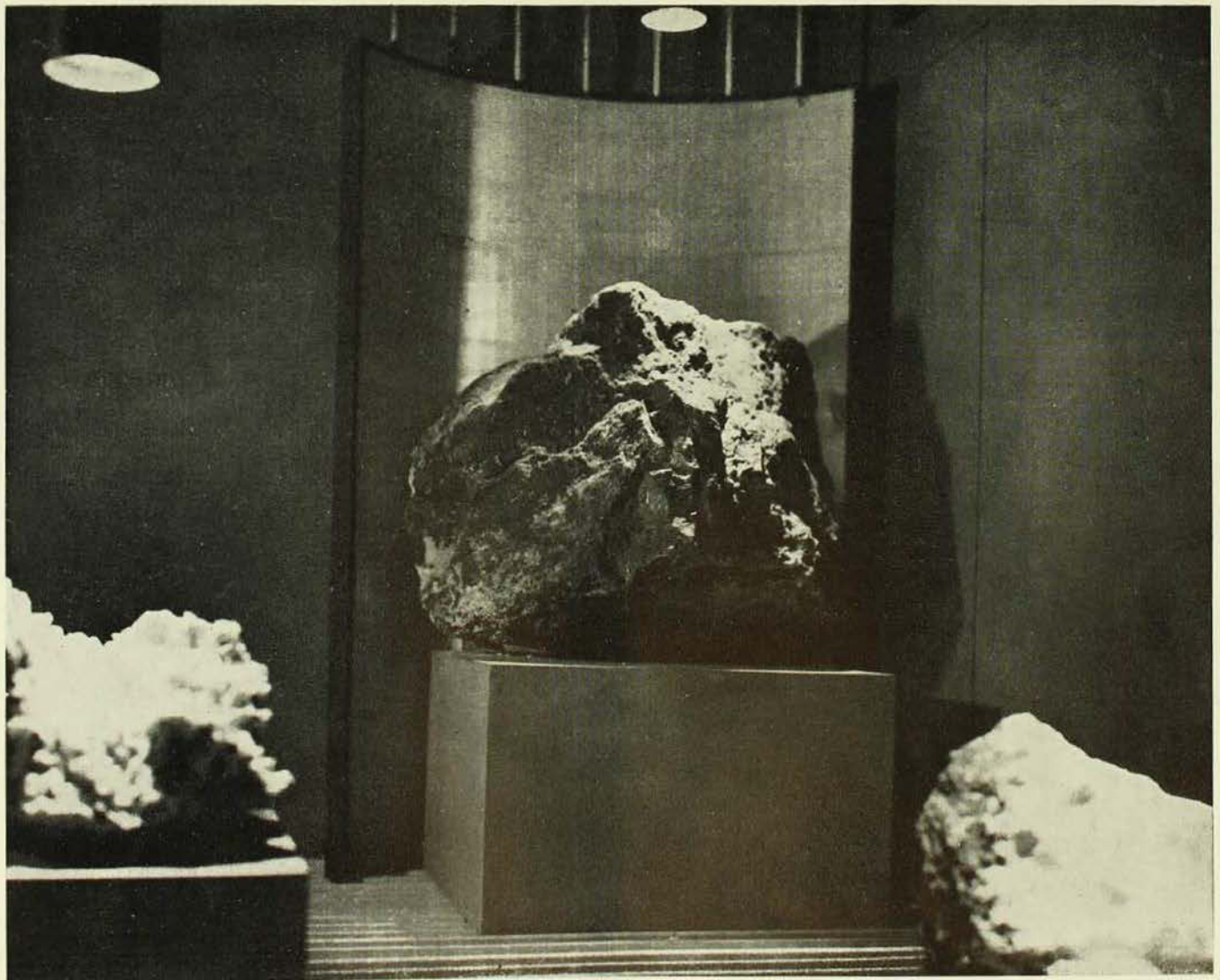


# *The* AUSTRALIAN MUSEUM MAGAZINE

VOL. XIII, No. 12

Price—THREE SHILLINGS



The Australian Museum's new exhibit of pitchblende, the richest source of the radioactive metal uranium. This huge specimen (centre), the largest piece of pitchblende ever mined, weighs just on seven-eighths of a ton. It came from the El Sherana Mine, Northern Territory. Specimens of cerussite (left) and pectolite, though not mineralogically connected with pitchblende, are displayed with it because of their great size and high quality.



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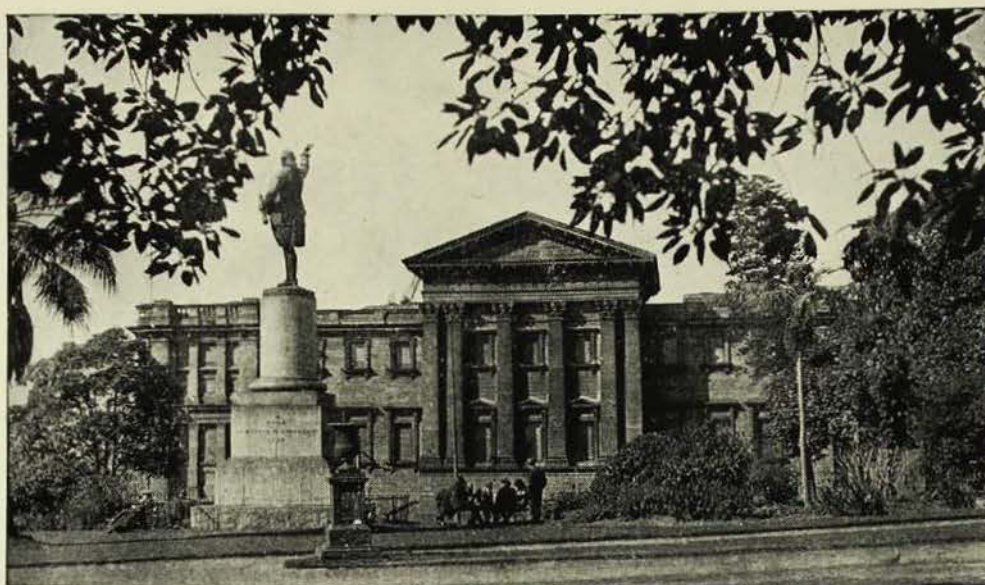
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This issue is devoted entirely  
to the minerals of Australia

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● The pitchblende specimen shown in the photo on our front cover was presented to the Museum by the Australian Atomic Energy Commission. The cerussite specimen was presented by North Broken Hill Ltd., and the pectolite by Mr. M. Myers, of Styles Blue Metal Pty. Ltd. The photo was taken by the Commission.

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DECEMBER 15, 1961

## *HILL END—THEN AND NOW*

By R. O. CHALMERS

IN the early days of the colony of New South Wales, the first life-line west of the infant city of Sydney over the coastal plains and the Blue Mountains was to Bathurst. Several finds of gold were made west of the mountains, the first being by Assistant Surveyor McBrien, who was surveying the Fish River, one of the tributaries of the Macquarie, between Rydal and Bathurst, in 1823.

Both Strzelecki and the Rev. W. B. Clarke, "the father of Australian geology", also discovered gold between the Blue Mountains and Bathurst, the former in the Vale of Clwydd in 1839, the latter near the head of Winburndale Rivulet, to the east of where Sunny Corner now stands, in 1841. In both instances the Governor, Sir George Gipps, requested that the finds should not be publicized because of the public unrest that might be caused. In 1844 the famous English geologist, Murchison, was so impressed by these and other discoveries in the Bathurst district that he actually advised unemployed Cornish miners to emigrate to New South Wales and dig for gold.

In May, 1851, the first official announcement was made following Hargrave's discovery of alluvial gold at Ophir, for which he received from the Government a sum of £10,000, not inconsiderable for those days. By the end of that month Samuel Stutchbury, an English geologist and the

sole member of the newly-established Geological and Mineralogical Survey of New South Wales, who officially confirmed Hargrave's discovery, reported 1,000 miners at Ophir, many of them getting large quantities of gold. The heaviest nuggets weighed from 1 oz. to 4 lb. By the end of 1851, Stutchbury was able to report, after his survey of the Macquarie and its tributaries from Lewis Pond's Creek, on which Ophir is situated, right up to the east of Wellington, that "there is scarcely any part wherein gold may not be found—further I may state that, as the search goes on, discovery of the precious metal is being made on the ranges and flanks thereof, far above the present water levels". (Extract from a letter of Stutchbury's to the Colonial Secretary, October 17, 1851.)

### **"Kerr's Hundredweight"**

The fever was spreading beyond the valley of the Macquarie. As parties of prospectors extended out to the north-east from Ophir, others were working down from Mudgee to Dirt Holes Creek. It was at Big Nugget Hill, on the western side of where Hargraves now stands, that the spectacular mass of gold in quartz known as "Kerr's Hundredweight" was found on July 18, 1851, by an Aboriginal shepherd employed by a property owner, one Dr. W. J. Kerr. As the "Sydney Morning Herald" of the day quaintly reported it, "Gold being the





Hill End during the gold boom of the early 1870's (above) and as it is today, a "ghost" town (below). In the lower photo the three most prominent buildings, survivors of the gold-boom days, are: the only hotel now open for business (extreme left), a two-storey derelict hotel (right of centre), and a church (right). In the top photo the hotel still open is the prominent two-storey building in the left middle-distance, the now derelict two-storey hotel is slightly right of centre, and the roof and back wall of the church are seen on the extreme right.

(Top photo. from the Holtermann Collection, Mitchell Library, Sydney; lower photo., Howard Hughes.)

universal topic of conversation, the curiosity of this sable son of the forest was excited, and provided with a tomahawk, he had amused himself by exploring the country adjacent to his employer's land and had thus made the discovery". Three blocks of quartz weighing 300 lb. yielded in all about 1 cwt. of gold. The largest block was almost pure gold because, of a total of 75 lb., 60 lb. was gold.

In this same year a party of prospectors from Ophir who had struck out in a north-easterly direction for about 15 miles found themselves on the general plateau level, at about 2,800 ft. above sea level, broken only by shallow northward-flowing gullies ablaze with wattle. A couple of troopers and a black tracker were pitching camp, on the way to Dirt Holes Creek a few miles north, presumably to keep law and order among the growing throng of miners. The prospectors pressed on to Dirt Holes Creek,

but, finding the whole place pegged out, returned south within a few days. Imagine their surprise to find hundreds of miners at work near the troopers' camp. The black tracker had dug up a fair-sized nugget while putting up a tent pole and the news had spread. (History does not relate if the troopers ever reached Dirt Holes Creek!)

This was the site of Tambaroora, and the miners soon spread their activities to cover an area some two miles to the south, which subsequently became known as Sargent's Hill and lies within the town boundary of Hill End. In addition to alluvial gold, reef gold was soon found right through this area, and the first stamper battery ever brought to Australia was put in operation to crush and extract the gold from the quartz two miles north of Tambaroora. It consisted of a beam engine working 15 head of stampers driven from a Cornish boiler and worked by Cornish miners.



## Holtermann "Nugget"

About a mile south of Hill End, the general plateau narrows down to a steep ridge plunging down on the western side about 900 ft. into Oakey Creek which, pursuing a southward course, joins the Turon River within another mile or so. This ridge is the fabulous Hawkin's Hill. The steep western flank was taken up by a succession of dozens of claims, each with shafts sunk on the dozen or so principal gold-bearing quartz veins that lay at depths below the surface not exceeding 500 ft. The most sensational finds were made between 1870 and 1872, and the highlight of them all was the Holtermann "nugget" from a depth of 130 ft. on Beyer and Holtermann's claim. This was in fact not a nugget, which is a solid lump of pure gold without any other mineral, but a great slab of slate 4 ft. 9 in. high, 2 ft. 2 in. wide and no more than 4 in. thick, with little or no quartz showing, but plenty of gold. It weighed 630 lb., and at a guess there was about 2 cwt. of gold in it, estimated at £13,000. The weight and value of the gold are not known with certainty because it was crushed together with other ore from the mine.

The photograph of Holtermann standing beside the famous specimen is well known to all because this enterprising and versatile gentleman used it in advertising patent medicines which he was peddling and even made it the subject of a stained-glass window that can still be seen in one of the older buildings of the Sydney Church of England Grammar School, ("Shore" to all Sydneysiders), situated in a commanding position in North Sydney. This building was originally Holtermann's home, built out of the fortune he made at Hill End.

## Rip-roaring Gold Town

The boom period of Hill End was relatively short, lasting only from 1869 to 1875, the yield of gold in these seven years being over £1,200,000. This was the period when the population of Hill End reached 30,000, greater than that of Adelaide at the time. It was a rip-roaring town, with 225 mining companies, 52 hotels, five banks busily engaged in handling the ceaseless flow of gold, and a number of theatres to which the populace thronged to see world-famous



Holtermann and his so-called nugget, really a slab of slate very rich in gold.

Photo.—Holtermann Collection, Mitchell Library, Sydney.

actors and entertainers. Much of the atmosphere of Hill End in its heyday has been accurately preserved for us, because Holtermann had a passion for photography and engaged a master photographer of the time, Beaufoy Merlin, to record the life not only of Hill End but of other famous mining towns of the period, such as Gulgong. Everyone will remember the excitement of a few years ago when Merlin's superb negatives, after being lost for many years, were found undamaged in a house in a Sydney suburb. They included the old photos in this article.

After 1875, the story of Hill End is that of many another boom town which gradually slipped back to become a ghost town. By 1917, the late L. F. Harper, of the N.S.W. Geological Survey, after describing





Miners' huts and shafts on the western slope of Hawkin's Hill, about a mile from Hill End, during the gold boom of the early 1870's. It was on Hawkin's Hill that the Holtermann "nugget" was found. The slope today is devoid of habitation and mining activity.

Photo.—Holtermann Collection, Mitchell Library, Sydney and Kodak (A/asia) Pty. Ltd.

the boom years, wrote wistfully: "Now two hotels supply the wants of the thirsty few and accommodate the weary travellers". At present only one hotel caters for the thirsty, but they are not as few as they were in 1917. The ghost town, Hill End, has a main street still lined with magnificent elm and plane trees, sufficient old buildings still standing to conjure up a vision of past years, small-scale reef mining going on, and mute evidence of the former activity on Hawkin's Hill in the shape of old wrecked head-frames and "flying foxes" (aerial ropeways). This all gives the old town considerable charm, and more and more

visitors are attracted each year. Most of these have a feeling for our historic past, but I suspect that among them are a few incurable optimists who visit Hill End in the hopes of finding a bonanza.

The whole Hill End-Tambaroora area was one of the most important alluvial fields in the State, but, being rather eclipsed by the great wealth of the reefs of Harper's Hill, no record was kept. Alluvial mining seemed to dwindle away at the same time as the reef mining. One of the greatest difficulties at Hill End is lack of water. The nearest river, the Turon, lies 1,400 feet below Hill End and about four miles to the south.

## MUSEUM EXPEDITION

During May, June and July of this year three members of the Australian Museum staff carried out field work in Central Australia. They were the Assistant Curator of Reptiles, Mr. H. G. Cogger, who led the party, the officer in charge of the Museum's Preparation Section, Mr. R. D. Mackay, and the Museum photographer, Mr. H. D. Hughes. The principal aim of this work was to study various problems associated with the ecology and biology of desert reptiles, and the significance of the Central Australian mountain ranges in reptilian distribution. However,

general collections of other animal groups were made, and many aspects of the expedition were filmed. The party travelled in a one-ton jeep via Broken Hill to Port Augusta, through Coober Pedy and Kulgera, to the Musgrave Ranges in the North-west Aboriginal Reserve in South Australia. Most of the party's work was in the Musgrave, Mann and Tomkinson Ranges in South Australia, but a short period was spent at Ayers Rock, Mount Olga and Alice Springs before return to Sydney via Tennant Creek, Mount Isa and western Queensland.



# NEW ZEALAND GREENSTONE

By J. J. REED

New Zealand Geological Survey, Department of Scientific and Industrial Research, N.Z.

THE predominantly greenish-coloured, fine-grained rock used by the Maoris for the manufacture of many of their implements, weapons and ornaments, has been known since European settlement in New Zealand as greenstone. This greenstone is either the mineral nephrite (Maori *pounamu*) or the mineral bowenite (Maori *tangiwai*), and was obtained by the Maori from three regions in the South Island of New Zealand.

The Teremakau-Arahura region has long

been famous as the main source of nephrite greenstone, and fortunately two early explorers, Thomas Brunner and Charles Heaphy, have given eye-witness accounts of the Maori method of finding and working the stone, which occurs as stream and river boulders weathered from the parent rock in the mountainous Southern Alps. The Maori waited for the river to subside after floods and then waded about searching for the stone, which was readily recognised by the intensification of its colour by the water.

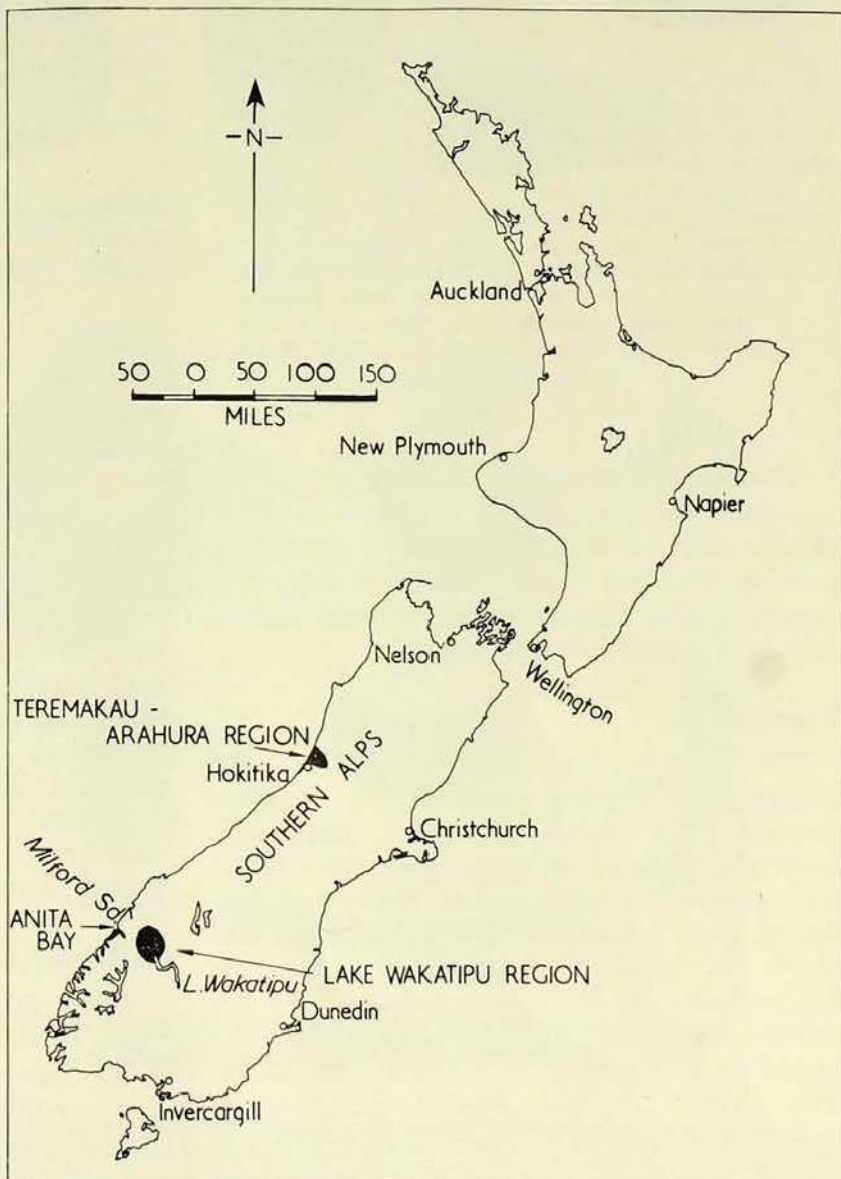
The Maoris obtained greenstone from three localities in the South Island of New Zealand:—

- The Teremakau - Arahura region, the main source of nephrite greenstone (*pounamu*).

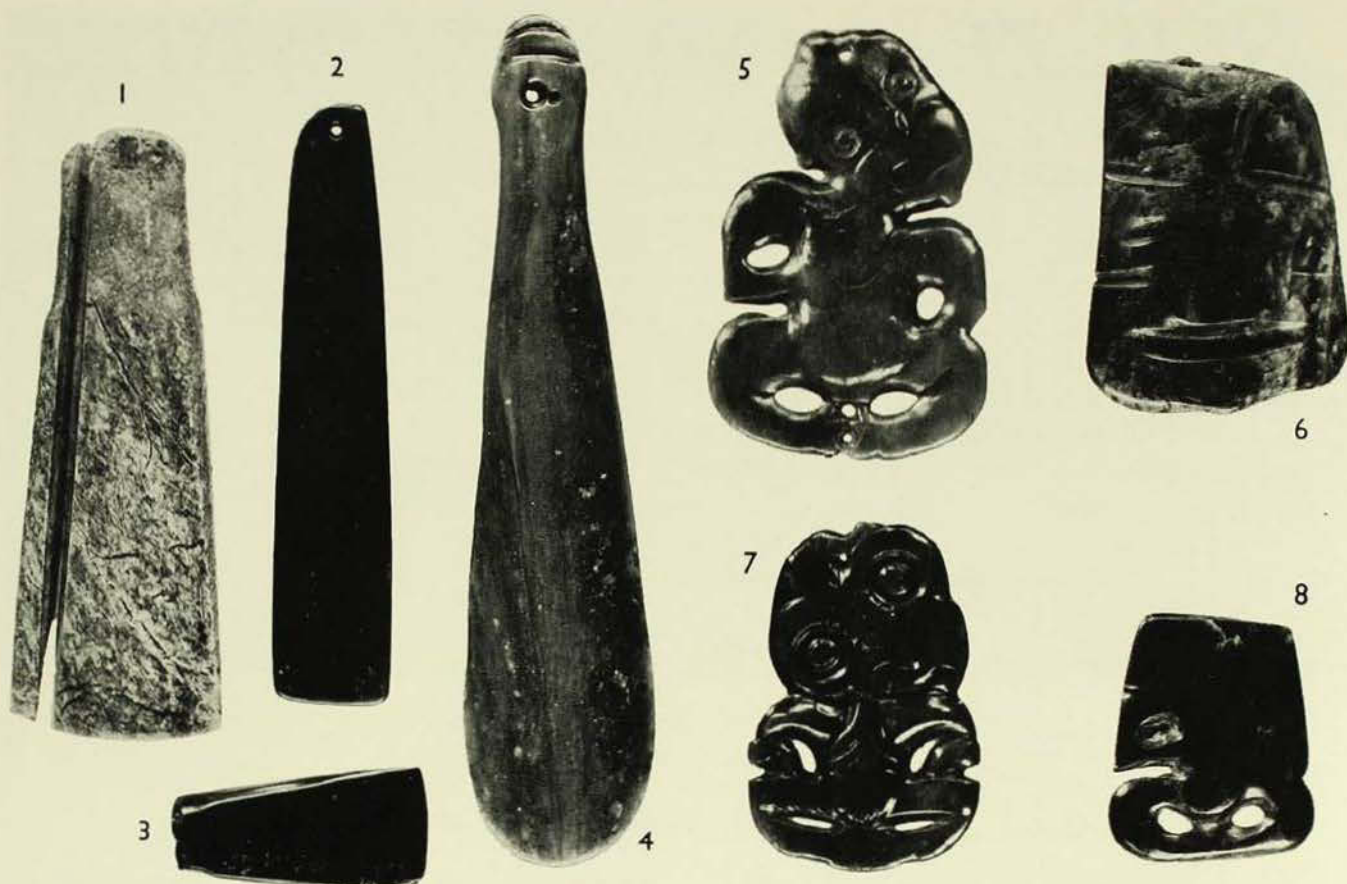
- Anita Bay in Milford Sound, the main source of bowenite greenstone (*tangiwai*).

- The Lake Wakatipu region, a source of a whitish variety termed *inanga* and of a much inferior nephrite.

Map by the author.







Maori greenstone artifacts: 1-3. The *toki pounamu*, an adze. (No. 1 shows the method of producing a straight side by the meeting of grooves cut from both faces.) 4. The *patu pounamu*, a flat short-club shaped in the simple *mere* form and used in hand-to-hand fighting.

Photo.—S. N. Beatus.

Maori greenstone artifacts: 5-8. The *hei-tiki*, or ancestral image-memento. Nos. 5 and 7 are completed forms, and Nos. 6 and 8 incomplete stages.

Photo.—S. N. Beatus.

The main source of bowenite greenstone was locally-derived beach boulders in Anita Bay in Milford Sound. The third greenstone locality was the Lake Wakatipu region, a source of the whitish variety termed *inanga*, and of a much inferior nephrite.

### The Hei-tiki

The Maori used greenstone to make implements (adzes, chisels), a famous weapon, the *patu pounamu*, that was invariably shaped in the simple *mere* form, and ornaments such as the renowned *hei-tiki* and ear pendants. The *hei-tiki*, or *tiki* as it is usually abbreviated by New Zealanders, is a representation of the human form worn around the neck by the Maori as a memento of deceased ancestors. The shape of this human image was distinctly influenced by the fact that a large proportion of *hei-tiki* were frequently made

from shaped adzes. The value and sacredness of the *hei-tiki* depended on its having been worn or handled by the dead of past ages, and when a long-absent relative arrived in a village the *hei-tiki* was taken from his neck and wept over for the sake of those who formerly wore it. The custom was to bury the *hei-tiki* with the wearer after death and later to remove it when the bones were taken up for reburial. The nearest of kin employed in the rites connected with the removal of the bones became the next possessor. If the deceased was the last member of a family, the *hei-tiki* was finally buried with him.

### Highly-prized Stone

Greenstone was the most highly-prized stone used by the Maori, and its value lay in its hardness and toughness. No other stone would carry and keep so keen and thin an edge. This hardness and toughness are partly due to mineral composition, but



primarily result from a characteristic microtexture of very closely felted and interwoven, very minute mineral fibres. Indeed, nephrites of the highest grade are so thoroughly felted that it is impossible to chip specimens with a heavy hammer. The quality of greenstone thus ranges from those with extreme toughness to those in which the constituent grains are more or less aligned in one direction, along which the rock tends to split or fracture (schistose greenstone). On the whole, bowenite greenstones are more schistose and less tough than the nephrite variety and were used more for ornaments.

The Maori recognised several varieties of greenstone, of which the main ones were:—

- *Kahurangi*—bright green colour, with darker shades or mottled; highly translucent and greatly prized, especially for ear pendants.

- *Kawakawa*—green of various shades, semi-translucent, and named from its resemblance to a leaf of a shrub of the same name (*Piper excelsum*).

- *Inanga*—whitish, opaque variety, ranging from grey to pale green, highly prized, and named from the colour

resemblance to whitebait, the young stages of the fresh-water fish *Galaxias*.

- *Auhunga*—pale green, intermediate between *kawakawa* and *inanga*.

- *Tangiwai*—a translucent bowenite variety, so named (“tear water”) on account of the delicate reflections and the appearance of drops of falling water occasionally seen in polished specimens by transmitted light.

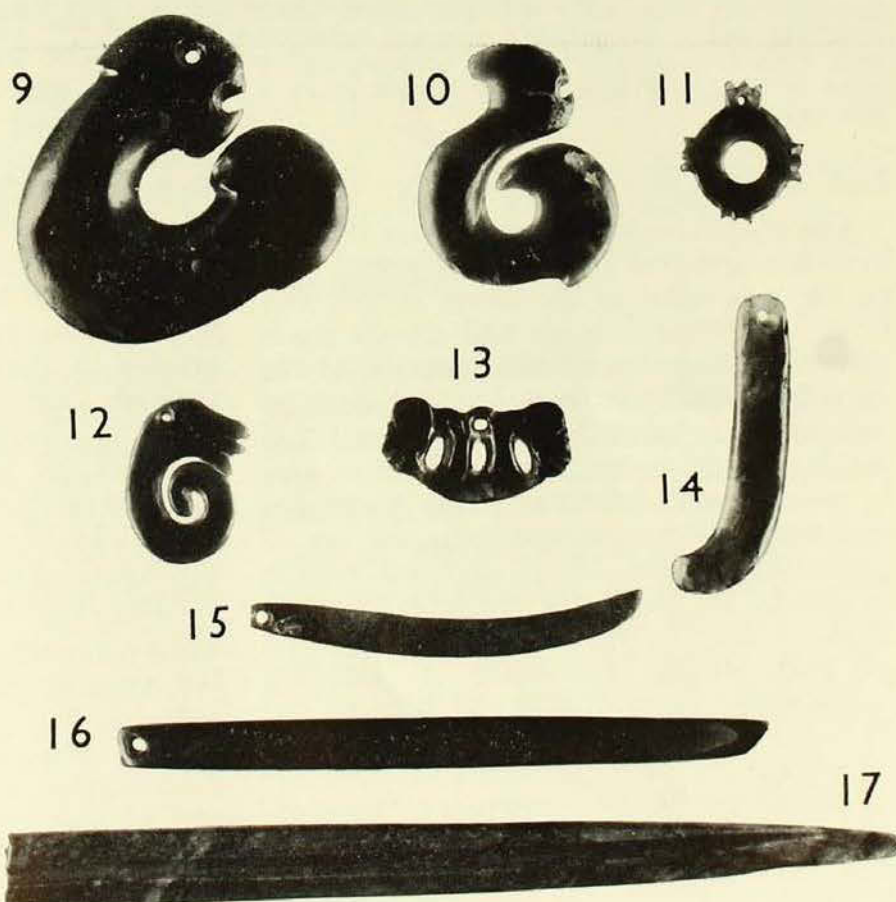
### Method of Working Greenstone

A graphic picture of the Maori method of working greenstone was recorded by one of the early explorers, Major Charles Heaphy, in 1846:—

“In order to make a *mere* (*patu pounamu*), a stone is sought of a flat, shingly shape, say, of the size, and roughly of the shape, of a large octavo book . . . The Arahura natives lay in a large stock of thin pieces of a sharp quartzose slate, with the edges of which, worked saw-fashion, and with plenty of water, they contrive to cut a furrow in the stone, first on one side, then on the other, until the piece may be broken at the thin place. The fragments that come off are again sawn by women and children into ear-pendants. With pretty constant work—that is, when not talking, eating, doing nothing, or sleeping—a man will get a slab into a rough triangular shape, and about 1½ in. thick, in a

Maori greenstone artifacts: 9-10. *Hei-matau*, an ornament in stylized fish-hook form. 11. *Poria-kaka*, a leg-ring for a captive *Kaka*, a trained decoy parrot used in hunting. 12. *pekapeka*, and 13, *koropepe*, rare types of ornament. 14-15. *kapeu*, drop pendants with golf-stick-like ends. 16. *Kuru*, a dual-purpose, simple, straight drop pendant, with one end a gouge chisel. 17. Off-cut from a slab, partly re-cut for drop pendants.

Photo.—S. N. Beatus.





	← NEW ZEALAND GREENSTONE →		
	← JADE →		
Mineral	JADEITE	NEPHRITE	BOWENITE
Mineral Group	Pyroxene	Amphibole	Serpentine
Chemical Composition	$\text{NaAlSi}_3\text{O}_6$	$\text{Ca}_2(\text{Mg,Fe})_5(\text{OH})_2\text{Si}_8\text{O}_{22}$	$\text{Mg}_3(\text{OH})_4\text{Si}_2\text{O}_5$

New Zealand greenstone is composed of either nephrite or bowenite, whereas jade in the narrow sense used by gemmologists is restricted to nephrite and to another distinct mineral, jadeite, which is not found in New Zealand. Most New Zealand greenstone, the nephrite variety, is therefore jade. For precise classification, the terms nephrite, bowenite and jadeite should be used rather than the mineralogically ambiguous names greenstone and jade.

month, and with the aid of some blocks of sharp sandy-gritted limestone, will work down the faces and edges of it into proper shape in six weeks more. The most difficult part of the work is to drill the hole for the thong in the handle. For this, pieces of sharp flint are obtained . . . and are set in the end of a split stick, being lashed in very neatly. The stick is about 15 in. or 18 in. long, and is to become the spindle of a large teetotum drill. For the circular plate of this instrument the hardened intervertebral cartilage of a whale is taken. A hole is made through, and the stick, firmly and accurately fixed in it. Two strings are then attached to the upper end of the stick, and by pulling them a rapid rotatory motion is given to the drill. When an indentation is once made in the *pounamu* the work is easy. As each flint becomes blunted it is replaced by another in the stick, until the work is done. Two *meres* were in process of formation while we stayed at Teremakau, and one had just been finished. A native will get up at night to have a polish at a favourite *mere*, or take one down to the beach and work away by the surf. A piece of *pounamu* and some slate will be carried when travelling, and at every halt a rub will be taken at it. Poor fellows! They had no tobacco, and a grind at a piece of hard *inanga* seemed to be a stimulant."

## Lost Art

The explorations by Brunner and Heaphy were later followed by the discovery of gold on the west coast of the South Island, and from the auriferous sands and gravels much greenstone was secured and came on to the market. Lapidaries, both in New Zealand and overseas, found a ready sale for faked curios, at first to the Maori and afterwards to tourists and collectors. This trade has continued, but not unexpectedly the use of greenstone by the Maori declined rapidly so that by the end of the nineteenth century it was a lost art. With the virtual cessation of gold mining, greenstone is becoming increasingly more difficult to obtain, and to conserve stocks, and also to protect and encourage *pakeha* (European) manufacture of imitation Maori ornaments, jewellery and souvenirs, an embargo on the export of raw New Zealand greenstone came into

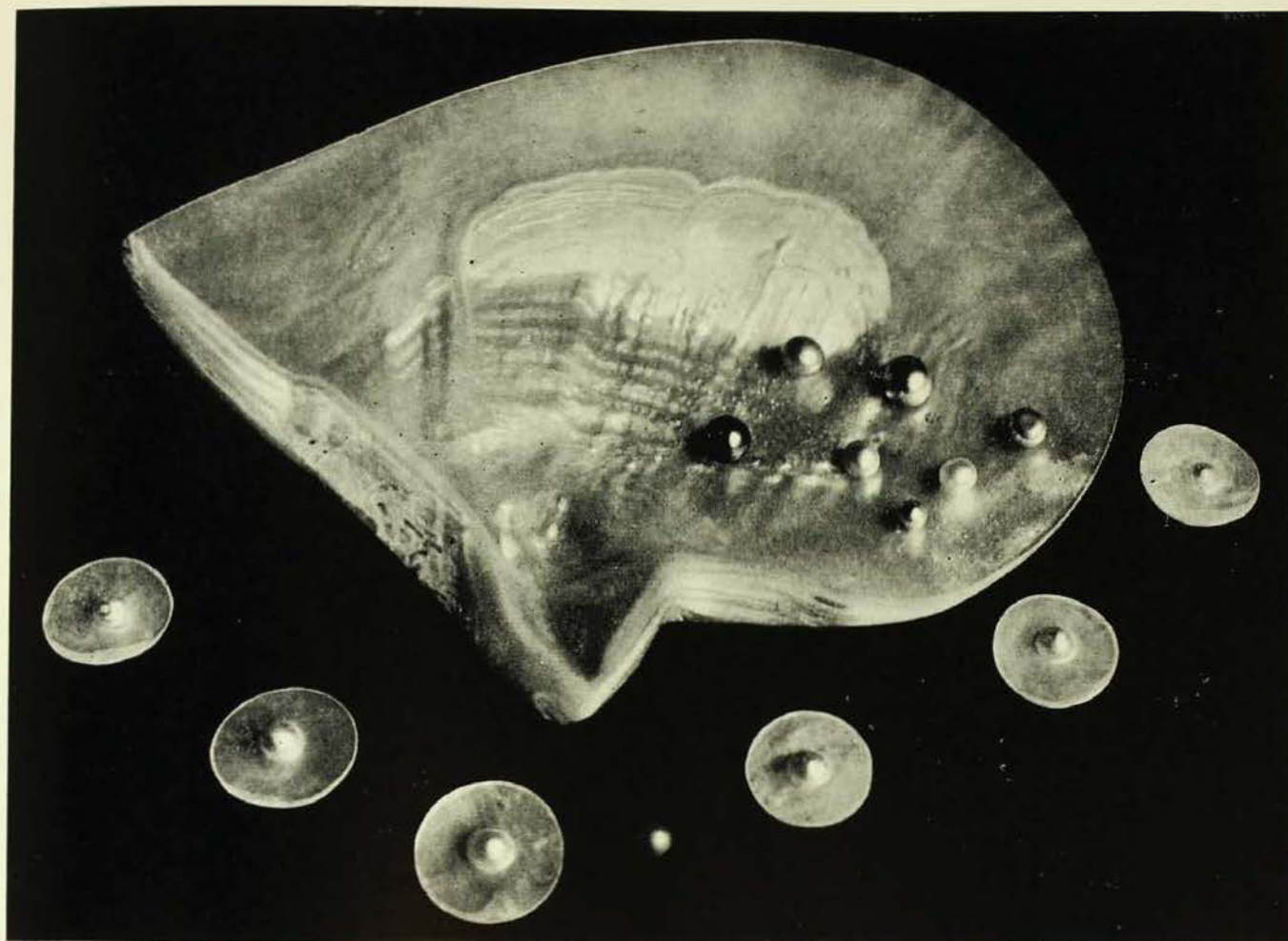
force in April, 1947. The greenstone used in this imitation work is generally of the *kawakawa* or *kahurangi* variety.

## Nomenclature Problem

Finally, a few words can be said on the vexed question of nomenclature, particularly the relationship between greenstone and jade. Greenstone is neither a mineralogical nor a geological term, but has wide usage, especially by ethnologists. It is not strictly accurate, since although green is the predominant colour, the range is from whitish to almost black. New Zealand greenstone is composed either of nephrite, an amphibole mineral of the actinolite-tremolite series, or of bowenite, a serpentine mineral. On the other hand, jade, in the narrow sense insisted on by gemmologists, is restricted to nephrite and to jadeite, the latter a pyroxene mineral not found in New Zealand. There are those who advocate the dropping of the name greenstone in favour of jade, a contention supported by the fact that the majority of New Zealand greenstone is the nephrite variety, especially that used by the numerically-dominant northern tribes. With the southern Maori, however, the position is different, for study of the greenstone articles in the Otago Museum at Dunedin showed that almost half are bowenites. There is clearly a need for a general term to cover all jade-like artifacts irrespective of mineralogical composition, and as the use of the name jade in this manner is not permitted, greenstone is the only other suitable term in common use.

The important point to remember is that the majority of New Zealand greenstone is jade in the gemmological or commercial sense. But for precise mineralogical classification of New Zealand greenstone, and of jade from elsewhere, it is necessary to use the terms nephrite, bowenite and jadeite.





Pearls on a polished pearl shell and (below) pearl blisters on the pieces of shell to which they are attached.

## *Pearls, the Jewels of the Sea*

By DONALD F. McMICHAEL

THE names of the tiny Arab Sheikdoms of Kuwait and Bahrein have recently been splashed across the newspaper headlines of the world. To most people, these names spell oil, that precious source of power drawn from the hidden depths which gives untold wealth to these tiny countries. But for centuries these and other sea-ports of the Persian Gulf have been known for a far more precious commodity, weight-for-weight, than oil has ever been. For they are centres of the great pearl fishery which has existed in the Persian Gulf for over 2,000 years and which remains today as a major producer of pearls and pearl-shell. Accounts

of these fisheries appeared as early as the third and fourth centuries B.C., and it is probable that many of the famous pearls of ancient times (such as those of Cleopatra) came from this part of the world.

Of all the precious stones which have been held in esteem by the human race, the pearl stands unique as the only one which is a product of a living animal. In this regard, it cannot be considered a gem-stone, but it ranks even above the diamond as the most romantic of jewels and, indeed, as one of the most valued. Pliny described pearls as "the richest merchandise of all, and the most sovereign commodity throughout the





A stack of Giant or Golden-lip Pearl shell, cleaned, graded and ready to be packed for export. The man is exhibiting two extra-large specimens, that in his right hand being 12 in. in diameter.

whole world". There are endless tales of pearls and the part they have played in the history of mankind. They have been at the centre of political events (it is said that one of the reasons why Julius Caesar set forth on his conquest of England was the famous freshwater pearl fishery of ancient Brittainia) and have graced the costumes of many of the world's greatest rulers; they have been plundered in war and stolen and fought over in peace, and many men have died in the search for them.

### **Pearling Industry's Decline**

Those who know something of the great story of the Australian pearling industry will be saddened at the thought that its days seem to be numbered. A recent announcement stated that soon only three pearling luggers would be operating out of Darwin, and similar reductions have occurred at the

other pearling centres, Broome and Thursday Island. The value of pearl-shell produced in Australia for the year 1959-60 was only about £500,000, less than half what it was a few years ago, and only a fraction of the pre-war production. Of course, it is not pearls which have been displaced in man's estimation, but the mother-of-pearl, or shell, which is the real basis of the industry's economy and which is succumbing to the competition of plastics. Pearls are, and always will be, regarded as of great value for jewellery, but today the value of pearls has been to some extent affected by the culturing of these gems, principally in Japan and more recently in Australian waters.

Pearls are the product of certain molluscs, or shellfish, which have the ability to lay down a nacreous or mother-of-pearl coating around minute objects which



accidentally penetrate into the mantle tissues of the animal. Nacre, of course, is a natural product, identical with the mother-of-pearl which coats the valves (shells) of the pearl-shell internally. When the object is coated with many hundreds of thin layers of nacre it often assumes the perfectly round shape which we think of as characteristic of pearls. Actually most pearls are far from perfect in shape, many being oval, pear-shaped, or flattened on one side. Such pearls are correspondingly less valuable, though size and perfection of the pearly layers play a big part in determining the value of a particular pearl.

The exact causative agent which stimulates the production of natural pearls is not always clear, though it seems likely that small particles of mineral matter as well as minute parasites may be responsible in many cases. The nacre is laid down by special cells of the outer mantle epithelium, that is, the layer of cells normally adjacent to the inside of the shell which normally secretes the mother-of-pearl on to the inside of the valves. In pearl formation, it appears that certain of these outer mantle epithelial cells migrate into the tissue of the mantle, surround the object which is to be the nucleus of the pearl, and cover it with layer upon layer of nacre.

### **Pearl Culture**

The pearl-culturist has developed a skilled technique in which an artificial nucleus of shell material (often derived from the North American freshwater mussel shells) is wrapped in a piece of mantle tissue taken from the pearl-oyster which is to be used for culturing. A trained operator then places this "sandwich" of nucleus and mantle tissue in a suitable place within the body of the pearl-oyster, which is then returned to the sea and left for some years. Of course, there is a certain percentage of failures, but the majority of the treated animals will, in due course, react to the foreign body in their tissues and in a few years a pearl will be produced. Many of these will be imperfect in one way or another, but a large proportion will be good, regularly rounded pearls. Australian pearl-culturists have been using the Golden-lip pearl shell, *Pinctada maxima*, and have

been able to grow very large and beautiful pearls in a short time, compared with the Japanese products, which are grown in the local Japanese species of pearl-oyster, *Pinctada martensi*. At present, the centres of pearl culture in Australia are at Thursday Island, Queensland, and Kuri Bay, Western Australia; one or two other localities have been leased for pearl-culture farms, but as yet no production has resulted from them.

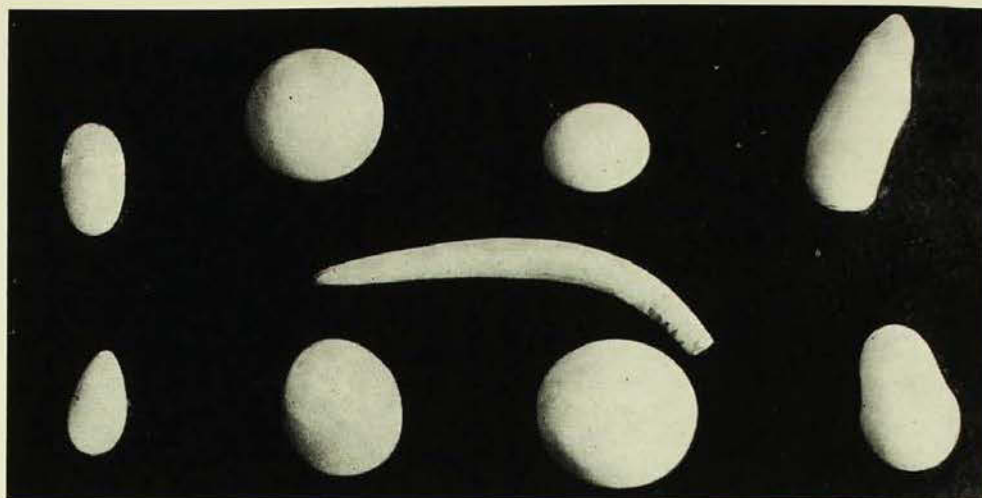
The huge quantities of cultured pearls which have now become available have obviously had some effect on the value of natural pearls. None the less, the price of natural pearls is about ten times that of cultured pearls of the same size and quality. Since it is virtually impossible to distinguish a cultured pearl from a natural pearl by external characteristics, it is obvious that this price differential is based on "exclusiveness" only. It is possible to distinguish natural pearls from artificial pearls by a variety of modern techniques, such as X-ray examination (which will reveal the presence of the large nucleus in a cultured pearl), examination under fluorescent light, or by direct examination of the centre of the pearl. The latter technique can only be applied when the pearl has been drilled for stringing, and it involves the use of a very fine beam of light which is directed into the drilled hole to allow an examination of the structure of the centre of the pearl. The reaction of pearls to a magnetic field has been used to distinguish the two kinds. Natural pearls, consisting entirely of concentric layers of nacre, do not react to such a field; cultured pearls, however, will orient themselves along the magnetic field, because their nuclei consist of shell material which is itself laminated, and the pearls become aligned according to this lamination.

### **Pearl-formation In Other Molluscs**

All molluscs have the ability to lay down shelly material around objects which come into close contact with the outer mantle epithelium. The Chinese have for centuries made mother-of-pearl coated images of the Buddha by inserting small, flat carvings in between the mantle and shell of freshwater mussels; the natural consequence of this is



Pearls, composed of a white porcellanous shell-material from a Giant Clam (*Tridacna*).



that the mantle coats the object with mother-of-pearl, just as it would coat the inside of the shell. Pearl-forming reactions of this type occur in most molluscs, but as the majority of them are not producers of true mother-of-pearl, but instead lay down a compact, white porcellanous shell material, the pearls which they produce are seldom of any value or beauty.

We often hear of people who have discovered a pearl in an oyster which they have been eating. Of course, such discoveries are made quite frequently, but the pearl which is found is neither very large nor of any value. Edible oysters have no nacreous layer in their shells, and so are incapable of producing a true nacreous pearl; those which they do produce are simply round shelly structures with a porcellanous texture, sometimes with a characteristic velvety sheen, but in no way resembling the true nacreous pearl. Furthermore, edible oysters seldom produce perfectly rounded pearls, and it can be stated that those which are found have no commercial value, except as curiosities.

Some molluscs which do not have nacreous shells none the less produce quite pretty and regular pearls which may have a small market value. Typical of these are the pink pearls sometimes found in the West Indian Queen Conch; however, it is said that the colour of these pearls fades quickly. Only the true Pearl Oysters (which are not closely related to the edible oysters) and the Pearly Freshwater Mussels can produce really valuable gem pearls. American and European freshwater mussels generally have

quite well developed nacreous layers internally and produce many fine pearls of good value; however, Australian freshwater mussels are generally rather thin and do not have well developed nacreous layers, with the result that few pearls of any value have been found in Australian species. The most likely species to produce a good pearl would be the large, elongate *Cucumerunio novaehollandiae*, which lives in the coastal rivers of northern New South Wales and south Queensland. This species is easily recognised by its coarsely-wrinkled shell, and as it has a well developed nacreous layer internally it is a potential pearl producer, though the only pearls known from it to date are small, elongate objects of little value.

Anyone wishing to gain an insight into the Australian pearl-fishing industry as it was in its hey-day should read Ion Idriess's fascinating account of pre-war pearling in Broome, "Forty Fathoms Deep" (Angus & Robertson, Sydney, 1937). Another very fine reference work is "The Book of the Pearl" by G. F. Kunz and C. H. Stevenson (McMillan, London, 1908), which gives an immense amount of information about pearls and the pearl-fisheries of the world as they existed about the turn of the century. Finally, the story of cultured pearls and the gifted founder of the Japanese pearl-culture industry, Kokichi Mikimoto, is told in Robert Eunson's book, "The Pearl King" (Angus & Robertson, London, 1956).

[Photos in this article are by Capt. Frank Hurley.]





The main settlement of Andamooka, looking south-west. The white mounds are opal diggings.

Photo.—Author.

## *Andamooka Opal Field*

By O. le M. KNIGHT

Honorary Correspondent of the Australian Museum

ANDAMOOKA opal field is located just to the west of the north-western shore of Lake Torrens in South Australia, nearly 400 miles north of Adelaide. The main settlement lies about eight miles west of the lake and about 20 miles south of its northern tip.

Like so many of Australia's great mineral fields, its discovery was due to the keen observation of that amazing group of men, the boundary riders. In August, 1930, Sam Brooks and R. Shepherd had been tank-sinking on Andamooka Station and were shifting camp from Swamp Dam, about eight miles north-west of the present settlement, to Four Corners Creek, now Opal Creek, when they came across some coloured opal "floaters" on One Tree Hill.

It was not until June, 1931, that Sam, with boundary rider Paddy Evans, sank the first hole on One Tree Hill. After sinking for about 6 ft., Paddy reckoned he had sunk a

"duffer" and started to climb out. But on digging his pick into the side wall to make a foothold, he struck a lump of "kopi" (gypsum) carrying good-coloured opal. He and Sam then carried on and took £600 worth out of this first hole.

Naturally, the excitement caused at the station was intense and every endeavour was made to keep the find a secret. Mr. Foulis, station manager, who had confirmed the identity of Sam's find in the first place, smuggled in four diggers from Port Augusta and they, with Alan Treloar and Jack Hughes from the station, started the first serious work.

Shortly afterwards, the first really good opal was found by them on Treloar Hill, about half a mile west of the original find and now the centre of the main settlement.

But this opal had to be sold, and it became increasingly difficult to keep the find



a secret. Early in 1932, the field was really established by the arrival of a number of others whose names will always be associated with Andamooka, and who, with the Brooks and Alan Treloar, still form the backbone of the settlement.

### Gibber Plains

To reach the field by car from Port Augusta one travels north-west on the highway to Woomera (119 miles) and then turns north on station roads through Arcoona Station (24 miles) and Andamooka Station (30 miles) and a further 20-odd miles north on a fairly well graded (but sometimes shifting) road to the opal fields. Or, if the necessary permits are obtained from the Department of Supply, it is possible to fly direct to Woomera and there take the mail coach to the field.

The country is gently undulating, mainly with gibber plains relieved by low sand-hills which carry most of the vegetation. It becomes hilly as one approaches Andamooka Station, beyond which the sand-hills become more prominent. It is arid-looking country with a rainfall of less than 6 in. per annum, but is not without its interesting features. The vegetation on the

sand-hills is cypress pine, mulga, myall, beefwood (*Grevillea striata*) and occasional patches of black oak, with saltbush, munyeroo, parakilya, Sturt's desert pea and white and yellow everlasting underfoot.

The gibber plains are typically wind-eroded, and on them can be found many of the curiously shaped pebbles known as "dreikanter", having three or more facets ground by wind-blown sand.

On the wind-swept areas of the sand-hills, particularly near cane grass swamps with which the sand-hills seem to be associated, can be found countless Aboriginal chipped stone implements, such as knives, scrapers, points and adzes, which give evidence of earlier less arid conditions and a large Aboriginal population. Some of these artefacts date back 4,000 years and even longer.

### Semi-dugout Dwellings

About 18 miles past Andamooka Homestead the first sight of the opal field is obtained. It appears as low, rounded hills, capped with the white dumps characteristic of any of the Australian opal fields. It is in reality a low, dissected tableland, the hills



Most of the dwellings at Andamooka are, like these, of a semi-dugout type, excavated into the sides of hills.

Photo.—Author.



being only about 100 ft. above the drainage system of Tea-tree Creek and its tributaries, including Opal Creek.

The population of Andamooka is at present about 300, mostly located within half a mile radius of the post office. It includes a small settlement of Aborigines—perhaps about 50. The originally scanty water supply has been increased to about 5,000 gallons a day from two wells in Opal Creek, but at present it is barely sufficient to meet the needs of a much increased population. Firewood and local building timber (cypress pine) have to be carted many miles and the available supply is rapidly diminishing. Some good-quality building stone has recently been quarried locally. Most of the dwellings, however, are semi-dugouts excavated into the sides of the hills, with log and mud roofs and sometimes walls. Floors are generally concrete, or mud, sometimes mixed with burnt gypsum. In spite of these unprepossessing externals, most of the dwellings are very comfortable and attractive inside and many are equipped with their own lighting plants, refrigerators, radio and other modern conveniences.

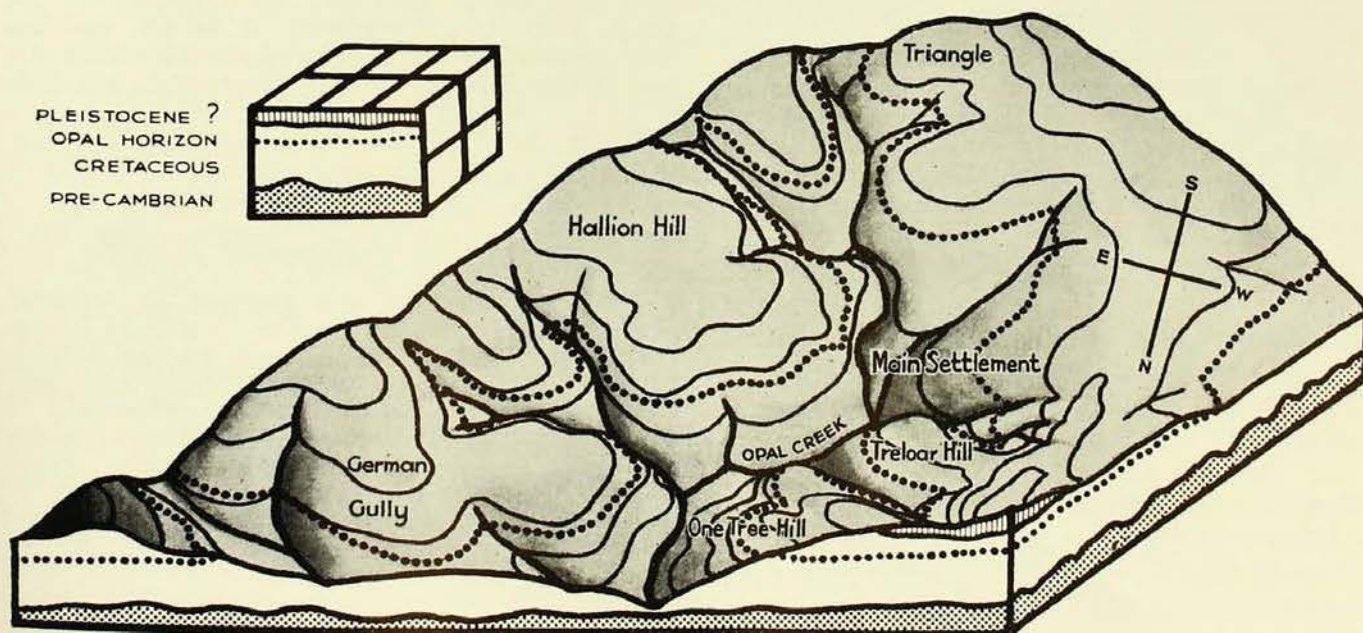
Other amenities are two schools, two well-stocked stores, a community hall, a picture show and a beautifully equipped medical

centre, which is attended monthly by a doctor from the Flying Medical Service headquarters at Port Augusta.

### Diggings On Tops And Slopes Of Hills

The opal mining extends over a distance of about three miles by one mile, and the first glimpse of the field shows that the diggings are confined to the tops and slopes of the low hills comprising the area. The potential opal-bearing area is, however, much greater and extends over 50 square miles or more. Sam Brooks has picked up good opal matrix near Edge Hill dam, about 13 miles south-east of the town.

The opal, usually of light colour, occurs as veins or pockets in narrow conglomerate beds of Cretaceous age—generally underlying beds of sandy clay more or less impregnated with gypsum. There may be three or more layers of this opal-bearing rock, and the depth of sinking will vary up to 50 ft. A limited amount of good-quality black opal also occurs at Andamooka. Fossilized shells occur, but only rarely do they carry colour. The replacement by precious opal of the cementing material in some of the conglomerate boulders, and the almost complete replacement of some of the shaly material, result in what is locally



Block diagram of portion of Andamooka opal field. Maximum depth of the opal horizon (opal-bearing beds) below the surface is 50 ft. The distance from One Tree Hill to the main settlement is about half a mile.



termed "opal matrix", which can be very beautiful and is frequently of large size. In other cases huge quartzite boulders have cracks from paper thickness to a quarter of an inch thick, completely filled with precious opal; the boulders frequently split along these cracks and are then known as "painted boulders".

Replacement of gypsum crystals by opal, which was a feature of some White Cliffs opal, does not appear to occur at Andamooka, nor does the gypsum, though abundant near the opal level, occur as fine crystals within the precious opal itself. This was a common fault of the opal found at Stuart's Creek opal field, about 30 miles north of Andamooka. There it caused ultimate crazing that completely ruined the opal. One of the great old-timers at Andamooka, Ben Grose, who was also one of the first to go to the Stuart's Creek field, told me that if a bag of Stuart's Creek opal were dropped on his table, he could identify it by sound without ever seeing it, because of the gypsum inclusions.

### **Mining Now Mechanised**

The early method of working at Andamooka was for the digger to sink a shaft to the opal level and then gouge 12 to 15 in. of opal dirt at the bottom with an ordinary pick, as far in as possible while lying on his side. He then "blew down" the roof over the gouging with small charges of "jelly", cleared out the mullock and repeated the process until he had gone in as far as he could or until he decided the opal had cut out.

This method has now largely given way to mechanical mining, with the aid of compressed air or electricity. Andamooka is today the most mechanized of all the Australian opal fields. Only the actual gouging on the opal level is done by hand. The shaft is sunk about 5 ft. below the opal level, the "toe" dug out by jack hammers and the top foot of the level gouged by hand. In this way, drives totalling hundreds of feet and high enough to walk in can be done in less time and with greater ease than by the old method.

The precious opal usually occurs in pockets, and frequently drives may be carried on for weeks between pockets.

Traces, however, keep appearing and the miner follows them in determining the level and direction of the drive. Experienced miners become very adept in determining the cause and trend of these traces, which frequently follow minor faults and dips in the rock structure. All traces are religiously kept and examined, and in the course of a few weeks their value may become quite considerable. A "pocket" may yield hundreds or even thousands of pounds worth of opal.

In a few places, huge open cuts have been made in the last few years by bulldozers working down to the opal level, but it is doubtful if the returns have justified the expense incurred. Not only does this method of working appear quite unsuited to the finding of isolated pockets of opal, but it frequently results in large areas being left in a condition dangerous to other workers.

Opal gouging, unlike most mining, seems to be a matter of personal effort, assisted where possible by mechanization of hoisting or digging—but still entirely an individual effort. This has been proved on all the Australian fields, and one has only to talk to the grand old-timers to see the inspiration, enthusiasm and individual effort that have been responsible for the millions of pounds worth of precious opal which has helped put Australia on the map.

[The diagram is published by courtesy of the South Australian Department of Mines, and has been modified by David Rae, of the Museum's Art and Design Section, from a diagram in the S.A. Mining Review, No. 109.]

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### **HERBERT E. GREGORY MEDAL**

The first award of the Herbert E. Gregory Medal for distinguished service to science in the Pacific was made at the Tenth Pacific Science Congress, held in Hawaii last August and September, to A. P. Elkin, Emeritus Professor of Anthropology at the University of Sydney, and a Trustee of the Australian Museum. The medal was established by the Trustees of the Bernice P. Bishop Museum, Honolulu, Hawaii, to honour the memory of Herbert E. Gregory, Director of the Bishop Museum from 1919 to 1936 and Silliman Professor of Geology at Yale University, U.S.A. Professor Elkin is distinguished by his contribution to anthropological research in Australia and Melanesia and by his active role in the development of institutions supporting Pacific research.





Two prospectors at Mintibi, hopeful of making an opal find.

Photo.—O. le M. Knight.

# ***MINTIBI—OPAL FIELD OF THE FUTURE***

By **GEORGE GRAHAM**

A Lightning Ridge opal miner

**I**N 1922, with the wanderlust upon me, I found myself in Oodnadatta, in the far north of South Australia. The mate and I had heard that a good opal find had been made at a place called Mintibi, lying about 150 miles west of Oodnadatta, in the Great Victorian Desert.

Inquiring at the tiny hotel, we not only found the report to be correct but also the man who had made the "strike", a handy old Territorian named Larry O'Toole.

The result of that meeting was a foregone conclusion. Larry and I amalgamated, and a few days later were on the mail (six trips a year at that time) for Welbourne Hills Station, about 100 miles out, and the last link with civilization. Welbourne Hills is

owned by the Giles family, one of whose forbears made a remarkable and historic survey trip through this unbelievably forbidding area back in the '70's. On our subsequent prospecting trips we had the good fortune to have one of his original maps, giving survey points and detailed local information, and even after the passage of years it was almost uncannily accurate; even certain timbered areas he had noted still remained.

At Welbourne Hills we transferred our big load of supplies to Larry's camels, six of them, all tied together in a "string" by lengths of ordinary string. These "ships of the desert" can handle huge loads; on one big fellow we estimated the load to be around 700 lb.



This is typical of the country around Mintibi. The white area and the two mounds behind it are opal diggings.

Photo.—O. le M. Knight.



In a couple of days we arrived at our destination, Sailor's Well, the nearest permanent water to the opal field, which lies about nine miles to the west. The well, about 16 ft. deep, gave a wonderful supply of high-class water.

The blacks of the area were the most primitive Aborigines I have encountered anywhere in Australia. How they managed to survive at all was a mystery to me. Larry, who had spent years in the area, gave us some idea of their tribal customs—most of them revolting.

Suprisingly, the area abounded with bird and animal life, although the meagre native rock-holes and soaks were often 30 or more miles apart. Bourke Parakeets, for many years listed as extinct, were there in vast numbers; in much lesser numbers were the beautiful Scarlet-chested Parakeets. Exploring a dark cave one day, I chanced to see a huge snow-white owl. His wing-spread was at least 5 ft.

The animals native to the region were practically all marsupials, ranging from old-man kangaroos to the tiniest of pouched mice. Rabbits were plentiful; indeed, they formed the natives' chief diet in those pre-myxomatosis days.

The country itself is harsh and uninviting—long, low ridges that dwindle away into the infinity of the encompassing desert. These same ridges, however, held the secret we were after, opal—and they held it well, at that.

We found it the hardest country to work we had ever encountered. Practically every hole we sank required the use of explosives, and several even defied that.

The opal was in seam-formation, "all-opal", and some which we got was definitely black opal of good quality.

Water, and the blazing summer heat, finally beat us. Eventually even the hardy camels stubbornly refused to make the trip.

As an opal digger of many years, I am certain that Mintibi and the great belt of ranges around it are destined one day to be great opal producers. Not at present, though. Mintibi now lies in the prohibited area of the Woomera Rocket Range.

O. le M. Knight, an honorary correspondent of the Australian Museum, who visited Mintibi in 1957, writes:—

Mintibi opal field is at approximately 133 degrees 18 minutes long., 27 degrees 18 minutes lat., eight miles along the road north-west from Sailor's Well. At Marla Bore, on the Alice Springs Road, take the road west to Wallatinna out-station (of Granite Downs Station), about 15 miles. From Wallatinna out-station the road goes three miles north to Larry's Well, then five miles north through heavy sand to Sailor's Well, then north-west to Mintibi. The road passes about a mile to the east of the fie'd. Turn off to the west near a small isolated conical hill, which is very conspicuous. Cross Amaroodinna Creek on the way.

The opal occurs, apparently in vertical seams, in a hard, white sandstone (on some parts of the field to the south the sandstone has weathered to almost white, loosely-bound sand).



The largest piece of pitchblende ever mined, now on display at the Australian Museum, is here seen ready for loading on to a truck at the El Sherana Mine, South Alligator River, Northern Territory, where it was found. The specimen weighs just on seven-eighths of a ton. Pitchblende is the richest source of the radioactive metal uranium.

Photo.—“Walkabout.”



## *World's Largest Pitchblende Specimen at Museum*

By R. O. CHALMERS

THE needs of the times stimulate the search for minerals. Uranium minerals had been found in South Australia as early as 1906, but nowhere had pitchblende, an oxide of uranium and the richest source of the metal uranium, been found in Australia until after the second World War. Even the great demand for uranium for the atom bomb project in the closing years of the war failed to reveal the great abundance of high-grade uranium ore in Australia.

Post-war demand for uranium led to an intensification of the search on the part of both the prospector and the geologist. A prospector found Rum Jungle, Northern Territory, in 1949, and four years later a geologist, B. P. Walpole, of the Commonwealth Bureau of Mineral Resources, found uranium minerals at Coronation Hill, in the upper South Alligator River, about 140 air miles south-east of Darwin. Prospecting in this rugged terrain, mostly on the sides of steep cliffs, revealed further lodes, the

richest of which was named El Sherana, a compound of abbreviations of the names of the three daughters of the discoverer.

### **Specimen Weighs 1875 lb.**

The El Sherana lode contained lens-shaped masses of high-grade pitchblende, and the company, United Uranium, was able to mine intact some very large masses, the largest of which, weighing 1875 lb., was brought to the surface in May, 1956. The sheer impressive bulk of this monster spared it from being crushed immediately and shipped off with thousands more tons of uranium ore. Yet it was by no means an economic proposition to retain it as a specimen because it is probably worth something in the order of £A5,000. The scientists of the Australian Atomic Energy Commission, realizing the great educational and scientific value of the specimen, advised that the Commission should purchase it from the company, which was done. After being



displayed in Darwin it was shipped to Sydney but because of its great weight was only displayed a few times at the Royal Easter Show and at special exhibitions in the Sydney Town Hall.

The Commission has now very generously presented this magnificent specimen to the Australian Museum, where it is on permanent display in a special case. Yellow and green coatings of secondary uranium minerals can be seen on the top surface of the pitchblende. A great variety of secondary uranium minerals are produced by the alteration of pitchblende and other primary uranium minerals by the action of groundwater. Both the yellow and green minerals are probably rutherfordine, uranium carbonate.

There are certain problems connected with a mass this size, not the least of which was the actual handling of it in bringing it into the Museum and setting it on a stand in the case. However, these difficulties were overcome by the co-operation given by Department of Supply personnel, expert in transporting great weights, and the ingenuity of the Museum's display and mechanical staff.

Another problem is the amount of radiation given off by such a large radioactive mass. There are limits to the amount of radiation to which the human body may be subjected and if these limits are exceeded the recipient may be harmed and long-term genetic damage may be caused to his descendants. Radiation in medicine in the form of X-Rays and radiotherapy is, of course, applied whenever necessary, and the use of radiation in industry is constantly increasing. A great deal of attention is consequently being given to what constitutes the permissible amount of radiation to which both the general public and workers in radiation industries may be subjected with safety. The figure for the general public has now been fixed by radiation authorities at 500 units each year. On the average, the human body receives 100 units each year from natural sources over which we have no control, as, for example, cosmic rays that come into the atmosphere from space, and radiation from the rocks and soil on which we live and from the radioactive potassium within our bodies. Note that this 100 units

is an average amount. If we live in Aberdeen, Scotland, or Stockholm, Sweden, where there are large granite areas, radiation from the rocks is higher than the average. If we happen to live in very high altitudes, as in the Andes, radiation from cosmic rays is higher than at lower levels.

The New South Wales Health Department has stated, after measuring the amount of radiation from this big specimen, that to obtain the maximum permissible dosage a member of the public would have to stand on the spot from where the specimen can be viewed for half an hour every day for the rest of his life. Therefore, the amount of radiation received by any member of the public from casual viewing is quite negligible.

One of the stages in the break-down of uranium to radium is the production of a radioactive gas, radon, which, in a matter of a few days, disintegrates to form solid radioactive products, which adhere to dust particles and can be inhaled. This is actually the greatest risk in uranium mining, and great care has to be taken to provide adequate ventilation in underground uranium mines. As early as the 16th century, miners extracting lead and silver minerals in a region on the boundaries of Saxony and Bohemia became afflicted by lung diseases, probably lung cancer. Unknown to these early miners, pitchblende occurred there also, (These mines later became famous as the source of the pitchblende used by the Curies in their classic experiments which led to the discovery of radium and radioactivity).

Radon, although being continually generated within the specimen in the Museum, is in such a small amount that it would be retained within the interstices of the specimen and change to solid products before it could escape. As an added precaution, however, an exhaust fan installed in the outside wall at the back of the specimen continually draws the air from the case and expels it in the open.

A geiger tube has been installed in the case and members of the public, by operating a switch, can compare the radiation count from the specimen with the almost negligible background count due to the cosmic rays in the atmosphere.



# RADIOACTIVE MINERALS

By J. R. STEWART

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**R**ADIOACTIVE minerals differ from all other minerals in that one or more of the elements present in them break down spontaneously to give off characteristic radiation which can be detected by means of a geiger counter, or similar instrument.

Prospecting for radioactive minerals can therefore be carried out almost entirely by means of a geiger counter. Although it is not necessary to have such a detailed knowledge of the occurrence, appearance and properties of the radioactive minerals as would be necessary in prospecting for, say, lead or gold, it is obviously advantageous to be able to recognise the more important radioactive minerals in order to assess the results obtained with a geiger counter.

Although there are naturally occurring radioactive isotopes of various light elements, the term "radioactive minerals" is confined to those minerals which contain uranium and/or thorium.

Uranium minerals may be divided into two principal groups—primary uranium minerals and secondary uranium minerals.

The primary minerals are those which were originally introduced into, or formed in, the rocks of the earth's crust. As a result of the action of air and ground waters, these primary minerals may be converted into secondary minerals which are normally hydrated oxides or phosphates. Silicates, arsenates, carbonates, vanadates, etc., also occur occasionally. Alteration of this nature is a near-surface phenomenon which takes place above the local water table. The extent of the secondary mineralization associated with a primary uranium deposit depends largely on the rainfall and ground water conditions. For example, there are spectacular occurrences of secondary uranium minerals in the South Alligator River area of the Northern Territory, where the climate is monsoonal, while secondary alteration is a minor feature of the Mary Kathleen (Queensland) ore body, which is situated in an area of very low rainfall.

Uranium minerals occur in three broad geological environments:—

- In granites and pegmatites.

Pitchblende (black) surrounded by an alteration halo of gummite (grey), from the Palette Mine, South Alligator River, Northern Territory.

Photo.—Australian Atomic Energy Commission.





- In vein deposits, often associated with granites or volcanic rocks.

- In flat-lying sedimentary rocks, particularly sandstones and conglomerates.

It is interesting to note that most of the western world's proven reserves of economic uranium ores are contained in sandstones and conglomerates near the base of the Proterozoic System (i.e., in rocks formed during the earliest geological time period).

### Primary Uranium Minerals

By far the most important primary uranium mineral is pitchblende and its crystalline form, which is known as uraninite. Pitchblende is a heavy, black, usually structureless mineral which is essentially uranium oxide. It is the major ore mineral in most of the important uranium mines in the world.

In deposits such as Mary Kathleen and White's Mine at Rum Jungle, N.T., the pitchblende (uraninite in the case of Mary Kathleen) is present in such a finely-divided form that it is not visible to the naked eye. It is, of course, easily detected with a geiger counter.

At the other end of the scale we have the magnificent occurrences of massive pitchblende in some of the mines in the South Alligator River area. The largest specimen of pitchblende in the world came from the El Sherana Mine in this area. It weighs 1875 lb. (about seven-eighths of a ton), and is now on show in the Australian Museum. Another similar, but smaller, specimen is displayed in the British Museum in London. The only other occurrence of massive pitchblende in the world which can be compared with those in the South Alligator area is the Shinkolobwe Mine in the Katanga Province of the Congo Republic.

Some of the pitchblende in the El Sherana Mine was in the form of radiating columnar aggregates. Several very interesting occurrences were also found in the Palette Mine, near El Sherana. Here gold, often clearly visible and of high grade, was erratically distributed through the pitchblende. Also present were the rare minerals coloradoite (mercury telluride) and clausthalite (lead selenide).

There are many other primary uranium minerals, almost all of which occur in pegmatites associated with granites, in a similar environment to minerals like beryl. Several occurrences of this type were brought into production when uranium was needed urgently for defence purposes, but it is doubtful whether any such occurrences can be considered economic sources of uranium at the present time. Pegmatites are, of course, a traditional source of fine specimens of numerous different minerals.

In Australia the primary iron uranium titanate, davidite, which was named after Sir Edgeworth David, is mined at Radium Hill in South Australia. Numerous other occurrences of davidite have been found in South Australia and in the adjacent Broken Hill field in New South Wales.

Some of the other primary uranium-bearing minerals are brannerite (Crocker's Well, S.A., and Mt. Isa district, Queensland); absite (Crocker's Well, S.A.); fergusonite, samarskite, euxenite and betafite. All these pegmatitic uranium minerals are refractory, that is, they are difficult to treat for the extraction of uranium. Associated with the pitchblende at Mary Kathleen is a new mineral, stillwellite, which is a greasy, brown-coloured complex rare earth borosilicate containing uranium. It was named after Dr. F. L. Stillwell, formerly Chief of Mineragraphic Investigations, C.S.I.R.O.

### Secondary Uranium Minerals

The secondary uranium minerals are notable not only for their radioactivity, but also because they are almost all coloured. As a group, they are probably more beautiful than the minerals of any other element. They are usually green, yellow or orange in colour and, when crystalline, make fine mineral specimens. Many of them are markedly fluorescent, almost always in shades of green, when exposed to ultraviolet light. Numerous occurrences of these secondary uranium minerals have been found in Australia.

One of the commonest is the apple-green-coloured hydrated copper uranium phosphate, torbernite. This mineral usually occurs in the form of mica-like plates



coating cracks and joint planes in the rocks. Its green colour is not as deep as that of the well-known copper mineral malachite. Torbernite has been found at Rum Jungle, in the South Alligator River area, in the Mount Isa-Cloncurry district, in the New England district of New South Wales, in Tasmania, and at various other places in Australia.

Autunite is a sulphur-yellow-coloured hydrated calcium uranium phosphate. It is similar to saleeite, hydrated magnesium uranium phosphate, which was found in quantity at Rum Jungle and in the South Alligator River area.

Massive pitchblende usually alters to a mixture of hydrated uranium oxides, with or without the addition of other elements such as silicon and calcium. In the South Alligator River area, the mineral gummite was formed as an oxidation product of pitchblende. This mineral owes its bright orange colour to hydrated lead uranium oxides, the lead having been formed by radioactive decay of part of the uranium present in the original pitchblende. Many specimens show a kernel or vein of black massive pitchblende fringed by a striking alteration halo of orange gummite. A similar effect is common at various localities in the U.S.A., at Shinkolobwe, and elsewhere.

Carnotite (hydrated uranium potassium vanadate) is very common in the Colorado Plateau area of the U.S.A., and also occurs at Radium Hill in South Australia. It has a characteristic canary-yellow colour.

Of the large number of other secondary uranium minerals, some are rather rare. Amongst those which occur in Australia may be mentioned phosphuranylite (hydrated uranium phosphate), zeunerite (hydrated copper uranium arsenate), uranophane (hydrated calcium uranium silicate), sklodowskite (hydrated magnesium uranium silicate) and kasolite (lead uranium silicate).

### Thorium Minerals

The number of thorium minerals is small compared with the number of uranium minerals, largely because thorium does not form secondary minerals. Although traces of thorium have been found in more than 100 minerals, only a few are of any importance from an economic point of view. All of the

thorium minerals may contain some uranium, just as all of the primary uranium minerals may contain some thorium.

The thorium minerals, like the refractory uranium minerals, occur principally in, or associated with, granite and granite pegmatites or in placer deposits derived from these rocks.

In Australia the only thorium mineral at present being recovered commercially is the mineral monazite. Monazite is present as a constituent of the heavy mineral beach sand deposits which occur along the east coast, in the Capel-Bunbury area of Western Australia and, to a lesser extent, in beach sand deposits elsewhere. The golden-brown coloured monazite in these deposits has been derived from the breakdown of granites and similar igneous and metamorphic rocks of which the monazite was originally a constituent.

Occurrences of monazite crystals are known in the pegmatites of the Harts Range, N.T., in the Mount Isa district, and at various localities in Western Australia. Minor occurrences of other pegmatitic thorium minerals are also known, but so far these are of mineralogical interest only.

The mineral thorianite (thorium oxide) is present in the Crater Beds near Rum Jungle but cannot be identified with the naked eye.

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### HONORARY ZOOLOGIST

Mr. F. A. McNeill, who retired from the curatorship of the Australian Museum's Department of Crustacea and Coelenterates last June, has been appointed an honorary zoologist to the Museum.

### FISH EXHIBITS

Progress continues to be made in the Museum's new Fish Gallery. In place of the old rows upon rows of bottles in order of classification, attractively modelled and coloured displays show specimens of particular interest and answer the questions about fishes most frequently asked by the public. Recently completed are the exhibits of piranha, archer fishes shooting insects, associations of certain fishes with other kinds of animals, venomous fishes, "where fishes live", the life-history of the freshwater eel, and several panels dealing with primitive fishes, scales, teeth, record lengths, etc. Many more modern exhibits are being prepared, ranging from marlin swordfishes to tiny freshwater species, and the new gallery is expected to be completed in 1962.



# *Recent Trends in Oil Exploration in Australia*

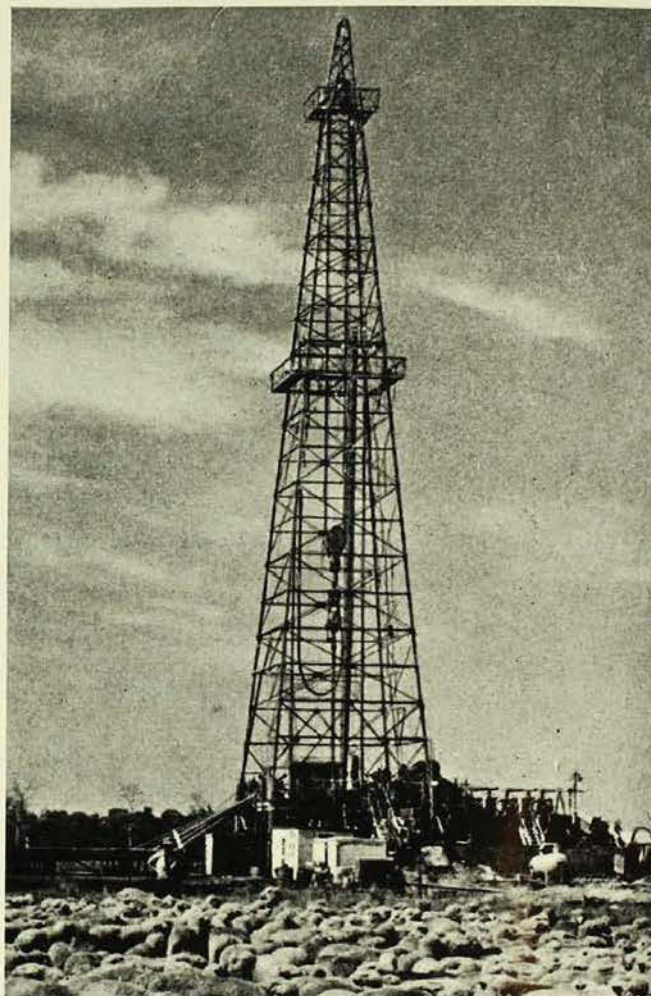
By L. R. HALL

Of the Geological Survey of New South Wales

OIL is usually found throughout the world in marine sedimentary basins, which have not suffered too intense deformation from crustal movements. Australia has many such basins, which in fact occupy about half the area of the continent. They vary greatly in size, the largest being the Great Artesian Basin, which covers over 600,000 square miles in Queensland, Northern Territory, South Australia and New South Wales. This great unit is warped into a series of sub-basins, the best known of which are the Surat and Eomanga sub-basins and the Frome Embayment. Other large basins are the Canning (170,000 sq. m.) and Carnarvon (40,000 sq. m.) in Western Australia; the Murray (100,000 sq. m.), embracing parts of South Australia, Victoria and New South Wales; the Eucla (75,000 sq. m.) and the Officer (80,000 sq. m.) which adjoin to the north of the Great Australian Bight, and the Barkly (80,000 sq. m.) in Northern Territory. Among the small basins are the Gippsland and Otway Basins of Victoria, each about 3,000-4,000 sq. m., and the Maryborough (4,000 sq. m.) in Queensland. Our own Sydney Basin occupies an area of approximately 16,000 sq. m.

In all there are approximately 24 major sedimentary basins in Australia, and it is within these that the exploration companies are prospecting for oil and natural gas.

The search in Australia in the early part of the century had been pursued in a rather desultory fashion and on a small scale; workers were hampered by primitive methods, limited finance and inadequate technical knowledge. It is only in the years succeeding World War II that the tempo of oil exploration has quickened. This increase has been most apparent within the last 10 years and has been accompanied by increased technical and scientific application.



Drilling rig at Cabawin, 170 miles west of Brisbane, where an encouraging oil strike has been made.

Indeed, it was the discovery of oil, in November, 1953, by West Australian Petroleum Pty. Ltd. in their first test well in the Carnarvon Basin at Rough Range which was responsible for a great surge of drilling activity and a generally boosted exploration programme. This impetus was partly engendered by the then firm belief that commercial oil had been found in the Rough Range area, and that with increased activity it would also be discovered in other sedimentary basins on the continent. Unfortunately, this intensified search was in



many cases ill-conceived, and many wells were drilled without adequate investigation beforehand and had little chance of success.

The typical wave of enthusiasm touched off by the Rough Range discovery began to wane in 1955, as drilling results in all the sedimentary basins proved very disappointing. Within months of drilling the discovery well, it was found that the oil pool was very confined and that commercial production was unlikely.

Many small companies began to drop out of the search, and the bigger companies settled down to steady, detailed exploration programmes. It was becoming clear that the search for oil must be placed on a very systematic and scientific basis; in the past too little attention had been given to preliminary investigations, and too many wells had been sunk with insufficient knowledge of the stratigraphy and structure of the geological formations. Now, greater emphasis was being given to detailed geological work, followed by gravimetric and seismic surveys prior to the location of a drilling target for a test well.

The Commonwealth Government, furthermore, appreciating the importance of oil to the national economy and aware of the need to foster the search, had issued the Petroleum Search Subsidy Act, 1957-58, which was designed to encourage the drilling of wells for stratigraphic information. A further Act in 1959 provided for subsidy of geophysical surveys. Additionally, the Commonwealth Bureau of Mineral Resources continued with a full programme of geological mapping and geophysical surveying in several of the sedimentary basins.

### **Experts' Investigation**

In March, 1960, the Australian Government called on the French Institute of Petroleum to undertake an investigation of the sedimentary basins of Australia in relation to the occurrence of petroleum. A team of geological and geophysical experts made a preliminary assessment, and set up a programme of work aimed at giving a reliable appraisal of Australian oil prospects. The outcome of the investigation

was a series of recommendations for future exploration, which are at present being followed up by the Bureau of Mineral Resources.

This practical government encouragement was responsible, in part, for increased overseas interest. The licence-holders gained greater financial assistance from the larger petroleum companies, as foreign capital realized the Australian market could be economically strategic.

Our knowledge of petroleum conditions on the mainland has expanded rapidly in the last four years as a result of the increased technical and scientific investigations by the exploration companies, and by the scientific help and incentive bonuses offered by the Commonwealth Government. In these few years an increased programme of exploration has emerged; a programme of careful investigation culminating in the drilling of several wells. Many of these were for stratigraphic information only, but a few were test wells. Most of the sedimentary basins received some attention.

During this latter period notable advances have been made in the investigation of several of the sedimentary basins, and the focus of interest has shifted to the eastern States of the continent.

Delhi Australian Petroleum Ltd. joined with Santos in 1958 to explore several large anticlines discovered in the central part of the Great Artesian Basin. In 1959-60 the companies drilled two deep stratigraphic wells—Innaminka (12,637 ft.) in north-eastern South Australia and Betoota (9,824 ft.) in south-western Queensland, which gave valuable information of the stratigraphy in the deeper parts of this enormous basin.

### **Port Campbell Test Well**

A test well drilled by Frome-Broken Hill Ltd. at Port Campbell in the Otway Basin in Victoria encountered "wet" gas and condensate under high pressure between 5,656 ft. and 5,666 ft. in December, 1959. Hopes ran high, but further wells showed that the early optimism at Port Campbell for a commercial oil or gas field was unjustified



as the reservoir was small, but it did prove great thicknesses of marine shales, which have been described as favourable source beds for petroleum, and has given hope of migratory oil being still present in the area. The high gas pressures and associated publicity further revived the interest of the exploration groups, and a small but significant boost in activity was apparent.

In the Gippsland Basin, Woodside (Lakes Entrance) Oil Co. has located several favourable structures after an extensive seismic programme. The company is now drilling a 12,000 ft. well near Lake Wellington.

In south-eastern Queensland, the Associated Australian Oilfields/Associated Freney Oil Field/Papuan Apinaipi group had been prospecting for natural gas and oil for some years in the Roma district, and the results from several recent test wells have indicated the existence of a large gas field. Pickinjinnie No. 1 well gave initial tests of 7,000,000 cubic feet per day. At the present time the companies have contracted with local government, and are operating a pilot scheme near Roma, whereby the local power station is using petroliferous gas to generate electricity. The contractors supply the gas at 6/- per 1,000 cubic feet metered into the power house. Production is from A.A.O. No. 4 well and Timbury Hills No. 2 well, both of which obtain the gas from the Hospital Hill Formation in the basal Mesozoic sands at depths of less than 4,000 ft.

### Hopes For The Future

In 1960 Australian Oil and Gas Corporation entered into a financial agreement with two American companies, Union Oil Development and Kern County, on leases the Australian company holds in the Surat sub-basin, which is an offshoot of the Great Artesian Basin. Detailed geological and geophysical investigations led to the location of a drilling target on a structure defined by seismic methods at a point between Cabawin and Tara. Cabawin is 170 miles west of Brisbane and 100 miles south-east of Roma. At a depth of almost 10,000 ft. a light-gravity oil with an estimated output of 60-80 barrels per day

## NEW NAME FOR MAGAZINE

The Trustees of the Museum have decided to change the name of *The Australian Museum Magazine* to *Australian Natural History* as from the issue of March 15, 1962.

The new title has been adopted because it more accurately describes the magazine's scope.

The nature and content of the magazine will remain unchanged.

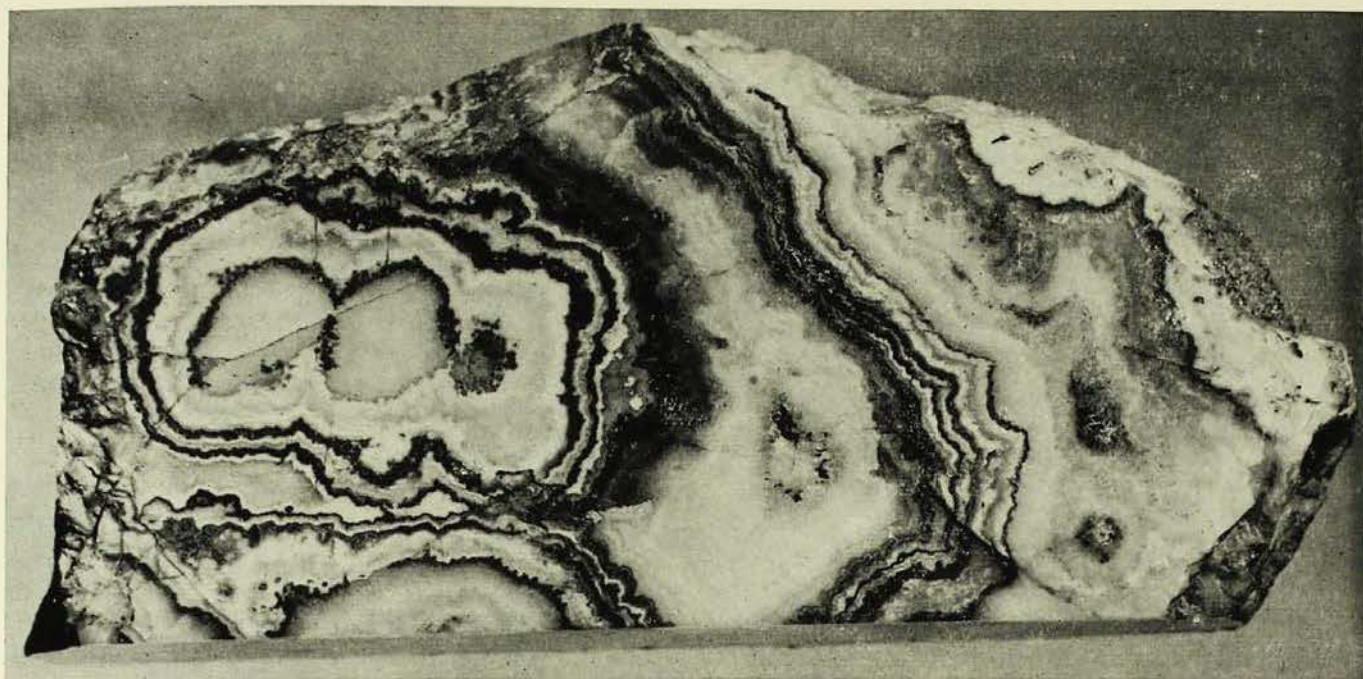
was struck in Permian marine beds; the well was completed at over 12,000 ft. The companies are now drilling on a new target a few miles from the first well.

This discovery of high-quality oil in the Surat sub-basin has promoted fresh interest in the Permian rocks cropping out along the eastern margin of the Great Artesian Basin.

Although the main interest is centred in the eastern States, West Australian Petroleum Ltd. has not abandoned the search in Western Australia, where £16.5 million has been spent in exploration. Following the drilling of Thangoo No. 1A and Barlee No. 1 wells near Broome, the company has transferred all its efforts to the Perth Basin, and is drilling a test well near Eneabba, north of Perth. This site was chosen following extensive geophysical work.

The encouraging indications at Port Campbell, Cabawin and Roma augur well for the future of oil exploration in Australia. The search goes on steadily, with oil company experts extremely optimistic that commercial oil will be tapped in Australia within two years. Considering that less than 500 wells have been sunk on the mainland of Australia in the search, it will be a remarkable achievement if this prediction is fulfilled.





Polished specimen of red and white banded agate from White Rock, Drake, New South Wales.

Photo.—Howard Hughes.

# **ORNAMENTAL STONES OF NEW SOUTH WALES**

By R. O. CHALMERS

THOSE varieties of minerals that have been prized throughout the centuries as objects of beauty, and hence used for ornamentation and decoration, can be divided into two main groups. The first are the transparent gemstones cut in faceted forms so that colour, lustre and brilliance are displayed to the full, provided scientifically correct proportions are observed in cutting. It is the second group that concerns us in this article. These are minerals that are hard, and hence durable, but are translucent or opaque and not transparent. They are valued principally on account of their colour and pattern. When designed to be worn on the person they are cut *en cabochon*, that is, in relatively small domed forms of varying degrees of steepness. They are also cut in slabs and other ornamental forms, the size being limited only by the availability of the mineral. One reads of unbelievably lavish use of slabs of

malachite and lapis lazuli in old buildings in Russia and Persia. Finally, they are carved, sometimes most intricately, as *objets d'art*. Minerals used in the above-mentioned ways are appropriately named ornamental stones.

## **Silica Minerals**

Ornamental stones consisting of varieties of silica (silicon di-oxide) are by far the largest group. The most important of the silica minerals is chalcedony. Chalcedony, although it has regular internal atomic structure, always occurs in massive form and never assumes an outward regularity of crystal shape like quartz, another of the principal naturally-occurring varieties of silica. It is described as cryptocrystalline. Chalcedony has a waxy lustre unlike the glassy lustre of quartz.

There are two main types of chalcedony. The first includes varieties of similar



appearance and texture, differing only in colour. Chalcedony is invariably translucent and is white, yellow, red or brown, rarely green. The presence of banding is the characteristic feature of agate, the second main type of chalcedony. The distance apart of the bands varies. Sometimes it is exceedingly small, there being a record of as many as 17,000 bands to the inch. Agate, like chalcedony, shows a variety of colours. Chalcedony and agate are deposited from solutions carrying dissolved silica. In the case of agate the solutions may be in the form of a gel, that is, they are colloidal or jelly-like, and deposition takes place, very often in rhythmic fashion, from colloidal solutions; hence, successive depositions in rhythmic concentric fashion give rise to the banding characteristic of agate.

Chalcedony and agate characteristically occur either as the linings or the fillings in more or less rounded cavities in volcanic or hypabyssal rocks. These are types of igneous rocks, that is, rocks that originated in a hot, molten state. Volcanic rocks have been poured out on the surface and hypabyssal rocks have been intruded in a molten condition at relatively shallow depths in the earth's crust. In both instances, hot solutions containing silica have circulated through the rock in the closing stages of consolidation. They have entered cavities in the rock, where they deposit silica, sometimes in the form of chalcedony, sometimes in the form of quartz. Both varieties are frequently found associated. Sometimes these cavities are actual holes formed in the semi-fluid rock by the escape of steam. In other instances the solution may have been able actually to dissolve part of the rock away and so form its own cavity. Igneous rocks are usually not very resistant to weathering, and eventually break down into soil. These linings or fillings of cavities, being highly resistant to weathering, are liberated in the soil as break-down of the rock takes place.

### **Jasper, Chert And Flint**

Silica is also carried in solution by deep-seated groundwater which, over long periods of time being closely in contact with the rocks and continually permeating them and circulating through them, has an opportunity

to dissolve the silica contained in them. These solutions penetrate fine-grained rocks, such as shales or limestones, and replace the original constituents of the rock, leaving a dense mass of silica in its place. All these types of dense, fine-grained silicified sediments are known by a variety of names, such as jasper, chert and flint, and it is difficult clearly to define each type.

In practice, the name jasper is applied to attractively coloured red and green types. Chert seems to apply more to paler cream, fawn and buff varieties. The name flint is usually confined to the dense, dark grey, siliceous material found in the chalk formations of England. Chalcedonic, crystalline and opaline silica may all be found in varying proportions in jasper and chert. Opaline silica is a variety containing a certain amount of water. Common opal may be deposited in volcanic rocks in the same way as chalcedony, or by groundwaters.

Silicified or petrified wood is wood that has been infiltrated by solutions rich in either chalcedonic or opaline silica. A considerable amount of the woody material may remain unchanged, but it is completely encased in silica and the pore spaces are so filled with silica that substantially the whole mass is converted to silica while still retaining its woody structure.

The foregoing brief account of the geological occurrence of ornamental stones may serve as a guide to likely localities where they may be found.

### **Unique Volcanic Flows**

Varieties of chalcedony are found filling cavities in the huge basalt flows that are found in so many parts of the eastern highlands of New South Wales, notably in the Liverpool Ranges and in the New England district. To these should be added the unique volcanic flows and intrusions of the Warrumbungle and Nandewar Ranges, consisting of trachytic types of rocks differing somewhat in composition from basalt. In the New England district, also, extensive beds of jasper associated with other sediments form an almost continuous outcrop all the way from Nundle, south-east of Tamworth, up through Attunga to Bingara, on the Gwydir River, in the north. All members of the chalcedony and jasper



groups, being siliceous and therefore hard and resistant, are carried long distances in streams flowing to the west of the New England tableland and are concentrated, sometimes in quite large accumulations, in the soil of western flood plains. There are a number of such accumulations found in the Boggabri and Narrabri districts, notably at Bellata. In railway cuttings near Bellata accumulations of attractive waterworn pebbles of chalcedony, carnelian (the red variety of chalcedony), agate, jasper and silicified wood, up to 15 ft. thick, are found. So plentiful are these pebble deposits that the local council uses them for the roads.

An attractive sardonyx, the red variety of agate, is found at Woolabra, 30 miles north of Narrabri. It seems certain that the original source of this material was the volcanic rocks of the Nandewar Mountains and the jasperoid rocks of the western flanks of the New England tableland.

All varieties of siliceous ornamental material, including common opal, can be found in creeks that rise in the Warrumbungle Ranges. Trachytes similar to those in the Nandewars and Warrumbungles occur in the Macpherson Ranges on the border of New South Wales and Queensland, and it is from here that ornamental stones, notably a blue chalcedony, are found in the Numinbah Valley which, though actually in Queensland, is visited by many New South Wales collectors. Volcanic rocks of earlier geological age occur in other parts of the State, such as the coastal plains and scarp of the coastal range all the way down the South Coast from Wollongong to Nowra. It is from these rocks that the pebbles of agate, chalcedony, jasper and silicified wood found at Minamurra and in the Kangaroo Valley have originated.

Jasperoid rocks, too, are widespread in other parts of New South Wales. On the North Coast they are found at Tinonee, Krambach and Wingham, and a possible northern extension of this belt may have given rise to the handsome jasper pebbles that abound on the ocean beaches at Port Macquarie and possibly at Laurieton also.

Radiolarian cherts are found in numerous areas in the Southern Tablelands at Taralga, Goulburn, Yass and Canberra. There is an

extension of the Yass-Canberra belt running north to Trunkey and Tuena, and this may well be the source of a most handsome deep-red jasper found at Tuena.

Small pebbles of chalcedony, agate and jasper have been shed from beds of conglomerates of Narrabeen age at Garie and Bellambi, to the south of Sydney, and at Norah Head, to the north, but their original source is unknown, except that it was in the highlands far to the west in Triassic time and streams rising there brought down to the freshwater lakes the loads of sediments that eventually became consolidated to form the rocks we find today in the great Sydney basin.

A number of minerals other than the numerous members of the silica family are used for purposes of ornamentation. Throughout a large area in the southern part of New England, more or less centred on Walcha, there are a number of small deposits of manganese minerals, principally manganese oxides of economic importance. In a number of places, the most important of which is Danglemah, 22 miles south of Walcha, dense, fine-grained, crystalline masses of deep rich pink rhodonite (manganese silicate) are found associated with the oxides. This material lends itself admirably to cutting and polishing.

Some 22 miles west of Sydney, at Prospect, extensive quarrying has proceeded for a period of many years now in a great intrusive mass of olivine analcite dolerite, 350 ft. thick, revealing superb specimens of prehnite, which is a hydrated silicate of calcium and aluminium deposited from hot solutions in cavities in the dolerite. Prehnite is a relatively hard mineral that stands up to shaping without fracturing, takes a good polish, and is a most attractive ornamental stone bearing a certain resemblance to jade. The most common colour is green, but other attractive colour varieties, ranging from pale straw to rich golden-brown, are found. It is worthy of note that at Prospect there also are found a violet-coloured chalcedony and common opal, some opaque and ranging from white to green, and some almost transparent and at times showing a moonstone-like iridescence.



# VICTORIAN GOLDFIELDS

By K. G. BOWEN

Department of Mines, Victoria

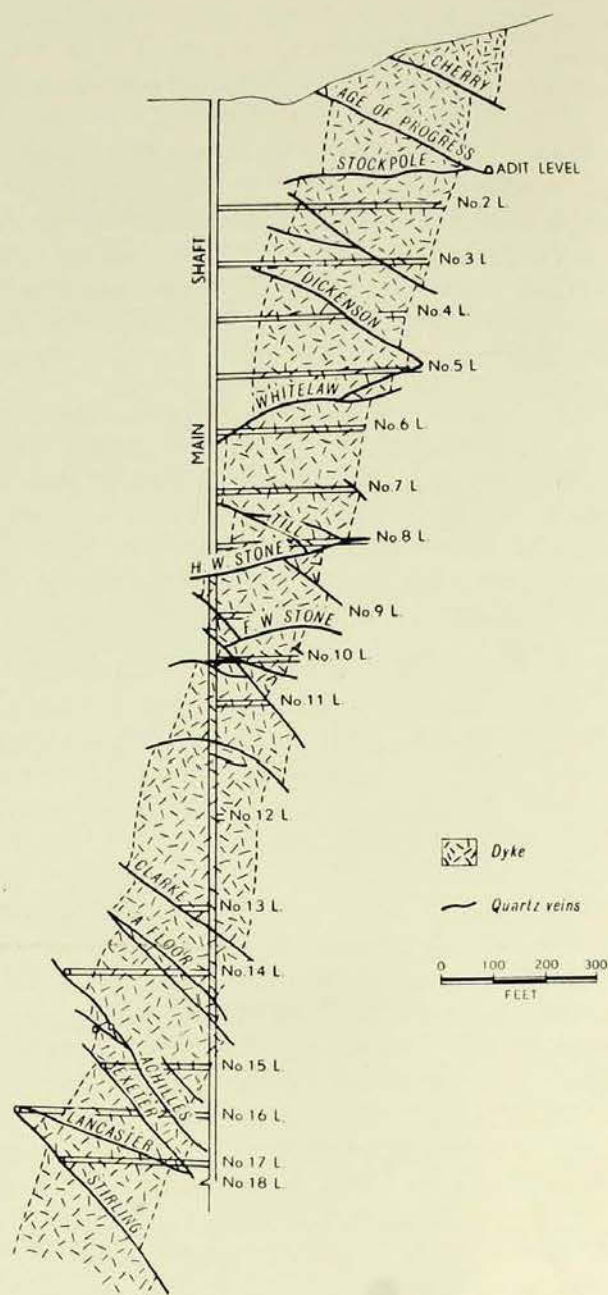
WHILE Victoria was celebrating its establishment as a separate colony on July 1, 1851, some excited miners were hurrying to report their gold strikes. James Esmond recorded his gold discovery at Clunes on July 5, 1851, and on the same day Louis Michel and party were credited with a discovery at Andersons Creek, now known as Warrandyte.

Prior to these two discoveries gold had been reported from a number of different localities from as early as 1841. Because the authorities of the period regarded rumours of gold discoveries as a threat to law and order, these early finds were hushed up. However, following the discoveries at Clunes and Andersons Creek, the gold fever that the authorities feared set in, and the opening up of the rich alluvial fields followed quickly on these early discoveries.

During the gold-rush period gold was won almost exclusively from alluvial deposits on or quite near the surface. Shafts were put down through the alluvial gravels, which were then washed by various means for their gold content, panning being the simplest.

It was in these alluvial workings that the world-famous nuggets were found. The largest, the Welcome Stranger, was found at Moliagul on February 5, 1869, immediately below the surface. Its gross weight was 2,520 oz., and it was sold for £9,436/16/8. The second largest, the Welcome, found at Bakery Hill, Ballarat, on June 15, 1858, had a gross weight of 2,217 oz. and was sold for £10,500. Despite the fact that probably less than half the nuggets found were placed on record, 1,327 nuggets, ranging from 20 oz. to the 2,520 oz. Welcome Stranger, have been recorded.

As the easily-won alluvial gold became scarce, attention was turned to the basalt-covered alluvial gravels of the deep leads, and the gold-bearing quartz reefs found outcropping at the surface and in the deep-lead mines. At Ballarat four distinct basalt



Cross-section through the main shaft of the Morning Star Mine, Woods Point, showing the occurrence of ladder veins in a large dyke bulge.

flows covered the leads in some mines, and mining of these deep leads was carried to a depth of 500 ft. The deep leads yielded good returns of gold, but, because the gravels and even the basalts contained large quantities of water, continuous pumping of the water was necessary and in many of the mines millions of gallons were pumped per day. Considerable capital was required to



finance the extensive underground workings of the deep-lead and quartz mines, and the day of the individual miner gave way to the mining companies.

Most of the Victorian goldfields are confined to the belt of Siluro-Devonian and Ordovician rocks of the Eastern Highlands; they stretch from Stawell in the west of the State as far east as Mallacoota, and include such places as Daylesford, Castlemaine, Ballarat, Bendigo, Ararat, Beechworth, Bright, Harrietville, Omeo, Glen Wills, Cassilis, Maryborough, Woods Point, Walhalla, etc. Almost all of these fields have now closed, some having ceased to exist at the end of the gold-rush period when the rich alluvials were worked out, others only within the last decade. Others, however, have been in almost continuous production since their discoveries in the middle of the last century. Of the three large mines still operating in Victoria, the A1 Mine, Gaffneys Creek, and Morning Star Mine, Woods Point, have been in almost continuous production for 100 years. The third, the Wattle Gully Mine, Chewton, has been mining a flat west-dipping quartz reef, somewhat akin to the "leather jackets" of Ballarat, since the early 1930's.

Ballarat was one of the earliest fields discovered in Victoria and the alluvials were of exceptional richness. The deep leads were followed from the shallow alluvials to depths of 500 ft. and were phenomenally rich in sections. A large number of nuggets were found in both the alluvials and deep leads, and include 33 over 100 oz. in weight.

The Ballarat field can be divided into three separate fields, each with distinct structural features. The most famous of these was the Ballarat East or Indicator field. Quartz reefs, locally known as "leather jackets", occupied flat west-dipping faults, which, on crossing the fold axes, steepened and became bedded. Gold was unevenly distributed throughout the "leather jackets", but rich shoots with very coarse gold, sometimes with slugs up to 500 oz., occurred along the intersections of the "leather jackets" with favourable beds known as indicators. The most important of these beds was the "Indicator", a narrow bed of slate rarely more than  $\frac{1}{8}$  in. thick and in places pinching to a merest trace. This bed was

traced along its strike for a distance of four miles. Other famous indicators were the Pencil Mark and the Black Seam.

The Ballarat West or Sebastopol field comprised three main anticlinal axes, the Albion to the west, the Guiding Star and the Consols on the east. The lodes were confined to a zone 60 to 100 ft. wide, characterized by a number of black slate zones which repeated over the three anticlines. The lodes were largely narrow persistent bedded lodes, and were only auriferous where the beds had a west dip, the reefs in east-dipping sediments being barren.

The Little Bendigo field, the third of the Ballarat fields, was similar in structure to the Ballarat West field, in that bedded reefs and spurs were only auriferous in west-dipping slates.

Bendigo, like Ballarat, was a noted alluvial field and yielded several nuggets up to 573 oz. in weight. This field contained the deepest mine in the State, the Victoria Quartz, with a depth of 4,613 ft. below the surface. About 100 shafts exceeded a depth of 1,000 ft., 40 were between 2,000 and 3,000 ft., 15 between 3,000 and 4,000 ft. and two over 4,000 ft.

The Ordovician strata of the Bendigo field are folded into a series of north-south anticlines and synclines. Associated with these anticlines were the famous "saddle reefs" the shape and repetition in depth of which were recognized by the early miners. The saddle reefs rarely conform to the ideal picture of a saddle-shaped mass of quartz, conformable to the bedding and filling an open space created by slipping of beds over each other at the crest of the anticline. Commonly, they occur where two strike faults of opposed dip intersect at the crest of an anticline. The reefs are roughly triangular in cross-section, but where one of the faults is stronger than the other the saddle reef is asymmetrical. These saddle reefs repeat at irregular intervals of depth, and as many as 24 successive saddle reefs have been intersected in a single mine. Not all the reefs contained gold in payable quantities, but as a general rule the more productive mines were associated with domal structures on the anticlines where the pitch of the anticline changed from north to south.



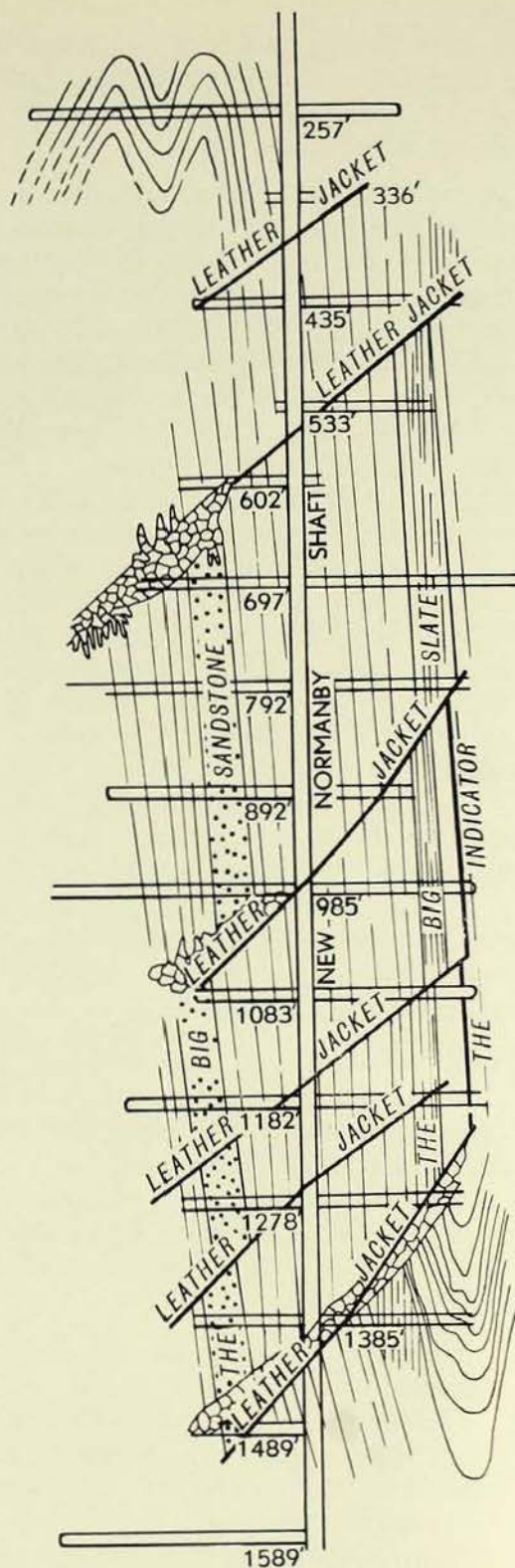
The quartz reefs of the Walhalla-Woods Point field were invariably associated with the dykes that intrude the sediments of the area. The dykes vary from acidic to ultra-basic in composition and from fine-grained to granitic in texture. Two distinct types of dykes are recognizable in the field, narrow continuous dykes ranging from a few inches to 30 ft. in width, and comparatively short dyke bulges. The bulges are either local enlargements ranging up to 1,700 ft. in length and 300 ft. in width, or near-circular pipes or plugs.

The reefs associated with the narrow dykes are found on either wall of the dyke. In the bulges the reefs or floors, as they are locally termed, dip at a low angle and are longitudinal or transverse to the major axis of the dyke. The reefs follow reverse faults and cross from wall to wall of the dyke, ziz-zagging downwards and producing the so-called ladder veins of the Morning Star, Woods Point and A1 Mine, Gaffneys Creek. The reefs have continued to depths of over 2,000 ft. in these mines, although not all are auriferous. Some, however, are exceedingly rich; the Victory Reef (A1 Mine), discovered in 1943, carried up to 20 oz. of gold per ton, and, from 1943 to 1947, following the discovery of this reef, the mine yielded 78,080 oz. of gold from 34,690 tons of ore and, in this period, paid £490,500 in dividends.

Nearly all the Walhalla companies operated on Cohen's Reef and on the same gold shoot. The reef over most of its course was associated with a diorite dyke varying from a few inches wide to several feet. Total production from this shoot approached 1½ million oz. at an average grade exceeding 1 oz. per ton, and this was undoubtedly the richest single shoot in Victoria. Victoria's leading gold producer, the Long Tunnel Co., produced over 800,000 oz. of gold from this shoot, approximately 300,000 oz. more than Victoria's second richest mine, the Band and Albion Consols, Ballarat.

Gold production in Victoria reached a peak in 1856, when 3,053,744 oz., valued at £12,214,976, were produced. From 1852 until 1861 yearly production was over two million oz. and did not fall below one million until 1876. Thereafter production steadily declined, with some minor

fluctuations, to 28,566 oz. in 1960. In all, since 1851 Victoria has produced 78,469,389 oz. of gold valued at £327,620,632.



Transverse section of the New Normanby Mine, Ballarat East, showing west-dipping "leather jackets" and the "Indicator".