who had an invaluable practice in the depths of a similar nature from the Croydon mine [a description of the cave follows].

"The next day, Monday, I spent in the eastern surroundings of Camooweal viewing several groups of karst formations. Quartz pebbles are often quite nice … inhabitants decorate their houses with seashells or decorative groups of crystals. Cut pieces are rare as grinding is very expensive in Australia, and most opals, sapphires and other gems are sold to German agents."

Cobb & Co. had stagecoach services available between Cloncurry, Camooweal, Riversleigh, Lawn Hill, Burketown and Normanton which were undoubtedly used (Figure 25), a total distance travelled of about 1,000 km. Burketown was then the port of entry for supplies to settlements in remote NW Queensland.

Figure 25. [American-style buggy] at rock outcrop near Riversleigh. Right beside the old road from Riversleigh to Lawn Hill, a former Cobb & Co. Stagecoach route.

Daneš reached Riversleigh and Lawn Hill stations and certainly visited some karst near the former. At Normanton he toyed with the idea of the steamer connection via Cape York to Cairns every 3 days, but the railway apparently prevailed as a train was timed to leave the next day. Conveniently opened only a year earlier, this isolated stretch between Normanton and Croydon still operates and has never been connected to other Queensland Rail networks. From Croydon a coach connected via Georgetown to Charleston (since renamed Forsayth), from which a slow train still rattles off to Cairns, taking even longer now than it did then. Pausing only for more studies of the valley of the Barron River, he returned to Brisbane, gave a number of lectures, went on to Sydney, visited Jenolan Caves (Figure 26), and planned to return home.

In Sydney he consulted personally with Oliver

Figure 26. The shape of the "Mystery" in the Jenolan Caves.

Trickett about Yarrangobilly and presumably Wombeyan and Wellington. However Jenolan was the only one of these he was able to visit, in August 1910, and then only briefly, describing it as one of the most important in the world, and for this he appears to have secured support from the NSW Government. In the same month he left for home via Melbourne, Adelaide and Perth. There he found time to investigate karst at Yallingup (Figure 27) in early September 1910 (probably with support from the WA Government) and in the gold-bearing area of Coolgardie, Kalgoorlie and Leonora.

Figure 27. Caves House, Yallingup.

He laments that because his time in Queensland " … lasted too long, I was obliged to abandon the original plan of visiting the Eucla area, and could no longer visit even the smallest of the great limestone plateaux, the so-called Mosquito Plains (i.e. Naracoorte)". Other correspondence shows that his original intention was to visit the Nullarbor from the remote telegraph station at Eucla, using one of its occasional supply ships.

First Consul-General to Australia

With his considerable historical and geographical skills, in 1920 Daneš was appointed the first Consul-General to the Commonwealth of Australia of the newly born Republic of Czechoslovakia. Accompanied by his wife Božena they travelled from Trieste to Port Said and Massawa (now in Eritrea, then in Abyssinia i.e. Ethiopia), they explored oases around Aden, then transferred to the P&O *Orvieto* from Colombo to Fremantle, arriving on 9 August 1920, where he was interviewed by *The West Australian*. Not one to miss an opportunity to at least sample Australia's largest karst, they crossed the Nullarbor on the just completed Transcontinental Railway, although his notes on that subject are based entirely on earlier literature. The journey was interrupted long enough to make brief diversions to Buchan either then or shortly afterwards, and to caves near Deloraine and elsewhere in Tasmania, and eventually they reached Sydney on 26 August 1920.

Most of his writings from the next two and a half years are about plebeian matters such as trade opportunities, with mostly short excursions around Sydney, where he lectured widely about his country to business and political groups, the Royal Australian Historical Society and at the Australian Museum. We know he travelled to and addressed the Australasian Association for the Advancement of Science in Melbourne (Daneš 1921a, 1921b), visited Buchan Caves probably in 1921, also Kosciuszko, Tasmania and Papua, later visiting Tasmania again, but again he lamented a lack of opportunity to visit more caves there or in South Australia. The joys of travel didn't finish there, however, leaving time to travel to New Guinea, the Bismarck Islands, North Queensland and later Yass and the site of Canberra.

Not having remaining time or the means for a longer trip to Central Australia, Božena and Jiří sailed at the end of 1922 via New Zealand, Fiji, Tonga, Western Samoa, Hawaii, Japan, Korea, Manchuria and China. From China he took ship to Vancouver and thus across Canada to Europe, reaching Prague in July 1923.

Jiří Viktor Daneš: further biographical notes

Daneš married in 1914 and in March 1917 was called to active military service as an officer in Sarajevo. As the 3-year old war progressed the Austrian-Hungarian government was running short of fertiliser for gunpowder. A good source was guano in the caves of Bosnia which Daneš and Cvijić had explored earlier. It was Daneš's remit to survey the caves and report on these deposits. There is some suggestion in biographical notes that, arriving back in Sarajevo on 29 October 1918, he was confronted by the first reports of secession from the Empire of the south Slavic people, and within a day the city was in flames. The State of Czechoslovakia was proclaimed in Prague the following day. He helped form a voluntary Czech Legion to restore order and protect Czech citizens, and the city eventually was handed over to the Serbian army.

With the war behind him, in 1919 he was appointed full Professor at Charles University.

From 1923 to 1925 he taught geography at the Faculty of Philosophy at Comenius University (Bratislava, Slovakia) where he established the Department of Geography, and in 1925-26 became Dean of Science in Prague. In 1924 he summarised his findings about limestone physiography in Australia into three main groups:

1. the highly folded Cambrian, Silurian and Devonian limestones of eastern Australia; the extensive, less disturbed Barkly Tableland,
2. the tertiary limestones of the Nullarbor Plain and the Murray Basin Plains of South Australia and Victoria; and
3. the limestone sand dunes in southwest Australia

The map accompanying this short work (Daneš 1924) (Figure 5) is possibly the earliest in Australia to delineate limestone areas of the entire country (though the map curiously does not show limestone on the Nullarbor Plain even though he had crossed it in 1920).

In December 1927 he began another speaking tour to the USA, lecturing at about 30 universities and again studying karst.

His untimely death in Los Angeles in 1928 cut short a remarkable life which might well have lasted until Joe Jennings arrived in Australia in 1953, shortly thereafter to revive karst studies in this country.

The *Australian Dictionary of Biography* recognizes Daneš in two paragraphs about karst (Brinke 1988), recording that his works on tropical karst in Australia, Indonesia, Jamaica and elsewhere continue to be quoted up to the present. Unfortunately the Australian Dictionary uses an incorrect middle name for Daneš. Some equally valuable works on anthropogeography contain much valuable thought and observations. Cigler (1981, accessed 25 November 2014) appears to suggest that Daneš was damned with faint praise, concluding that "In Australia his penetrating writings on both physical and human geography have largely been ignored by scholars."

In Sydney in 1920 Sir Edgeworth David was instrumental in having his ex-student and physical geographer Thomas Griffith Taylor appointed as founding head of the Department of Geography at the University of Sydney. Daneš (1910b) had taken issue with many of Taylor's investigations of the rivers of northeast Queensland (Taylor 1911a, 1911b); curiously, they do not seem to have met or enjoyed any professional relations in the 1920s.

Daneš's published output was extraordinarily prolific, especially by the standards of the day, yet many reports have never been published and are lodged in the State Archives of the Czech Republic.

Martínek (2017) and Hanták (2013) both make clear that Daneš had planned an extensive comparative monograph on the karst areas of the world. His estate and donations went to the Czech Academy of Sciences and Arts, the Daneš Endowment, supplying funds mainly to young researchers in geography and natural sciences. The Czech Association of Geomorphologists still awards the Jiří V. Daneš Prize for the best dissertation in Physical Geography/Geomorphology.

Hanták mentions that all Daneš's travels were financed from his own funds without requesting any assistance from the state. He concluded that Jiří's sacrifice was thwarted by his desire for recognition and he never achieved fulfilment of all his goals. Hanták suggested that recognition of his role still remains possible via the comprehensive archives of the Academy of Science in Prague where his work could be explored, along with the archives of Karel Domin (a theme taken up by Martínek a few years later).

Martínek (2017 p. 290) questions whether Daneš "created any school of thought: after researching his works and the works of younger colleagues and pupils, it seems we must unfortunately answer this question in the negative. Daneš clearly influenced a number of important scientists … but not so much for many of them to build on his work and ideas. Daneš had a large number of pupils, but it was not sufficient to build up an integrated school of thought."

Martínek goes on to mention "… his reports on the situation in Australia, which Daneš worked on with scientific diligence. Besides interesting opinions on Australian society of the time, we also hear of his promotional ideas for the new state, for which he also took advantage of the opportunity to lecture at various scientific and other meetings". He clearly eschewed an easy life, was his own boss, had the means to achieve what interested him, and set out to do it.

We have seen above Daneš's endeavours to seek high-level Australian government support for his 1910-1911 expedition, but only this year has it emerged that in 1923 he also met the Prime Minister of New Zealand, albeit in his consular capacity.

Daneš was extraordinarily prolific in the range of both his professional and popular writings. Martínek catalogues 214 publications in Czech, English, French, German and Russian, about 35 relating to Australia. The breakdown of these are: 19 books and monographs (5 on Australia); 51 (9) professional articles; 21 (3) texts in popular magazines; 94 (10) of minor news; and 29 (8) newspaper accounts. Many are lodged unpublished in the State Archives of the Czech Republic including the 35 Australian items. These Australian items are not just on karst but discuss Canberra, Lord Howe Island, kerosene, capture of the Flinders & Barron Rivers, Lightning Ridge, the northernmost camp of Burke & Wills, and Aboriginal customs. Certainly he did not visit all these areas as his reports also cover the Ruwenzori Mountains in Africa for example.

Thus we know from the above and from his later return to academia from consular pursuits, that he intended part of his life's work to encompass a world monographic review of karst. He left an extensive yet unfinished work, a significant part dealing with Australia and lodged unpublished with the State Archives of the Czech Republic, concentrating on physical geography, geomorphology and consular reports. His major legacy in the Australian context is "Karst Studies in Australia", published in German in 1916 and only recently completely translated. As a physiographer (these days called a geomorphologist) Daneš was our first professional karst scientist, albeit a visitor, and his writings rank with those of Sir Thomas Mitchell and Julian Edmund Tenison-Woods.

Our conclusion is that Daneš was a wonderfully observant old-school geographer, a great traveller and a prolific writer. But karst was his great pleasure to which he kept returning. It helped inform his life's goals and was a great obsession.

All photographs accompanying this paper are by Daneš unless otherwise specified. Most have been sourced from the book written jointly by Daneš and Domin, *Dvojím Rájem* (1911).

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**Sadly, only the titles of these papers appear to have been published and Daneš's name is incorrectly shown as "Dr T.V. Danues".*

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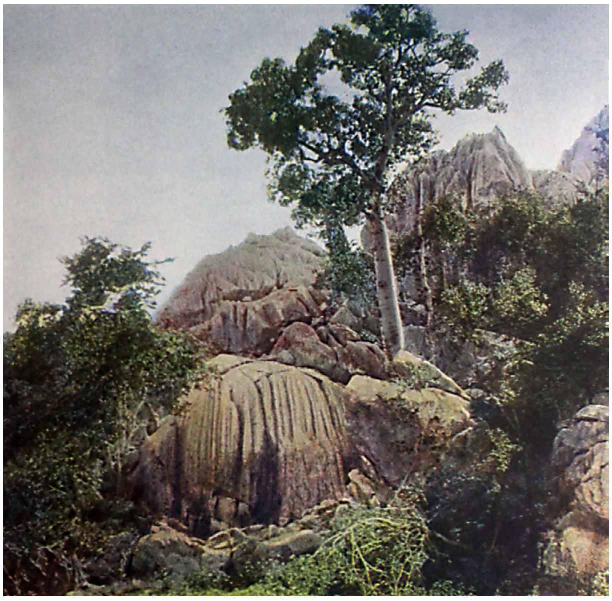
COVER

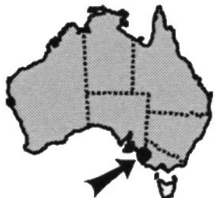
For those who do not download the entire Vol. 44 and therefore do not see the cover, we append here a reduced copy of the cover illustration:



Front cover: Karst at Chillagoe. Colour plate facing page 124 of volume II in the first edition (1911) of *Dvojím Rájem,* "Through a Double Paradise" by Dr J. V. Daneš and Dr K. Domin, associate professors at Charles University in Prague.

Helictite, (2018) 44**:** 45-58

New evidence confirms Thomas Hannay as the first photographer of Naracoorte Caves and emphasises the importance of historical writing in caves



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Abstract

Naracoorte Caves National Park in South Australia is a UNESCO World Heritage site renowned for its Quaternary vertebrate fossil record spanning the past 500,000 years. Although the primary heritage values of the park relate to the fossil deposits, significant other values include biological, geological, cultural and historical aspects. In 1860, the Reverend Julian Tenison-Woods commissioned a series of photographs of Blanche Cave for use by the engraver Alexander Burkitt in illustrating Woods' 1862 book *Geological observations in South Australia*. The identity of the photographer was unknown until recently, when we discovered an engraving in a Melbourne periodical that cited Thomas Hannay of Maldon as the producer of the photo. Despite this breakthrough, there was no direct evidence linking Hannay to Naracoorte Caves. In May 2018, we discovered an inscription on the wall of Blanche Cave that can be attributed to Thomas Hannay, providing evidence of the photographer's visit to the caves. This inscription highlights the importance of historical writing in caves as primary information for historical research. In this paper we present background information on the 1860 Hannay photographs of Naracoorte Caves and describe the inscription found in Blanche Cave. We also discuss the historical value of cave inscriptions and the issues relating to cave restoration projects that involve removal of 'graffiti'.

Key words: Naracoorte Caves, Thomas Hannay, cave photography, Julian Tenison-Woods, Alexander Burkitt, historical graffiti, cave conservation

The Naracoorte Caves

Naracoorte Caves National Park, in the south-east region of South Australia, is renowned for its vast deposits of Quaternary vertebrate fossils spanning the past 500,000 years (Reed & Bourne 2000). The global significance of the park's palaeontological values was formally recognised in 1994 with inscription on the UNESCO World Heritage list as the Australian Fossil Mammal Sites (Riversleigh/Naracoorte). A serial nomination with Riversleigh in north-west Queensland, the two localities contain rich fossil records that document the evolution and palaeoecology of Australia's mammal faunas spanning more than 20 million years (Reed & Bourne 2009).

Originally known as the Mosquito Plains Caves, the Naracoorte Caves were first recorded by European settlers in 1845 and subsequently became popular attractions for the local community and visitors to the district (Hamilton-Smith 1986; Reed & Bourne 2013). Prior to 1885, access to the caves was unrestricted, leading to damage and degradation of the large and easily accessed caves such as Blanche Cave. By the late 1860s, several authors reported that the caves were in a degraded state due to specimen hunting, social activities and graffiti (Reed & Bourne 2013). The caves were further damaged during the mining of bat guano in the 1870s.

An article describing a visit to the South East district by the Select Committee to enquire into draining works in Victoria documents the presence of graffiti in Blanche Cave:

> *The Blanche Caves may fairly be considered one of the natural wonders of South Australia, although they have been greatly denuded of their pristine beauty by the characteristic destructiveness of tourists. Nearly every stalactite in the caves has been carried off, and several stalagmites – in wanton mischief it must have been done – have been thrown down. Indeed, parodying Byron's well-known lines it may be aptly said :- "Man's defacing fingers have swept the lines where beauty lingers.*

The ceilings have been cleared of every stalactite, and some visitors have still further disfigured the caves by tracing in the roof, with the smoke of a candle, their names or initials. It seems almost a pity that some steps cannot be taken to preserve these caves from injury by mischievous visitors, for they must be numbered among the very few natural wonders of which as a colony we can boast. (*The South Australian Chronicle and Weekly Mail*, Saturday 20 April 1872, p.12.)

In 1876, the land surrounding the caves became the responsibility of the Forest Board and was designated as the Cave Range Forest Reserve. During Governor Sir William Jervois' visit in 1880, local citizens relayed concerns regarding the state of the caves and pressure increased for formal protection (Hamilton-Smith 1986). In 1885, 50 acres surrounding the caves was set aside as a reserve and the caretaker Daniel Battams appointed to care for the caves and oversee visitors. This marked the beginning of formal tourism to the park, with a fee recovered from visitors to assist with development and protection of the caves.

Today, the park is a major tourist attraction, scientific research locality and holds three levels of heritage listing including State Heritage (1986 and 2016), National Heritage (2007) and World Heritage (1994). Although the primary significance of the Naracoorte Caves is their palaeontological record, the various heritage listings reflect the many other important aspects of the caves including geological, biological, cultural and historical values.

Naracoorte's caves have inspired photographers for over 150 years. Early photographs provide insight into the condition of some caves prior to development and reflect the activities of significant historical figures related to the caves (Reed & Bourne 2013; Reed 2016). In 1860, three photographs of Blanche Cave were produced by a photographer who until recently remained unidentified. New research suggests the unknown photographer was Mr Thomas Hannay of Maldon in Victoria (Reed 2016). However, despite this breakthrough there was no direct, physical evidence connecting him to the Naracoorte Caves. Here we present new evidence directly linking Thomas Hannay to Blanche Cave and confirming his presence at the site.

Thomas Hannay – first photographer of Naracoorte Caves

A set of three photographs produced in 1860 (Figures 1, 2 & 3), portray scenes from the second and third roof window entrances of Blanche Cave at Naracoorte (Figures 4 & 5). Held in the collection of the State Library of South Australia (B36858,

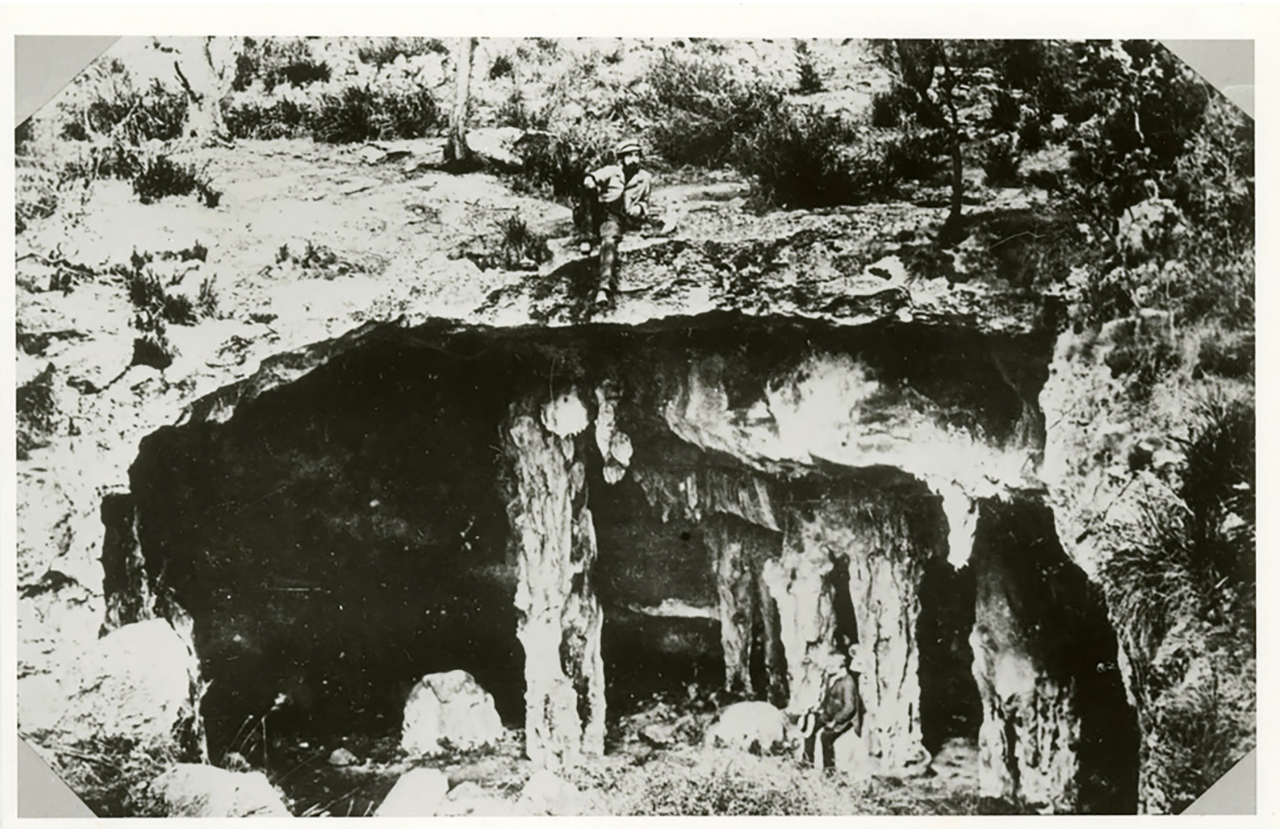

Figure 1. Blanche Cave, 1860, second roof window entrance. Julian Tenison-Woods seated above cave. Photographer: Thomas Hannay. State Library of South Australia, B36858.

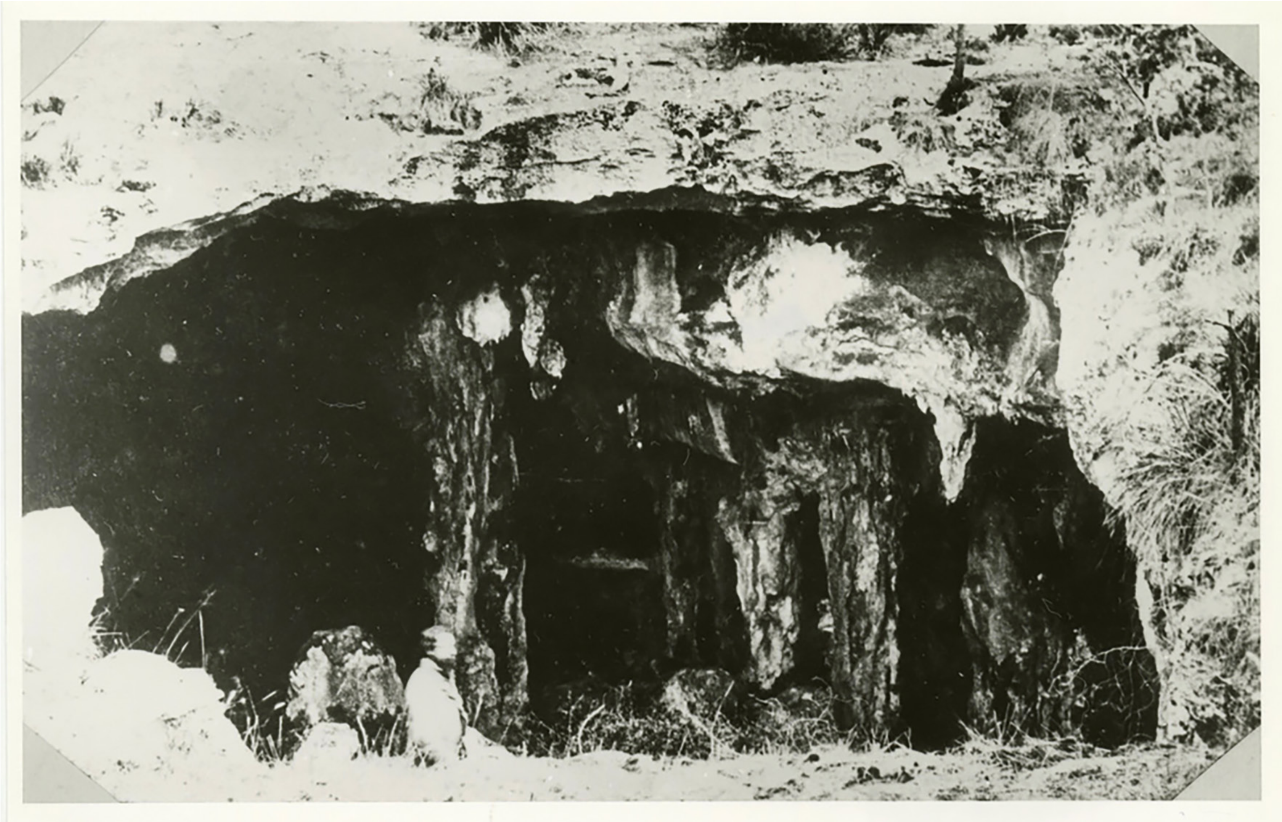

Figure 2. Blanche Cave, 1860, second roof window entrance. Julian Tenison-Woods figured.
Photographer: Thomas Hannay. State Library of South Australia, B36859.

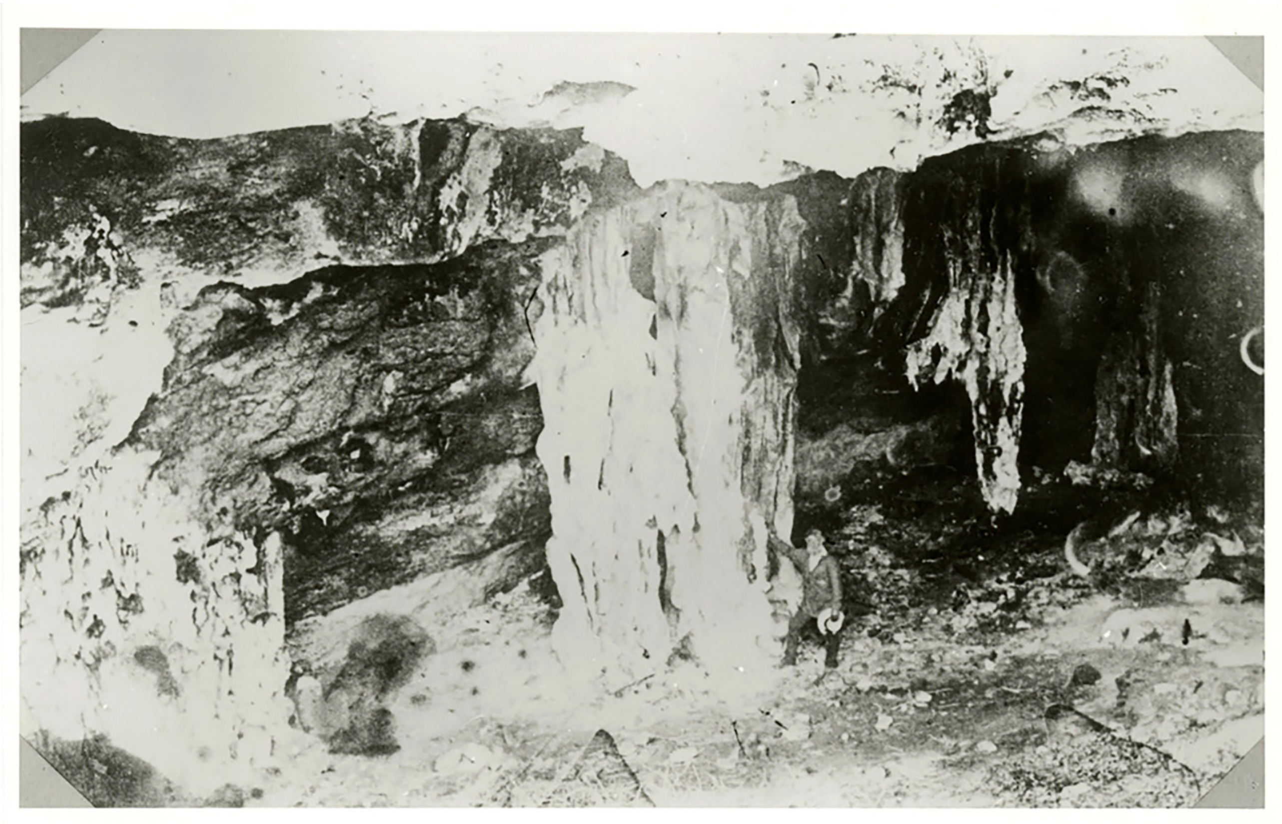

Figure 3. Blanche Cave, 1860, third roof window entrance.
Photographer: Thomas Hannay. State Library of South Australia, B36860.

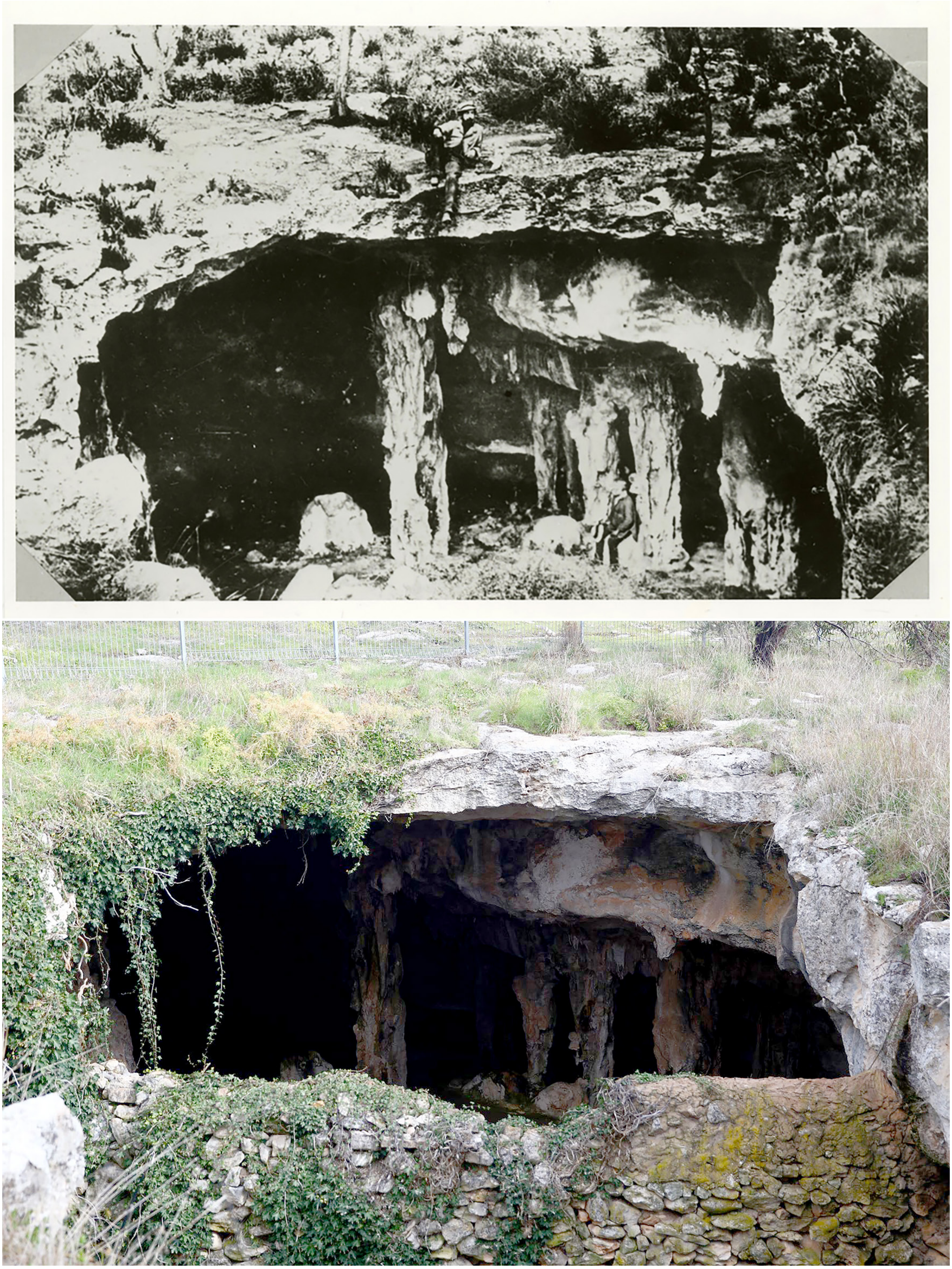

Figure 4. Blanche Cave second roof window entrance.
Above – 1860 photograph by Thomas Hannay. State Library of South Australia, B36858.
Below – 2018 photograph by the authors.
Note the presence of a stone wall, which was constructed sometime after 1885.

Figure 5. Blanche Cave third roof window entrance.
Above – 1860 photograph by Thomas Hannay. State Library of South Australia, B36860.
Below – 2018 photograph by the authors.

B36859 and B36860[1]), the photographs are significant for their association with the Reverend Julian Tenison-Woods who appears in two of the images (Reed 2016). Indeed, Woods commissioned the photographs to be used by artist Alexander Burkitt to produce engravings for the book 'Geological observations in South Australia: Principally in the district South-East of Adelaide' (Figures 6 & 7; Woods 1862; Hamilton-Smith 1997). Woods is

[1] Additional photographs held in the collection of the State Library of South Australia (SSLA) show various scenes of Naracoorte and surrounds from 1860/1861 (SSLA B36862, B36864 to B36867). They have the same album mounting as the Hannay photographs and may be attributable to him. The style and subject matter reflect other examples of his work.

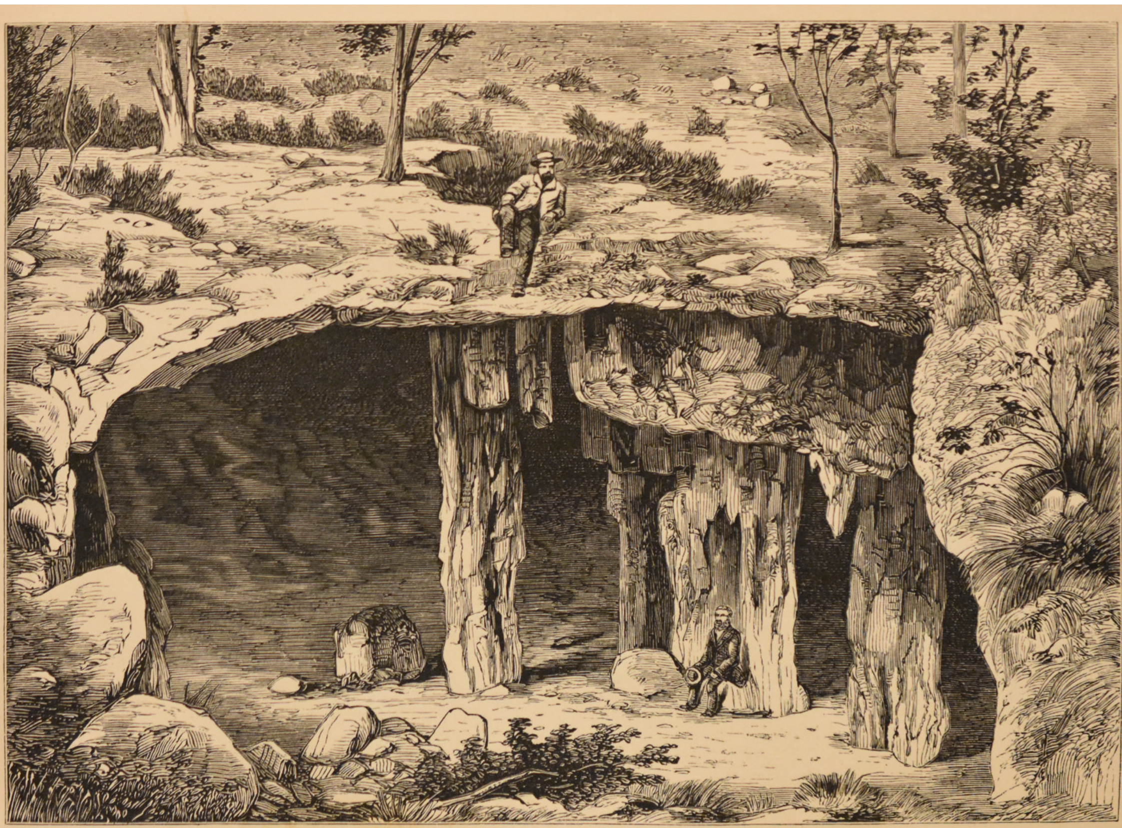

Figure 6. “Caves of Mosquito Plains Third Chamber”, woodcut by Alexander Burkitt; photographed from original plate in Woods (1862).

Figure 7. “Caves of Mosquito Plains Second Chamber”, woodcut by Alexander Burkitt; photographed from original plate in Woods (1862).

pictured conspicuously sitting on the edge of the cave entrance in one photograph (Figure 1) and standing inside the cave in another (Figure 2). The third image shows the view from above the third roof window entrance (Figure 3) and includes an unknown gentleman who is also seen in another of the photographs (Figure 1). It is possible that this man is Alexander Burkitt as he was known to travel with Woods during the preparation of the book.

Hamilton-Smith (1997) noted the association between Woods and Burkitt, but was unaware of the identity of the photographer who produced the three images:

> *The remarkable Father Julian Tenison Woods had three photographs taken of the Blanche Caves at Naracoorte in South Australia. These were then used as the basis of Burkitt's illustrations in Woods' 1862 monograph Geological Observations in South Australia. Although copies of the photographs exist, the location of any original prints is unknown, and the identity of the photographer similarly remains a mystery. It may have been Burkitt himself, or perhaps one of the itinerant photographers who toured regional areas at the time.*

A story titled "The Mosquito Plains Caves" appeared in an 1862 periodical (*The Leader: a weekly journal of news, politics, literature and art*, 22 March 1862, V. 10, No. 325: 1). It was accompanied by an engraving depicting a scene from one of the 1860 photographs of Blanche Cave (Figure 8; also compare Figure 1). This

THE MOSQUITO PLAINS CAVES.
FROM A PHOTOGRAPH BY THOMAS HANNAY, MALDON.

Figure 8. "The Mosquito Plains Caves. From a photograph by Thomas Hannay, Maldon". *The Leader: a weekly journal of news, politics, literature and art* (Melbourne), 22 March 1862, Vol. 10, No. 325, p. 1

engraving has not been reported previously by cave historians (Reed 2016). It bears the signatures of two artists, namely the engraver Samuel Calvert and the painter Nicholas Chevalier, both influential artists of the time (Reed 2016). Calvert was known to produce wood engravings from paintings and drawings by Chevalier, and the presence of both signatures on the Blanche Cave picture suggest they collaborated in the production of the image (Reed 2016). Additional biographical information about these artists is presented in Reed (2016). The most significant detail from the picture in *The Leader* is provided by the caption, which cites the photographer as Mr Thomas Hannay of Maldon and confirms the identity of the unknown photographer of the 1860 images commissioned by Tenison-Woods.

The Maldon-based photographer Thomas Hannay was active around Portland and other areas of regional Victoria during the late 1850s, particularly 1859 (Reed 2016). A large collection of his images, depicting rural settlements and people, is held in the State Library of Victoria. Particularly striking are his images of Aboriginal people from regional Victoria. Although considered to be an amateur he did exhibit his work and published in the Portland newspaper. Two gentlemen named Thomas Hannay lived in Maldon at the time the Blanche Cave photographs were taken (Reed 2016). Charles Thomas Hannay (known as Thomas) was born in 1805 and died in Maldon on 6 December 1883 (Reed 2016). His son, Thomas Hannay, was born in 1834 and died in 1897 (Reed 2016). Hannay senior was originally from Scotland and became a well-known and respected member of the Maldon community. The junior Hannay was a renowned marksman and also served as a Councillor in Maldon and later worked in Melbourne as the superintendent of the Immigrant's Home (Reed 2016). We cannot confirm which Hannay was the photographer of Naracoorte Caves, but suggest it was probably Hannay senior (Reed 2016).

Noted historian of Australian caves, Elery Hamilton-Smith, asserted the 1860 Blanche Cave photographs were the first showing an Australian cave (Reed 2016):

> *... the unknown photographer who provided the pictures of Tenison-Woods at the caves was also the first to photograph an Australian cave.*

Given the date of Thomas Hannay's Blanche Cave images, they may also be some of the earliest photographs in the world to depict a cave. Charles L. Waldack photographed Mammoth Cave in the United States in 1866 and he is regarded as the first photographer of an American cave (Howes 1989; Thompson, 2000). Early photographs from Europe depict scenes from entrances and within caves, with the first artificially lit cave photographs captured using magnesium light at Blue John Caverns by Arthur Brothers in 1865 (Howes 1989). Further research may yield additional early photographs of Naracoorte Caves..

The Hannay inscription in Blanche Cave

Despite information in *The Leader* identifying Hannay as the cave photographer, there was no physical or other evidence linking him to Naracoorte Caves. In May 2018 during a tour of Blanche Cave, one of us (ER) recognised that an engraved signature on the cave wall belonged to Thomas Hannay. We have been aware of this signature for many years, but until Hannay had been identified as the photographer of the 1860 images (Reed 2016), the significance of it was missed. This inscription provides direct evidence that Thomas Hannay visited Blanche Cave and it is located adjacent to the area where two of the images (Figures 1 & 2) were staged at the second roof window entrance (Figure 9). Additional initials in the same style as the main inscription are visible to the left and may represent another attempted engraving (Figure 10), but we will focus here on the full inscription which reads: 'T HANNAY PHOTOGRAPHER' (Figure 11).

The inscription is arranged across two lines, with 'T HANNAY' on the top line and the single word 'PHOTOGRAPHER' beneath. It is around one metre long, carved and scratched into the limestone. The uneven surface of the rock clearly proved difficult to mark in such a way, as the inscription is irregular and incomplete in places where the limestone is harder due to a calcite matrix (Figure 11). The presence of multiple scratches of around one-millimetre thickness within each carved letter suggest the marks were made with a sharp blade or knife. The carved surfaces have revealed the cleaner, creamy-white limestone beneath, while the surrounding wall is stained by biological growth and natural weathering. Unlike the many people who signed their name in Blanche Cave, Hannay did not add a date to his inscription; however, there is no reason to believe it was not directly associated with the 1860 photographs and dates to that time.

Figure 9. Location of the Hannay inscription in Blanche Cave. Arrows indicate the signature on the wall (right) and the rock where the figure was seated in the 1860 photograph (see Figure 1).

Figure 10. The Thomas Hannay inscription (indicated by a black arrow) on the NW wall of Blanche Cave adjacent to the second roof window entrance. The white arrow indicates a set of initials 'T.H.' in a similar style to the other inscription.

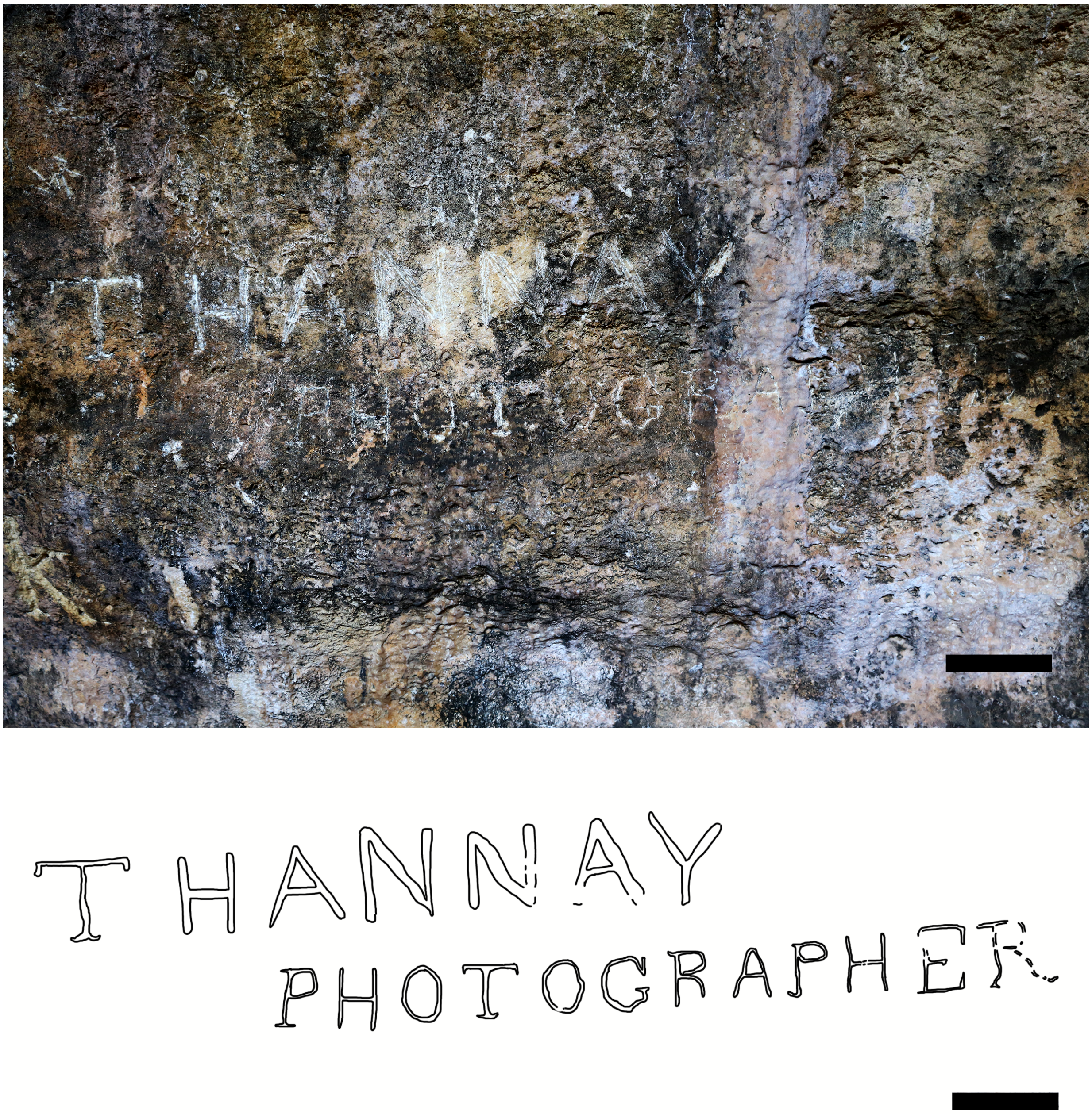

Figure 11. The Thomas Hannay inscription on the cave wall in Blanche Cave (above) and an outline of the inscription (below). Scale bars are 10 cm.

The priest, the photographer and the engraver

Woods first reported his observations of the Mosquito Plains Caves in 1858, following a visit in 1857 (Woods 1858; Reed & Bourne 2013). It was this work that formed the basis for his later book. Hamilton-Smith (1997) suggested Reverend Julian Tenison-Woods commissioned the 1860 photographs for the purpose of producing engravings for his book and these were completed by artist Alexander Burkitt. The use of photographs in printed materials was not common at the time, although an advertisement in the *Border Watch,* Friday 3 October 1862, p. 1 mentions the use of photographs to produce scenic views in the book:

In the Press and will shortly be published in one volume, 8vo., GEOLOGICAL OBSERVATIONS ON SOUTH AUSTRALIA, By the Rev. Julian E. Woods, F.G.S., F.R.S.V., &c., &c. This work will contain a popular account of the Geological and Mineral Features of a great portion of the South Coast of Victoria and South Australia, and will be illustrated by many Engravings of newly discovered Fossils, named and classified. The work will likewise be largely interspersed with views (from photographs) of the extinct Volcanoes of Mount Gambier, the Caves at Mosquito Plains, &c., &c., besides an interesting account of the Geology of these remarkable features. Orders received by H. T. Dwight, Bookseller, near Parliament Houses, Melbourne; Mr. W. A. Crouch, Mount Gambier; or at the Office of this Paper. As only a limited number of copies will be printed, subscribers names should be sent in as early as possible.

Alexander Horace Burkitt (also known as A.H. Burkitt) was born in London in 1807. He was interested in art and antiquities from an early age and later became an engraver (Love 1980). In 1855, following the death of his wife Jane, he and his children moved to Australia to join his eldest son Horace who worked as a telegraph operator in Geelong and Melbourne (Love 1980). In February 1858, Alexander and family moved to Portland in Victoria to live with Horace after the opening of the Portland electric telegraph station (Love 1980). This placed Burkitt just 200 kilometres from Naracoorte immediately prior to the publication of Tenison-Woods' first account of the caves in March 1858 (Woods 1858). Furthermore, the photographer Thomas Hannay was very active in Portland at the time and a series of his images was chosen for publication in the *Portland Chronicle* in 1859 (Reed 2016). If Burkitt and Woods were acquainted and had already agreed to collaborate on production of figures for the book, then Hannay's increased profile as a photographer in Portland and his proximity to Burkitt may have won him the commission.

After moving to Portland, Alexander Burkitt worked and journeyed around Victoria and the south-east of South Australia, including travels with Tenison-Woods while the priest completed *Geological Observations*. Although this has been reported to have occurred during 1862 (DAAO 1992), it is more likely 1860 to 1861 as the book was published in 1862 and Woods wrote an acknowledgement to Burkitt dated November 1861:

> *One word in conclusion, with regard to the engravings. The views are from photographs. The fossils, &c., are from drawings by Mr. Alexander Burkitt, of Williamstown Observatory, Melbourne (late of the Isle of Wight). This opportunity is taken of returning very grateful thanks to that gentleman for his exertions in perfecting the illustration of the work. Penola, South Australia: November 15, 1861.* (Woods 1862).

Alexander Burkitt became an assistant at the Williamstown Observatory in 1861/62 and in 1864 moved to Queensland where he settled in Ipswich. He died at Cleveland, Queensland in 1873. Burkitt and Woods worked together on one more project, with the production of engravings for another book (Woods 1865) for which Burkitt was acknowledged:

> *... secondly, to Mr. Alexander Burkitt, late of the Williamstown Observatory, not only for the maps and sketches which illustrate the following pages, but also for a really terrible amount of copying, and a zeal for the success of the whole work, to which I can scarcely do justice here.*

The value of historical writing in caves

In 1879, Thomas Washbourne took a series of photographs in Blanche Cave, showing scenes beneath the second and third roof window entrances (State Library of Victoria H96.160/227 to 231). A report in *The Hamilton Spectator* (Thursday 21 August 1879, p. 2) records his visit to the Naracoorte Caves:

> *Photography. – Mr. Washbourne, after a lengthened absence, has returned to Hamilton, bringing with him some of the finest photographic pictures we have yet seen from his studio. Four of these are of a decidedly novel character, being representations of the inside of some of the wonderful caves at Narracoorte, which, owing to "the dim religious light" in which he was compelled to take them, occupied a considerable time, but his industry was well rewarded."*

One of the Washbourne photographs shows the area adjacent to the Hannay inscription, with a man leaning against a large column (Figure 12). Unfortunately, the Hannay signature is not visible, but others are obvious on the cave wall. As far as we are aware this is the first photograph showing 'graffiti' in the Naracoorte Caves. The signatures from this scene are no longer clearly visible and are now concealed by biological growth and natural weathering (Figure 13).

The Thomas Hannay inscription in Blanche Cave demonstrates the value of historical writing in caves, particularly when it is used as a primary source of information for research into the history of significant localities (Whyte 1997; Bilbo & Bilbo 1995). While these markings may be deemed unsightly or counter to the current paradigm of cave management, it can be damaging to the cave environment to remove them (Bilbo & Bilbo 1995). Graffiti removal and other cave 'cleaning' may not only have consequences for historical research, but also impact biological organisms and the integrity of the cave walls and other values.

Cave cleaning in Stick Cave at Naracoorte in the late 1980s resulted in exclusion of the cave cricket *Novotettix naracoortensis* from one side of the cave entrance and a decline in use of the cave by crickets (Simms and others 1996). Microbial and other biological communities on cave walls are part of the energy dynamics of the cave ecosystem and important food sources for animals such as invertebrates. Natural cave walls also provide habitat and refuge for animals and this can be obliterated by cleaning.

Figure 12. 1879 photograph by Thomas Washbourne of a scene near the NW wall of Blanche Cave adjacent the second roof window entrance. State Library of Victoria Image H96.160/231

Figure 13. Comparative views of the area from the Washbourne photograph (Figure 12), showing the scene in 1879 and in 2018. Note the difference in the visibility of the graffiti behind the columns. It is interesting to note the stalagmite near the signature area in the modern photo. This is not apparent in the 1879 photograph and must have been placed there.

A project in Cathedral Cave at Naracoorte Caves was aimed at restoring a heavily vandalised cave to a more natural state to benefit cave biology and improve the aesthetics and safety of the cave for visitors (Bourne 2001). The project was successful overall and today the biology of the cave is thriving. Carved inscriptions in the entrance chamber of the cave were left intact in favour of preserving natural biological communities (Bourne 2001). However, it was noted that removal of candle smoke markings from the walls in the dark zone resulted in an immediate impact on cave invertebrates. As the cleaning was done carefully and in small, patchy areas, cave fauna re-colonised relatively quickly; but this is an important example of how well-meaning restoration has consequences (Bourne 2001).

The decision to remove inscriptions becomes complicated when there is obvious and unsightly modern graffiti overlying areas of cave walls and other traces of damage by unwanted visitors (Bilbo & Bilbo 1995). If the only reason for removal is aesthetic (i.e. it is unsightly), we suggest that is not sufficient justification if it results in damage to the cave wall. Removal of graffiti may be justified in some cases as a deterrent to future vandalism by not drawing attention to an area, but in 'soft' limestones such as Naracoorte it may in fact serve the opposite purpose. The Miocene marine limestone at Naracoorte Caves is relatively 'soft' and unconsolidated compared with much older limestones hosting other Australian cave systems. The surface of walls at Naracoorte is often covered with biological growth, particularly near entrances, and also micro-crystalline soft calcite deposits known as 'moon-milk'. Any damage to the walls is very obvious due to its different colour and cleaned areas may provide an obvious 'fresh canvas', leading to more graffiti. Effective management of visitor activities should reduce the occurrence of new markings.

Another dilemma for cave managers relates to the age of the markings. When does graffiti become history? In some cases, such as the inscription in the Drachenhöhle in Austria dating to 1387, the significance is obvious (Kempe 2017). A much later example from Jenolan Caves is a signature and sketch from around 1949, by renowned Australian artist Brett Whiteley (Whyte 1997). Bilbo & Bilbo (1995) use the cut off for historic writing as 50 years old or greater, but there does not appear to be any consensus on how managers approach this issue. Nonetheless, they suggest few cave restoration projects are preceded by the identification and documentation of historical writing prior to cleaning. Policies for cave restoration projects should be part of a site's management plan, and standard procedures developed that include thorough documentation, including photography of areas prior to restoration and consultation with specialists if historical writing is found. The decision to remove graffiti or clean areas of caves should be weighed against the potential impact on other values.

Conclusions

The discovery of the inscription by Thomas Hannay in Blanche Cave at Naracoorte confirms that the photographer visited the cave. The photographs he produced in 1860 are likely the first to depict an Australian cave and illustrate the association between Woods, Hannay and the engraver Alexander Burkitt, providing a fascinating insight into the early history of the Naracoorte Caves and the activities of three historically significant figures.

Historical writing in caves serves as primary evidence for historians and should be considered important cultural heritage. We suggest graffiti removal is largely inappropriate in soft limestones such as at Naracoorte as the conservation benefits of leaving surfaces intact outweigh the aesthetic reasons for removal. If cave cleaning is to be conducted it should be done only after thorough documentation of the area and justification for restoration is considered.

Acknowledgements

Thank you to the late Elery Hamilton-Smith for sparking our interest in the historical aspects of Naracoorte Caves. We thank students from the Australian Science and Maths School, Zac Dean and Kiana Gwatking, for their assistance with finding the Hannay signature in Blanche Cave. Thanks also to the Caves Manager Nick McIntyre and staff of Naracoorte Caves National Park for their support and assistance with this research.

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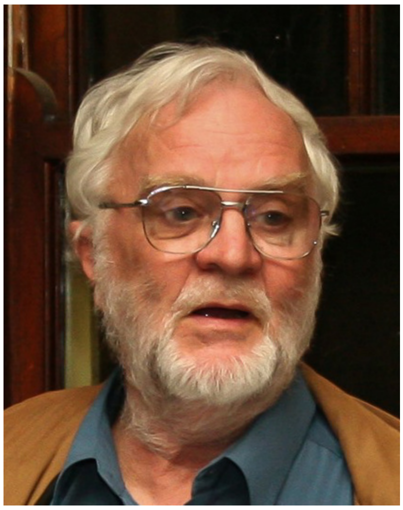
Vale John Dunkley AM
19 March 1943–1 February 2018

Greg Middleton and Andy Spate



John Robert Dunkley passed away on 1 February 2018, aged 74, at peace after several traumatic months for himself and his wife, Jeanette. He was an important figure in Australian speleology and particularly in the development of the Australian Speleological Federation, with which he was involved from the 1960s until 2018.

John attended West Ryde and Eastwood primary schools in Sydney before starting high school at Fort Street High. Later he studied at Sydney University, thanks to a Commonwealth scholarship. He studied economics, though he later conceded it is rightly named "the dismal science" and he taught it for the first ten years of his career. John is reported to have said "I despaired of it [economics] then and I despair of it now. It just doesn't deliver the answers it appears to promise to the problems facing people" (Ellery 2013).

Originally a member of the NSW teaching service, John switched to teaching geography and later in his career became interested in teaching legal studies. John and his wife, Jeanette, moved from Sydney to Canberra when the ACT teaching service was established in 1974. Over the next 23 years until his retirement in 1997, he taught at almost every high school in the territory including Narrabundah, Weston Creek, Melrose High and Lake Ginninderra College.

Probably the first biographical note on John appeared in *Caves of the Nullarbor (1967), of which he was co-editor:*

> *J.R. Dunkley B.Ec., Dip.Ed. (Sydney) a former secretary of Sydney University Speleological Society, and at present Secretary of the Australian Speleological Federation, has participated in several expeditions to the Nullarbor. His particular interests include aspects of cave conservation and historical records.*

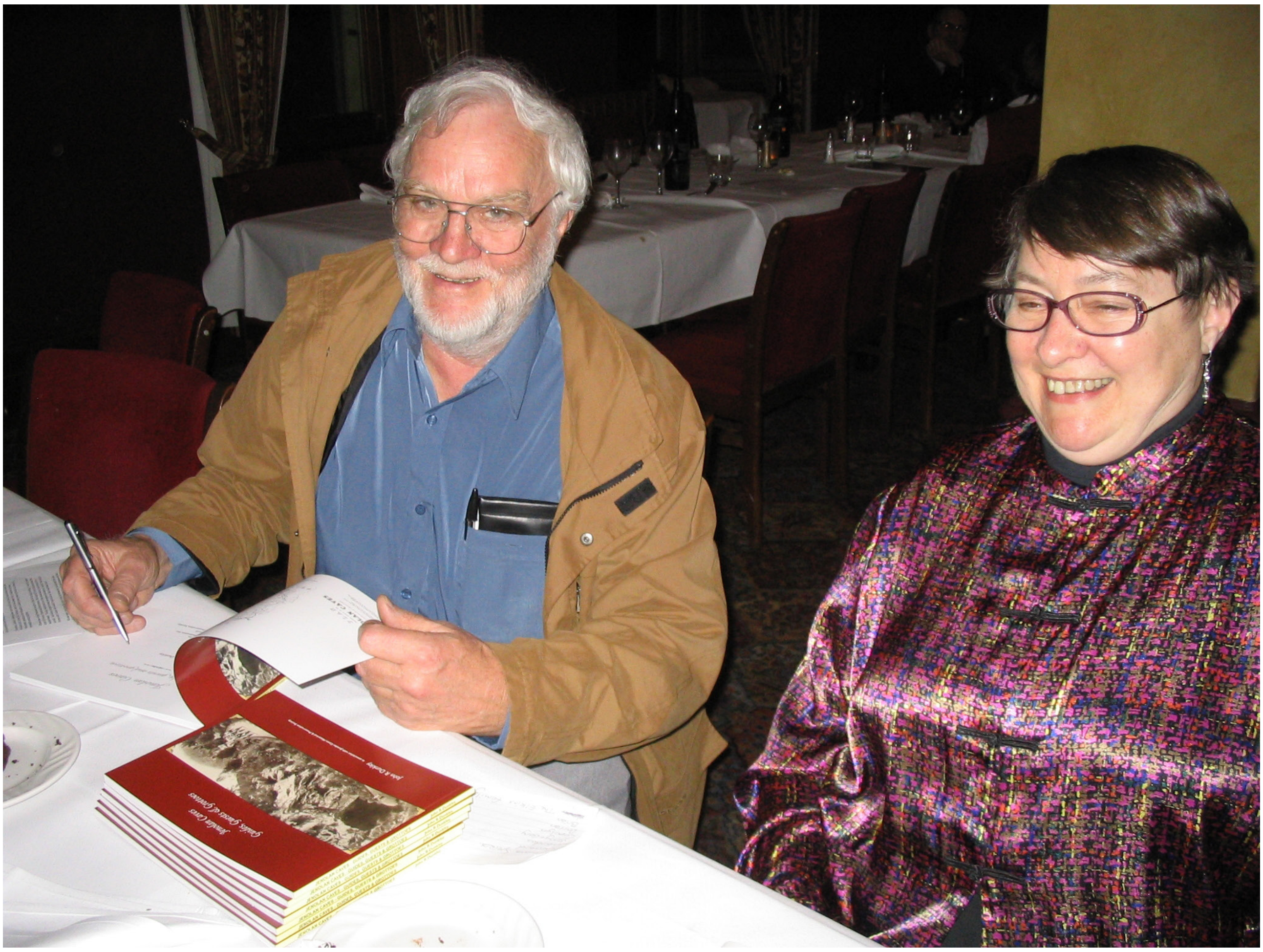
John published widely in the speleological literature on many subjects (see 'Published Works', below) and was a member of a number of ASF-affiliated clubs, most notably Sydney University Speleological Society, Canberra Speleological Society and Highland Caving Group.

In 2013, John recalled "My first real limestone cave was Junction Cave at Wombeyan. It was a tourist cave, quite well lit, with some large chambers and well decorated - it was an attractive cave" and further: "I quickly became blasé about common decorations; there is an awful lot of it. I am most interested in large and impressive caves and the sheer spectacle of chambers such as at Abrakurrie on the Nullarbor." (Ellery 2013).

Jenolan Caves

John joined the Sydney University Speleological Society (SUSS) in the early 1960s and soon developed a great personal interest in Jenolan which has been a long-term major focus of SUSS. His many trips there led to his writing *The exploration and speleogeography of Mammoth Cave, Jenolan* with Edward G. Anderson in 1971. This was the first Australian book to document a single cave system in detail. John assisted with a second book focused on *Jenolan, The caves of Jenolan 2: The Northern Limestone,* written by Bruce Welch in 1976. Both of these books were funded by the Speleological Research Council, a company closely associated with SUSS, and of which John was an active member.

While he subsequently turned his interest to caves further afield, John never lost his fascination with Jenolan and its interesting history. When the Jenolan Caves Historical & Preservation Society (JCH&PS) was established in 1972 he was elected its first treasurer and became vice-president in 1974. In 1986 he wrote Jenolan Caves as they were in the nineteenth century which was published by SRC Ltd and JCH&PS. In 2007 he completely rewrote this as Jenolan Caves: guides, guests and grottoes; it was published jointly by ASF and JCH&PS. He enthusiastically supported the "Science of Jenolan Caves" symposium organized jointly by the Lin-



John and Jeanette Dunkley at the launch of "Jenolan Caves, guides, guests and grottoes" at the JCH&PS 35th Anniversary Dinner, Jenolan Caves, August 2007. Photo: Jenny Whitby.

nean Society of NSW and ASF in 2013, at which he presented a paper on the history of cave science at Jenolan. A number of the presented papers were subsequently published but he was disappointed that the proceedings were not published as a separate volume.

Nullarbor Plains

John played an active role in Nullarbor trips in the 1960s. He participated in a private trip to Mullamullang in May 1965 with Bill Crowle and Dick Heffernan, during which significant discoveries were made (Hill 1966, p. 8). John was also involved in the CEGSA Dec. 65-Jan. 66 expedition, reporting on it (anonymously) in the *SUSS Newsletter* of February 1966 (Dunkley 1966). He was also on the January 1966 and August 1966 CEGSA expeditions (Hill 1966, p. 4).

This involvement led to his editing and producing *Caves of the Nullarbor* with T.M.L. Wigley in 1967. This was probably the most significant book produced by Australian speleologists up to that time. As well as editing, John wrote the introductory chapter "The geographical and historical background". The book was published by the Speleological Research Council in Sydney and seems to have been the spark that initiated John's long-term interest in speleological publication.

Australian Speleological Federation, Speleopolitics and Awards

Apart from being an active caver, John was an enthusiastic 'speleo-politician', which is really just to say that he was interested in the running of organisations that carry out speleological activities. He became Secretary of SUSS not long after joining, held a number of other committee positions and rose to be Vice-President and President of that society in the period 1970 to 1973. He became Secretary of ASF in 1966-67, was VP 1981-82, 1999-2002, 2005-15 and President 1983-86, 2002-05. He held a number of other positions in ASF, including Convenor of the NSW Coordination Committee, the Commission on International Relations (with Elery Hamilton-Smith), the Commission on Cave & Karst Management and Director of the Karst Conservation Fund. After his involvement in the drawn out, but ultimately successful, Mt Etna Caves conservation

(Left to right) Terry Bolger, Frank Garnier and John Dunkley in the Khammouane karst (Phou Hinboun National Protected Area) in October, 2008. Photo: Noy Somphilavong.

campaign, John was particularly keen to get ASF registered as an Environmental Organisation. This took three years' work, but was achieved in June 2001. Among other benefits, this gained tax-deductibility, enabling the Karst Conservation Fund to be set up. John was a founding Director and remained on the Management Committee until 2016. The establishment of this fund was probably the personal achievement of which he was most proud.

For his "significant service to the exploration, science and conservation of caves and karsts" John was appointed as a Member of the Order of Australia in 2013. A list of positions John held in speleological organisations (probably not exhaustive) and awards he received, is appended.

Australasian Cave and Karst Management Association

John had a long-term passion for cave conservation and management. When Elery Hamilton-Smith arranged for the First Australian Conference on Cave Tourism in 1973 at Jenolan, John played a major role in its organization and presented a paper on cave tourism and conservation. A further six conferences were organized or encouraged by the ASF Commission on Cave and Karst Management. By the time the 7th conference was held in NSW in May 1987, there was wide agreement that a separate organization for cave and karst management was necessary. The Australian Cave Management Association was formed at Yarrangobilly at the end of that conference. Subsequently ACMA became the Australasian Cave and Karst Management Association (to include New Zealand representation). John could see the need for the creation of ACKMA as a more professional body but was concerned that it moved the management focus away from ASF and he was always keen that the two organisations should work together (Dunkley 1991). He took over from Elery as Convener of ASF's Cave and Karst Management Commission in 1989 and continued with the commission until it was dissolved in 2003.

Thailand

John first visited Thailand in 1969, noting the limestone outcrops along the Death Railway in Kanchanaburi. His interest in that region had been sparked by a talk given by Elery Hamilton-Smith at the 1968 ASF Conference. However, he did not return until 1981 when, on a trip over Christmas and New Year, he visited Chiang Mai and Lampang in the north, Kanchanaburi and Phang Nga and Krabi in the south. It was on this trip that John first heard rumours of the massive karst in Mae Hong Son in NW Thailand. Researching in the National Library in Canberra in the winter of 1982, he noted the massive dolines in the mountains between Pai and Mae Hong Son and later that year made the acquaintance of John Spies, an Australian trekking guide and author, who was based in Chiang Mai. Spies had had an article published in an airline magazine and

*At entrance to Tham Din Phieng, N.E. Thailand.
Photo: Terry Bolger*

through that John had been able to track him down; he proved a most valuable contact.

John made his first reconnaissance expedition to Mae Hong Son in January 1983, followed by further visits in January and May 1984. These small group visits established the huge potential of the area. At the 1984 ASF conference John recruited a team and the first large scale expedition to Mae Hong Son was in the field in May 1985. This first expedition was followed by further expeditions in 1986, 1988, 1990 and 1992. As well as these major expeditions to Mae Hong Son, John also visited various other karst regions throughout Thailand, and in neighbouring Burma and Laos, during this period.

All of his library research and field work was summarised in John's 1995 book 'The caves of Thailand' which listed over 2,500 caves and sites of speleological interest. He added a supplement in 1997.

The 1992 expedition was the last large Australian expedition to Mae Hong Son. John had grown out of the project and had other interests. However, after a break of 15 years his interest in Thailand was rekindled and he started visiting again. Along with nostalgic trips back to Mae Hong Son, he had several road trips through north-east Thailand researching for his new interest in sandstone caves. John's last caving visit to Thailand was in February 2017 when, as well as touring the north-east, he visited caves in Chiang Mai and Lampang. Among his last writings was "Unusual caves and karst-like features in sandstone and conglomerate in Thailand" with Martin Ellis and Terry Bolger published in Helictite in 2017.

Bullita Cave, Northern Territory

John was heavily involved in the exploration of Bullita Cave, Judbarra/Gregory National Park, from 1991 to 2008. He was informed about the likely significance of the area by Keith Oliver (formally with OSS and a guide at Cutta Cutta Caves in the NT). John got the first CSS trip going under Neil Anderson's leadership. It then became a CSS-TESS project, but as the system grew more cavers became involved from across the country. A cave that was originally thought to be about 6 km long, was eventually found to be over 130 km and the longest in the country.

Speleological History

John evidenced a strong interest in Australian cave history and he contributed many papers in this field to a variety of publications. His contribution to his first major speleological publication, *Caves of the Nullarbor* (1967), dealt with the geographical and historical background. In 1976 his contribution to Welch's *The Caves of Jenolan 2: The Northern Limestone,* was 'Speleological history of Jenolan'. He subsequently wrote two books on Jenolan history and a number of significant papers on early Australian cave explorers. He presented at the Australian Caves History Seminar at Jenolan in 1985. His contribution to the *Encyclopedia of Caves and Karst Science* (2004) drew on his interest in both Southeast Asian caves and history.

One of his last projects, about which he was most enthusiastic, was to have published an English translation of J.V. Daneš's *Karst Studies in Australia 1916.* He arranged for John Pickett to prepare the translation which is published in this volume of *Helictite* and, with Bruce Welch, he prepared the paper tracing Daneš's travels in Australia, also published here. Sadly, he did not live to see these works in print.

John Dunkley made enormous contributions to so many aspects of Australian speleology, particularly in relation to publications, exploration, documentation, conservation and management of caves and karst, and historical studies. His influence and his legacy will be appreciated as long as caves and karst are studied in Australia.

John on edge of Selma (karst) Plateau in Oman, November 2016. Photo: Greg Middleton

Awards and Positions Held

1964-66 Secretary and Editor, SUSS

1966-67 Assistant Secretary, Publicity Officer and Jenolan Area Director, SUSS

1966-67 ASF Secretary

1969-73 Editor, ASF Newsletter [at times with others]

1970, 1973 SUSS Vice-President

1970-73 SUSS President

1972 NSW Coordination Committee Convenor

1972-74 JCH&PS Treasurer

1973 Appointed Life Member of SUSS

1973 Secretary, 1st Australian Conf. on Cave Tourism, Jenolan Caves, July 1973.

1974-82? JCH&PS Vice-President

1980 Awarded Edie Smith Award by ASF

1981-82, 2000-02, 2005-15 ASF Vice-President

1983-85; 2000-02 President, Canberra Speleological Society

1983-86, 2002-05 ASF President

2000-2018 Member, ASF Helictite Commission.

2001-2016 Director, ASF Karst Conservation Fund

2007 Appointed Life Member of ASF

2013 Member of the Order of Australia "For significant service to the exploration, science and conservation of caves and karsts."

Published Works (excluding routine trip reports and minor items)

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2017 Unusual caves and karst-like features in sandstone and conglomerate in Thailand. *Helictite,* 43: 15-31 [with Martin Ellis and Terry Bolger].

2018 The Australian travels of Jiří Viktor Daneš: Geographer, speleologist and world traveller. *Helictite*, 44: 31-43 [with Bruce Welch]

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Papers should not exceed 10,000 words, plus figures. Contributors intending to write at greater length or requiring any advice on details of preparation are invited to correspond with the Editors at ozspeleo@iinet.net.au. Short notes or 'Letters to the Editor', expressing a personal view or giving a preliminary report of interesting findings, are also welcomed. Discussions of published papers should be received within six months of the publication date, and will be passed on to the original author for response.

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