COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF SUPPLY AND SHIPPING.
G. T. CHIPPENDALL, *Secretary*.

MINERAL RESOURCES SURVEY.
H. G. RAGGATT, *Director*.

BULLETIN No. 14
(GEOLOGICAL SERIES No. 5).

THE BAUXITE DEPOSITS OF THE BOOLARRA-MIRBOO NORTH AREA, SOUTH GIPPSLAND, VICTORIA.

BY

H. G. RAGGATT and H. B. OWEN (Mineral Resources Survey) and E. S. HILLS,
(Professor of Geology, University of Melbourne).

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Following is a list of Bulletins. It should be noted that only Nos. 1, 2, 3 and 14 have been published and that the others are not available for general distribution at present:—

Bulletin No. 1—(Palaeontological Series No. 1)—"The Tertiary Geology of East Gippsland, Victoria". By F. Chapman and I. Crespin. Printed and issued 1932 as Palaeontological Bulletin No. 1.

Bulletin No. 2—(Palaeontological Series No. 2)—"The Larger Foraminifera of the Lower Miocene of Victoria". By I. Crespin. Printed and issued 1936 as Palaeontological Bulletin No. 2.

Bulletin No. 3—(Palaeontological Series No. 3)—"The Occurrence of *Lacazina* and *Biplanispira* in the Mandated Territory of New Guinea", and "A Lower Miocene Limestone from the Ok Ti River, Papua". By I. Crespin. Printed and issued August, 1938, as Palaeontological Bulletin No. 3.

Bulletin No. 4—(Miscellaneous Series No. 1)—"Supplies of Raw Materials for Fertilizers". By H. G. Raggatt and P. B. Nye. Dittoed and issued 12th February, 1943, as Miscellaneous Report No. 1.

Bulletin No. 5—(Mineral Resources Series No. 1)—"Sulphur-Bearing Materials". By P. B. Nye. Roneoed and issued June, 1942, as Mineral Resources Report No. 1.

Bulletin No. 6—(Miscellaneous Series No. 2)—"Fluorescence of Scheelite and Its Application to the Mining Industry". By J. M. Rayner. Roneoed and issued 18th September, 1942, as Miscellaneous Report No. 2.

Bulletin No. 7—(Miscellaneous Series No. 3)—"Preliminary Study of Australian Diatomites with Special Reference to Their Possible Value as Filter Media". By I. Crespin. Roneoed and issued 5th January, 1943, as Miscellaneous Report No. 3.

Bulletin No. 8—(Geological Series No. 1)—"Geological Report on the Renison Bell Tin Field". By N. H. Fisher and H. G. W. Keid. Dittoed and issued 10th June, 1943, as Mineral Resources Survey Report No. 1943/23.

Bulletin No. 9—Palaeontological Series No. 4)—"The Stratigraphy of the Tertiary Marine Rocks of East Gippsland". By I. Crespin. Roneoed and issued 10th August, 1943, as Palaeontological Bulletin No. 4.

Bulletin No. 10—(Miscellaneous Series No. 4)—"Piezo-Electric Quartz". By F. Canavan. Issued in roneoed form, 1st December, 1943.

Bulletin No. 11—(Geological Series No. 2)—"The King Island Scheelite Mine". By P. B. Nye and C. L. Knight. Issued in roneoed form, December, 1943.

Bulletin No. 12—(Geological Series No 3)—"The Mount Chalmers Gold and Copper Mine". By N. H. Fisher and H. B. Owen. Issued in roneoed form, September, 1944.

Bulletin No. 13—(Geological Series No. 4)—"Notes on the Occurrence of Piezo-Electric Quartz in Australia with Special Reference to the Kingsgate Field". By M. D. Garretty. Issued in roneoed form, October, 1944.

Bulletin No. 14—(Geological Series No. 5)—"The Bauxite Deposits of the Boolarra-Mirboo North Area, South Gippsland, Victoria". (Revision of Geological Report No. 1943/58 issued 26th October, 1943.)

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FOREWORD.

During recent years a great deal of exploratory work has been done in the search for bauxite in South Gippsland. Most of this work has been done by Messrs. Sulphates Pty. Ltd., of Melbourne. This company has made prospecting reconnaissances over most of the Boolarra-Mirboo North area and has scout-bored many of the bauxite deposits discovered. Following a recommendation by the Minerals Committee, the Controller of Minerals Production put in hand a drilling programme to prove a reserve of 400,000 tons of commercial grade bauxite. The drilling was done by Victoria Gold Dredging Co. N.L. and geological supervision was provided by this Branch. Concurrently with the other two programmes the Victorian Mines Department also conducted a drilling campaign. By courtesy of that Department officers of this Branch were able to keep in close touch with this work also.

Professor E. S. Hills made an independent geological survey of some of the deposits in 1942. He paid particular attention to geological mapping and to laboratory studies which throw much light on the constitution and origin of the bauxite. His investigations and those of this Branch are complementary to each other and it has been decided to combine them to this bulletin.

It is necessary to point out that the authors have found it impossible to reach complete agreement on all points which have arisen out of the surveys, and that where divergence of interpretation exists, each opinion has been stated separately. Essentially there is only one basic difference in our conclusions, namely, H.G.R. and H.B.O. consider that all the bauxites occur on one horizon above the Older Basalt, whereas E.S.H. considers that the Childers and Nahoo deposits occur below the Older Basalt. In its main investigation the Survey did not pay much attention to the Childers and Nahoo deposits, as they are not very important commercially. However they have been examined recently by Dr. N. H. Fisher and Mr. H. B. Owen with the result that the Survey still finds itself unable to agree with Professor Hills' conclusions. Nevertheless his descriptions of the deposits are included in full but a note has been added indicating briefly why we disagree.

It will be appreciated that secondary, but important, differences arise from this primary one concerning the stratigraphical position of the deposits (e.g., on the origin of the deposits). Also if Professor Hills is right, the scope for prospecting and chances of finding further deposits are greater (in certain areas) than if the Survey's views are correct.

The Survey is greatly obliged to Professor Hills for his collaboration in the writing of this bulletin. In addition to the description above-mentioned Professor Hills has contributed Chapter VIII. on the constitution of bauxite, most of Chapter XI. on the origin of the bauxite and all the petrological descriptions not otherwise specifically acknowledged, i.e., nearly all the petrological work has been done by him.

Thanks are due especially also to Sulphates Pty. Ltd. for their generosity in placing the results of their work at our disposal and for making analyses of bauxite. The co-operation of the Victorian Mines Department is also gratefully acknowledged. In addition, Professor Hills wishes to express his thanks to Mr. G. Baker for certain heavy mineral analyses credited to him in this bulletin and to Mr. D. O'Donnell, Director of the P.M.G. Research Laboratories, for X-ray diffraction photographs of bauxite and associated minerals.

H. G. Raggatt, Director.

Canberra, 7th August, 1945.

I.—SUMMARY.

For over twenty years it has been known that bauxite deposits occur in South Gippsland, but until recently it was believed that the quantities available were small. However, a recent prospecting campaign has revealed at least twelve deposits, in addition to those known previously, making a total of 24 deposits within an area of 150 square miles, the centre of which is 16 miles south-west from Yallourn and 74 miles east-south-east of Melbourne. None of the deposits is more than 6 miles by road from a railway.

Five of the 24 deposits have been tested by bores and shafts and shown to contain reserves of 735,500 tons with the average composition —alumina 51.3 per cent., silica 7.66 per cent., ferric oxide 7.2 per cent., titania 5.5 per cent. There is little doubt that many more deposits exist. The largest individual deposit proved to date contains 214,000 tons* of relatively high-grade and 165,000 tons of low-grade bauxite. (Reserves of low-grade bauxite are not included in the total reserves given above. The figure is given here merely to indicate the size of the deposit).

From a study of available information it has been concluded that ore containing 50 per cent. alumina and 7 per cent. silica may be classed as metallurgical grade. This factor has been taken into account in calculating the reserves in the Gippsland bauxite deposits.

Rough beneficiation tests indicate that the grade of bauxite from most of the deposits may be greatly improved by a simple washing process.

It is shown that all (except two, according to E.S.H.) of the deposits occur either upon or a short distance stratigraphically above the Older Basalt and are overlain by the lower part of the Yallourn formation. The deposits are Oligocene or Lower Miocene in age.

Petrological investigation and X-ray defraction studies show that the hydrated alumina occurs as gibbsite and that other minerals such as diaspore or bohmite are absent.

The bauxites were derived by alteration of basaltic tuffs under aqueous conditions in a hot climate. The authors have been unable to agree in detail on the conditions under which alteration of the tuffs to bauxite took place and their different interpretations of the evidence are set out separately in the text.

II.—INTRODUCTION.

The first discovery of bauxite in South Gippsland which was brought to public notice is said to have been made in 1918 by Mr. Donald Clarke on the property known as "Nahoo", allotment 8, Parish of Narracan South. Bauxite from this deposit has been used for chemical purposes for over twenty years. It is understood that other occurrences had been noted prior to Mr. Clarke's report.

Eleven additional discoveries were made from time to time up to April, 1942, when the extensive prospecting programme mentioned in the foreword was undertaken. In the short time that has elapsed since then, a further twelve deposits have been discovered, making a

* All tonnages given in this report are expressed as long tons (2,240 lb.).

total of 24 deposits in the adjoining parishes of Moe, Allambee East, Narracan South, Mirboo and Budgeree in the county of Buln Buln. Several of these deposits have been systematically tested by shaft sinking and boring.

The deposits at Boolarra, Callignee and "Nahoo" have been reported on very briefly by Whitelaw (1921), Ferguson (1936) and Baragwanath (1940), but there have been no detailed descriptions of the deposits and no general account of their geological relationships.

It should be noted that there has been no authenticated report of the occurrence of bauxite in Victoria outside South Gippsland and that little is known of the deposits other than those in the Boolarra-Mirboo North area.

III.—SITUATION.

The bauxite deposits described in this report occur within an area of 150 square miles, the centre of which is 16 miles south-west from Yallourn and 74 miles east-south-east from Melbourne. The area is well served by railways as it is traversed by two branch lines from the Gippsland railway, one from Moe to Thorpdale, 91½ miles by rail from Melbourne, and the other from Morwell to Mirboo North, 109 miles by rail from Melbourne. None of the deposits is more than 6 miles by road from rail. (*See* Plate 8.)

The area was formerly heavily timbered, but the better-quality land is now fairly closely settled and the timber cover of these areas has been almost completely destroyed. Much of the poorer country, the greater part of which is underlain by post-basalt sand and grit, is still covered with scrub and some timber remains on these areas. As the bauxite occurs under these sands it is fortunately within such areas that the prospecting operations have been, and mining operations will be, carried on. Hence the industry can develop with a minimum of disturbance to the local rural community.

IV.—TOPOGRAPHY.

The area within which the bauxite deposits are situated lies in the South Gippsland hills and is part of a block-faulted and dissected region, the higher portions of which are about 1,200 feet above sea level.

The principal drainage is that of the Morwell and Tarwin Rivers. The former flows north to join the Latrobe at Morwell and the latter enters Bass Strait through Anderson's Inlet, six miles east from Wonthaggi.

V.—GENERAL GEOLOGY.

A.—STRATIGRAPHY.

The area has been geologically mapped by the Victorian Mines Department in the course of its systematic survey of parishes. Sulphates Pty. Limited have also made extensive reconnaissances in the area, the results of which they have freely made available. The area has been visited several times by the authors. One of us (E.S.H.) has made a geological reconnaissance over most of the area and has studied some of the deposits in detail; another of us (H.B.O.) supervised most of the drilling done by the Commonwealth Government. As a result of the foregoing and of recent prospecting operations which have been carried on in the search for bauxite deposits, the details of stratigraphical succession in the area under notice can be stated more clearly than was previously possible. (Unless it is obvious from the context the following notes refer strictly to the area included in Plate 8.)

The succession most commonly exposed is as follows:—

—	—	Maximum Thickness in Feet.	—
Recent	Alluvium ..	..	Clay, sand and gravel
Late or Post-Tertiary	"Torrent gravels"	..	Sand and gravel
Tertiary ..	Yallourn formation	760	Lignite, lignitic clay, clay and sand
	.. .. ..	34	Bauxite, coarse sand, clay
	Older Basalt ..	344*	Basalt and basaltic tuffs
	.. .. ..	40+	Sands, clay, lignite
Jurassic	.. .. ..	..	Sandstone, mudstone, black coal

* No. 1 Bore, Yarragon (*see* Stirling 1899).

The Jurassic rocks consist of alternating beds of sandstone and mudstone with, in places, thin beds of coal. The rocks are very felspathic and weather to a clayey soil. At intermediate stages of weathering they may bear a superficial resemblance to decomposed basalt.

In some parts of the area, the Older Basalts lie unconformably upon the Jurassic sediments but in others considerable thicknesses of Tertiary sediments including gravel, clay and lignite underlie the basalt (Stirling, 1899). (As pointed out later E. S. Hills considers that bauxite occurs below Older Basalt at Nahoo and Childers as well as above the Older Basalt in other localities.)

The Older Basalts are apparently represented by only one group of flows with no intercalated sediments. In outcrop, thicknesses of 70, 80 and 120 feet have been measured and a thickness of 344 feet was proved in No. 1 bore, Yarragon (Stirling 1899).

The bauxite deposits generally rest upon an uneven surface in the older basalts. In most places where this contact is clearly exposed the upper surface of the basalt is represented by red and yellow clays, but in others it is represented by blue and grey clays. In several of the bores, however, (Nos. 72, 76, 79, 88) on Napier's deposit lenses of quartz grit up to 8 feet thick were found between the bauxite and the basalt.

The greatest thickness of bauxite measured so far is 34 feet.

Clays and sands with which lignites are intercalated overlie the bauxite. It is important to note that every natural exposure of bauxite in the Boolarra-Mirboo North district reveals only clays and sands overlying the bauxite and it was not until boring was done that the presence of lignite and lignitic clays was revealed. There was thus some doubt about the precise horizon of the bauxite, but the boring has now proved that the post-bauxite sediments are part of the Yallourn formation. The section on Plate 8 is based mainly upon the geological parish maps issued by the Victorian Mines Department and shows how the beds assigned to this formation in the Mirboo North area may be correlated with beds proved by boring at Boolarra in the Morwell valley. It will be seen from this section that the lignite above the bauxite at Greenwood's is low, not high, in the Yallourn formation. Reference to Miss Crespin's (1943) Table 1 shows the wider correlation of the Yallourn formation with other stratigraphic units in Gippsland. Samples from two groups of bores in Gippsland have recently been examined by Miss Crespin for foraminifera. One group of bores was designed to prove bauxite deposits and the other brown coal. Foraminifera have been identified in several of the samples from both groups of bores which penetrated the Yallourn formation (Crespin, 1944).

Obviously a starting point in discussing the geological age of the bauxite is to consider its relationship to the Yallourn formation. As indicated earlier in this section of the bulletin the lignites above the bauxite are to be correlated with the lower part of the formation as proved by boring at Boolarra. This part of the formation is correlated by Miss Crespin (1943) with the Anglesean. F. A. Singleton (1941) considers the Anglesean to be of Upper Oligocene age but Miss Crespin (1943) considers it is low in the Middle Miocene of the Gippsland Tertiary sequence. The bauxites therefore are probably Lower Miocene or Oligocene in age.

As pointed out in the foreword the authors have been unable to agree as to the stratigraphical position of the Nahoo and Childers bauxite deposits and largely because of this they favour different hypotheses for the origin of the bauxite. This difference in turn has a bearing on the evaluation of the time factors involved. Hence a more explicit statement has not been attempted on the geological age of the bauxite.

It follows from this discussion that the basalts and pre-basalt sediments in the area under review are not likely to be younger than Lower Miocene. It is clearly no longer possible to maintain that they cannot be older than Lower Pliocene (Sussmilch, 1937).

B.—STRUCTURE.

We are not concerned here with the pre-Tertiary structure, but it may be noted that the Jurassic rocks were gently folded and extensively block-faulted prior to a period of prolonged erosion which resulted in the formation of the peneplain surface upon which the Tertiary sediments rest.

Subsequent to the deposition of the Yallourn beds, marked faulting again occurred, resulting in the formation of troughs in which are preserved great thicknesses of Tertiary sediments including lignite. The Latrobe River occupies one of these troughs and a minor one extends from Morwell to Boolarra.

The significance of this faulting so far as the bauxite is concerned may readily been seen from the section shown on Plate 8, which shows how the faulting has divided the area into blocks. As a result, bauxite is found over a wide range of elevations—500 feet above sea level, 2 miles west of Boolarra; 1,000 feet at Budgeree and 1,200 feet at Watkins, 3 miles north from Mirboo North.

VI.—METHODS USED IN PROSPECTING AND PROVING DEPOSITS.

Nearly all the deposits have been discovered by Messrs. Sulphates Proprietary Limited, who have kept in close touch with the Victorian Mines Department and ourselves. During this collaboration there has been free discussion which has resulted in establishing a geological background upon which prospecting has gradually come to be based.

A.—GEOPHYSICAL PROSPECTING.

Prior to the commencement of the drilling campaign on the Boolarra and Napier's deposits, some geophysical surveys were made by L. A. Richardson, Geophysicist of this Branch, to determine whether prospecting for and investigation of the bauxite deposits could be aided by such surveys. The electrical resistivity method was used and subsurface resistivity conditions were determined at 67 points on the Boolarra open-cut area, 14 points on Orgill's area and 34 points on Napier's area. A review of the results in the light of the information provided by the recent drilling operations and geological investigations reveals the following features:—

(1) The resistivity of the basaltic clay which forms a bedrock for the bauxite deposits, which have been tested, is commonly of the order of 100–500 ohm feet units. A higher resistivity has been noted in some places.

(2) The resistivity of the overburden and bauxite is variable over a wide range, but is almost invariably higher than that of the basaltic clay.

(3) The depth to the basaltic clay may be determined approximately in most places where the resistivity of the overburden and bauxite is appreciably greater than that of the basaltic clay.

Plate 9 shows resistivity curves illustrating effects due to deepening bedrock. Electrode separation, in feet, is plotted vertically and apparent resistivity, in ohm/feet units, is plotted horizontally. The progressive deepening of the high values of resistivity on the curves from point to point going easterly, can be regarded as evidence of increasing bedrock depth in that direction.

In general, therefore, the resistivity method provides a fairly ready means of determining approximately the depth to the basaltic clay and this may be used to facilitate prospecting in areas selected by geological methods as favorable for the occurrence of bauxite.

Probably other geophysical methods could also be used to reduce the cost of prospecting when a search becomes necessary for deposits which almost certainly exist but which do not outcrop.

B.—METHODS OF PROVING.

Three different methods of proving the deposits have been adopted—(1) by Sulphates Proprietary Limited, (2) Victorian Mines Department, (3) Department of Supply and Shipping. Each of these is briefly discussed.

(1) Sulphates Proprietary Limited have developed an effective method of prospecting by hand-boring followed by shaft sinking at selected points. Holes are spaced at 100-feet intervals on a rectangular grid and an auger of 1½ inches diameter is used. The method provides a quick and relatively cheap method of prospecting where depths do not exceed about 30 feet. The holes are not cased so that the bauxite is liable to some contamination from the sides of the hole, but analysis of auger samples provides a useful guide to the quality of the deposit. For purposes of accurate sampling the hand-boring is followed by shaft-sinking where boring has revealed a favorable thickness of bauxite.

(2) The Victorian Mines Department use a power-operated percussion drill which is also equipped with a hand-operated auger. Power is supplied by a small vertical Kelly and Lewis engine operating on fuel oil. The tools used consist of a drive pump and short sinker bar operated by solid rods with screwed joints. Drilling is effected by raising the rods about one or two feet by power and then releasing the load with a clutch, thus permitting the rods and pump to fall under their own weight. When necessary the pump is replaced by an auger which is turned by hand through a wooden capstan head fitted to the topmost rod. A crew of a foreman and two men operate the drill which is capable of sinking holes 5 inches in diameter.

(3) The Department of Supply and Shipping. The method used is the same as that used in testing alluvial (placer) deposits. In this campaign the work was done by Victoria Gold Dredging N.L., for the Minerals Production Directorate of the Department of Supply and Shipping. Two Bucyrus Armstrong percussion rigs were used with a string of tools consisting of a drive pump with detachable clack-valve, two sinker bars and swivel. The tool assembly weighed about 5 cwt. The most satisfactory length for the barrel of the drive pump was found to be 5 feet as with a longer barrel the hydrostatic head caused loss of the sample by splashing when the clack was opened.

While drilling was in progress 6-inch casing, in 5-feet lengths, was kept close to the bottom of the hole until bauxite was encountered. At this stage the casing was driven a few inches into the bauxite and the hole pumped clean of sand, clay or loose material. Flushing with water and pumping was continued until the mud-pump returned only clean water to the surface and the bottom of the hole was freed from sand, &c.

Boring was then continued with the drive-pump to 2 feet into the bauxite, the contents of the pump being collected in a numbered drum. The casing was then driven to the bottom of the hole and loose bauxite broken from the sides of the bore by the casing shoe was pumped out and added to the sample already collected.

The second and succeeding samples were then taken in a similar manner except that these samples were taken in lengths of 5 feet. The reason for taking the first sample for the shallower depth of 2 feet was to minimize the effect of any accidental contamination of the bauxite with the sand or clay. As the drillers became more proficient it was found that there was little or no contamination of the first sample taking place.

The samples were recovered in various degrees of moistness from a thin sludge containing a few hard angular lumps of bauxite to an earthy mass sufficiently damp to cohere when pressed in the fingers.

The samples were dried on iron trays over wood fires. They were constantly stirred to hasten drying and avoid local over-heating. When dry, the samples were cooled, crushed to $\frac{1}{4}$ inch with a Braun "Chipmunk" driven by a petrol engine and divided on a Jones sampler.

Provided experienced and careful men are employed all these methods give comparable results hence as (1) is by far the cheapest it is considered the most suitable to use provided the depth of drilling does not exceed 30 feet, and the bauxite is not too hard. Probably a self-contained truck-mounted drill would be the best all-round plant, but none of these was available when this campaign was in progress.

Experience shows that owing to the irregular shape of the deposits, a 100-foot square spacing is the widest which will give satisfactory results. Geological supervision is also advisable to avoid wasteful drilling. The progressive plotting of a structural plan as drilling proceeded showing contours on the basalt surface and isopacheous lines for the bauxite deposits proved useful in locating further drilling sites to maximum advantage and minimized drilling beyond the margins of the deposits. It was found that reasonably accurate forecasts of the thickness and depth of bauxite could be made for points 100 feet or so in advance of the drill.

VII.—COMMERCIAL GRADES OF BAUXITE.

"The specifications for commercial bauxite vary according to the purposes for which the bauxite is to be used. As bauxite is used for a variety of purposes, the range of specifications is wide. Bauxite is used mainly as an ore of aluminium and as raw material for the manufacture of aluminium chemicals, aluminium abrasives, and high alumina cement. Small quantities have also been used for the manufacture of refractories and in processes for the purification of petroleum products." (Gandrud, B. W., and De Vaney, F. D., 1929.)

Relatively small quantities of bauxite from Gippsland are used for chemical purposes and in the manufacture of firebrick. Ferruginous bauxite from the Wingello district, New South Wales, is being used by Broken Hill Proprietary Company in place of fluorite in the open hearth steel furnaces. Relatively large tonnages of pisolitic ferruginous bauxite are used in the Inverell and Wingello districts, New South Wales, for surfacing roads and paths.

The following notes refer to analyses of bauxite for use in the manufacture of aluminium.

In 1941 (H. A. Franke) put forward the following classification of *United States* ores:—

—	Al_2O_3*	SiO_2*
Metallurgical or "A" grade	55% or more	8% or less
"B" grade	50%–55%	9%–15%
"C" grade	45%–50%	15%–30%
"D" grade	30%–45%	30%–45% SiO_2 plus Fe_2O_3

* Certain chemical symbols are used frequently in this bulletin and to those unfamiliar with these symbols the following notes may be of interest.—

Al_2O_3 = Alumina. Each ton of alumina contains approximately half a ton of aluminium (Al). In other words 4 tons of ore containing 50 per cent. Al_2O_3 are required to produce 1 ton of aluminium.
SiO_2 = Silica, usually present as sand or clay.
Fe_2O_3 = Ferric oxide or more simply red iron oxide.
TiO_2 = Titania or titanium dioxide.
H_2O = Water, which may be present combined with other elements, or as moisture.

At that time also the following comment was made:—"Some authorities believe that with modern Bayer process equipment bauxite containing down to 48 per cent. alumina and 9 per cent. silica can be utilized. By beneficiation it is hoped to reduce the silica content of ore averaging 13 to 14 per cent. silica to 9 per cent."

The most recent American information on grades of ore accepted as suitable for treatment by the Bayer process is given by R. S. Dean (1943) and P. D. Wilson (1943). "The ore for the Bayer process has until recently carried only as high as 7 per cent. silica, but slightly higher silica content is now being tolerated." It is further stated in the articles quoted that ore containing 15 per cent. or less of silica is now classed as "Metallurgical grade".

The American classification relates to the special conditions existing in the United States, namely, a shortage of low silica bauxite, and cannot be applied rigidly to Australian deposits from which millions of tons could be won containing less than 8 per cent. silica.

Points to be noted in the American grading given above are the low alumina-silica ratio permitted even in Group A, namely 7:1 and the opinion expressed by some authorities that a ratio as low as 5.3:1 would not preclude the treatment of bauxite by the Bayer process with alumina as low as 48 per cent.

In the *Union of Soviet Socialist Republics* (Franke, H. A., and Herring, C. T., 1937 and 1938), ores worked in the Urals have the following composition:—

—	Al_2O_3	Fe_2O_3	SiO_2
	Per cent.	Per cent.	Per cent.
(A) Kamensk	36.0	35.0	5.3
(B) Vagran	50.0	26.0	3.7

The Kamensk plant uses the Bayer process and the electric current used at the plant is steam generated.

Deposits worked in *Hungary* (*Mineral Trade Notes,* September, 1941), have the following composition:—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	H_2O
Per cent. 50–63	Per cent. 2–4	Per cent. 15–30	Per cent. 2.5–4	Per cent. 16–20

These deposits have 15 to 65 feet of overburden.

The bauxites of *Guiana* and the *Netherlands East Indies* are usually referred to as high grade. According to H. A. Franke and C. T. Herring and R. W. van Bemmelen (1941), the Bintan (Netherlands East Indies) and Surinam (Dutch Guiana) bauxites have the following composition:—

—	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
	Per cent.	Per cent.	Per cent.	Per cent.
Bintan	53	2.5	13.5	1.2
Surinam	59	2.0	6.0	..

The deposits at Bintan are 12 feet thick and at Surinam 10 to 18 feet thick. It is not known for certain whether the foregoing analyses relates to crude ore, since it is believed that all ores from these countries are washed before shipment. They do, however, give some idea of the requirements expected in a high-grade ore.

A monohydrate ore used largely in Great Britain for the manufacture of aluminium has the following composition:—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Combined Water.	Moisture.
51.7	3.8	22.1	2.5	11.0	8.0

It may be noted that although during the war a wide variety of grades of bauxite have had to be used in Great Britain, plant efficiencies have been maintained (Keast and Hey, 1943).

It is interesting to refer here to the bauxite brought to Australia in 1941 from Soengi-Kolak on Bintan Island near Singapore. The average composition of 25,000 tons is reported by the Ministry of Munitions to be—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Combined Water.
Per cent. 56.02	Per cent. 2.06	Per cent. 11.23	Per cent. 0.97	Per cent. 30.19

The two samples which were taken by one of us (H.G.R.) from part of this shipment were analysed by The Zinc Corporation Limited.

The results given hereunder indicate the variability in composition of different sections of the shipment:—

—	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Loss on Ignition.
(A)	57.4	2.1	10.3	0.55	30.0
(B)	46.0	1.6	25.1	0.60	..

(A) Sample make up of grabs taken at regular intervals around ship's hold (includes fine and coarse material).
(B) Lumps of coarse material picked out at random.

It will be seen that bauxites with a great range in chemical composition are being used for the manufacture of aluminium and that the most objectionable single impurity is silica. It has been estimated that for every unit of silica in the ore there is a reduction of alumina recovery of 1.3 units.

It is concluded that ore containing approximately 50 per cent. alumina and 7 per cent. silica may safely be regarded as satisfactory for the manufacture of metallic aluminium. A normal bauxite (gibbsite type) of the above composition would contain not less than 26 per cent. moisture leaving not more than 17 per cent. as ferric oxide (Fe_2O_3) plus titanium dioxide (TiO_2).

The limits taken for the calculation of reserves in the Gippsland deposits are based on this conclusion. (See Section X.)

VIII.—CONSTITUTION OF BAUXITE.

For many years bauxite was considered to be a mineral with the composition Al_2O_3 $2H_2O$, but it is now known that it may consist of one or more of the hydrates of aluminium. References are still made in the literature to a dihydrate Al_2O_3 $2H_2O$, but the diffraction spacings published for this supposed compound (Hanawalt, Rinn and Frevel, 1938) agree so closely with those of gibbsite, as shown hereunder in Table I, that there seems no doubt about its real identity. A recent laboratory study by Laubengayer and Weisz (1943) has also failed to produce evidence for the existence of the dihydrate; the solids in the system $Al_2O_3.xH_2O$ are given by them as $Al_2O_3.3H_2O$—gibbsite and bayerite; $Al_2O_3.H_2O$—diaspore and boehmite; Al_2O_3—corundum and alumina. Gibbsite is precipitated by CO_2 from aluminate solutions at 100° C.

TABLE 1.

X-Ray Diffraction Data.

Crystalline Gibbsite, Childers.	" Amorphous " Gibbsite Nodules, Boolarra.	$Al_2O_3.2H_2O$.	Gibbsite (Published data).
A° 5.20–4.70 (1)	A° 5.20–4.70 (1)	A° 4.88 (1)	A° 4.85 (1)
4.40 (2)	4.40 (2)	4.39 (2)	4.34, 4.37, 4.36 (2)
3.35	3.35	3.33	..
2.45 (3)	2.45 (3)	2.45 (3)	2.45 (3)
2.275	2.275	2.38	..
2.175	2.175	2.17	..
2.05	2.05	2.05	..
2.00	2.00	1.99	..
1.92	1.92	1.92	..
1.81	1.81	1.81	..
1.75	1.75	1.75	..
1.69	1.69	1.69	..
1.46	1.46	1.46	..
1.41	1.41	1.41	..

Relative intensities for three most intense lines shown thus—(1), (2), (3).

Petrological examination of the Gippsland bauxites reveals that the hydrated alumina occurs as crystalline gibbsite having the typical optical properties of this mineral, and as micro-crystalline, crypto-crystalline and amorphous material occurring as replacements of felspars and titan-augite, as banded buff-coloured colloform masses and as pure white concretionary nodules. Analyses based on the determination of water content indicate that all these varieties are composed of the tri-hydrate $Al(OH)_3$. No diaspore or boehmite was recognized optically, and X-ray diffraction patterns confirm the absence of these minerals. Diagrams for pure crystalline gibbsite, bauxitised olivine basalt, and amorphous white concretionary lumps from the Boolarra deposit all reveal the same X-ray pattern. (Plate 1 and Table I.)

IX.—METHOD OF ANALYSIS.

The determination of alumina for the commercial valuation of bauxite is somewhat empirical and consequently it is necessary for a standardized procedure to be followed closely if uniform results are to be obtained in different laboratories.

There are two methods of analysis in use—

(A) Available alumina (total alumina).
(B) Free alumina (alumina extracted by caustic soda solution).

A.—AVAILABLE ALUMINA (TOTAL ALUMINA).

This is an acid extraction method and, with some modifications by different analysts, appears to be the one most commonly used commercially. The method is quicker than the alkaline digestion method and is used in essentially similar form by Zinc Corporation Limited, Broken Hill Proprietary Company Limited and Sulphates Proprietary Limited. Since most of the analyses quoted in this bulletin were made by Sulphates Proprietary Limited, an outline of the procedure used by that company is set out below.

Grind the sample to pass 60 mesh, dry at 105° C. for one hour and cool in a desiccator. Weigh 5 grams of the dried sample into a crucible and heat at about 600° C. for one hour. Cool in desiccator and weigh. Difference in weight is loss on ignition.

To a weighed portion of the dry sample add 20–25 ml. of sulphuric acid of specific gravity 1.60 in a suitable vessel and digest for some time. Evaporate until white fumes of SO_3 are evolved. Cool, take up in water and again evaporate to fumes. Again take up in water, filter, and wash residue with hot water. If the residue is white, it is dried, ignited and weighed as SiO_2. If grey or coloured, fuse the residue with $NaHSO_4$, cool, dissolve, melt in water, filter and wash. Add filtrate and washings to first filtrate obtained from acid extraction. Dry, ignite and weigh residue as SiO_2.

Make filtrate up to some convenient volume, say 500 ml., measure off a portion of this and divide into three aliquot portions—

(1) 50 ml. (= 0.5 gram). Precipitate with ammonia, filter, wash, ignite and weigh as Al_2O_3 Fe_2O_3 TiO_2. Calculate to percentage.
(2) 50 ml. Determine iron volumetrically by some standard method and calculate to Fe_2O_3. Calculate to percentage.

(3) 10 ml. or more (depending on TiO content). Estimate TiO_2 colourimetrically by some standard method. Calculate to percentage.

Then per cent. available alumina equals (1) minus (2) and (3).

B.—FREE ALUMINA.

This is an alkaline extraction method. It is considered that the term "free alumina" is misleading and results by this method of extraction should be stated as "alumina extracted by hot 10 per cent. caustic soda solution".

The method used in the Mines Section of the Victorian State Laboratories is—

Weigh 2 grams of finely ground sample and transfer to 300 ml. conical flask. Add 100 ml. of 10% NaOH solution and boil gently for three hours on a hot plate, keeping the flask covered with a small funnel or crucible to act as a reflux condenser.

Transfer contents of flask to a 200 ml. measuring flask, cool and dilute to the mark. Mix well and allow to settle.

Pipette off 50 or 100 ml. of solution, according to the grade, run into porcelain evaporating dish, acidify with HCl and evaporate to dryness over a water bath. Take up residue with hot dilute HCl, filter and wash with water.

Precipitate alumina with NH_4OH, boil, filter and wash, precipitate twice with hot water. Transfer filter to original beaker and add 50 ml. of hot water. Stir well to pulp filter paper and add 10 ml. HNO_3 and 5 ml. HCl. Warm until precipitate dissolves. Add NH_4OH to reprecipitate alumina, boil, filter and wash precipitate until free from chlorides. Dry, ignite and weigh as Al_2O_3.

The alkaline extraction method appears to have been used originally because it was supposed to give a reliable indication of the value of an ore for extraction of alumina by the Bayer process. In fact the laboratory conditions differ so markedly from those used in commercial practice that the results obtained by this method may not be regarded as a reliable guide to the commercial value of an ore.

In the Bayer process a caustic soda solution containing from 200 to 300 grams of free Na_2O per litre is used and the bauxite is digested in an autoclave for at least twice the period used in the laboratory method. The reaction proceeds at temperature from 135° C. to 190° C. Details in procedure vary within the foregoing limits according to the type of ore used, i.e. whether trihydrate or monohydrate.

X.—BAUXITE DEPOSITS.

A.—SUMMARY OF RESERVES.

The testing campaign to which these notes refer was planned primarily with the object of finding out whether there were upwards of 400,000 tons of bauxite of metallurgical grade in the Gippsland area. The campaign not only achieved this objective but indicated that individual bodies of ore are present (up to 200,000 tons) which are larger than had been expected. Although the ore occurs in separate bodies it has been shown that its composition and grade is rather uniform.

There is still plenty of scope for prospecting and ore bodies containing more than 200,000 tons may yet be proved to exist. However, as the grade of the ore so far proved has been much the same irrespective of the size of the ore-body it is unlikely that other deposits which may be discovered will differ greatly from those already investigated.

Twenty-four deposits of bauxite are now known to occur in the Boolarra-Mirboo North area. Of these, eight have been tested by boring and shaft sinking (Group 1), but little is known about the extent of the remainder (Group 2).

The tables hereunder summarize the data available concerning reserves and chemical composition of the deposits. In these tables the deposits are arranged in two groups but are numbered continuously and in the same order as in the next section of the report under the heading "Description of Individual Deposits".

It has been pointed out in Section VII. of this Bulletin that a study of all information available on commercial bauxites indicates that an ore containing 50 per cent. or more of alumina and approximately 7 per cent. or less of silica may safely be regarded as "metallurgical grade", i.e., suitable for the manufacture of aluminium.

In measuring the reserves of bauxite available in the deposits tested to date in Gippsland this factor was kept in view, and it will be noted that the average composition of the 736,000 tons of "proved reserves" is close to that prescribed as minimum for metallurgical grade. There is little doubt that the grade of ore which would be obtained in open cut working of the deposits would be somewhat better than the average quoted, since contamination by over-burden would be eliminated and silica contained in "clayey" material rejected. This improvement in grade could be effected without significantly reducing the tonnage. Also, as pointed out in Section XIII., the commercial ores appear to be readily amenable to simple methods of beneficiation.

GROUP 1.

Deposit.	Proved Reserves.	Composition.			
		Al_2O_3	SiO_2	Fe_2O_3	TiO_2
	Tons	Per cent.	Per cent.	Per cent.	Per cent.
1. Napier's No. 1	182,850	52.1	5.5	7.4	5.3
	or 214,000	50.0	6.0	10.0	6.0
2. Greenwood's	49,400	50.0	7.3	8.8	6.0
3. The Pines Lease—					
(i) Watkins*	235,000	51.6	10.1	5.4	5.3
(ii) Napier's No. 2 ..	19,000	50.8	10.0	7.6	4.8
4. Boolarra—					
(i) Sulphates Lease ..	53,000	53.0	5.0	6.5	4.5
(ii) Orgill's	53,600	52.5	5.0	6.5	4.5
5. Payne's—					
Western Section	61,500	52.75	8.03	5.5	6.1
Eastern Section* ..	50,000	..	..	..	..
Total	704,350	51.95	7.6	6.4	5.3
	or 735,500	51.3	7.66	7.2	5.5

* Data incomplete.

In addition to the reserves given in the above table, 165,000 tons of low-grade bauxite have also been proved by boring in Napier's No. 1 deposit. This ore averages 37 per cent. alumina and 12 per cent. silica.

GROUP 2.

Deposit.	Possible Reserves.	Grade.			
		Al_2O_3	SiO_2	Fe_2O_3	TiO_2
	Tons	Per cent.	Per cent.	Per cent.	Per. cent.
6. Childers or Rodda's ..	Unknown, probably small	51	11	4.5	6
7. Nahoo	50,000	52	15	3.5	4.0
8. Bond's	Unknown, probably small	..	..	..	..
9. Roy's	"	..	..	..	..
10. Crutchfield's ..	"	..	..	..	..
11. De Hais'	"	..	..	..	..
12. Fox's	Unknown	..	..	..	..
13. Foy's	100,000 or more	56	4	4.8	..
14. Lovell's	Unknown	..	..	..	..
15. Sargent's	"	..	..	..	..
16. Tierney's	"	..	..	..	..
17. Harrison's	"	..	..	..	..
18. King's	21,400*	51.7	10.0	4.9	7.0
19. Polley's	Unknown	..	..	..	..
20. Smith's Mill ..	19,000*	45.8	7.0	13.5	7.2
21. Wanke's	6,000	50	6	9	..
22. Martin's	Very small	..	..	..	..

* Data incomplete.

It will be noted that little attempt has been made to give figures for possible reserves. Experience has shown that deductions based on outcrops are unreliable, due to the irregular shape of the deposits, poor exposures and landslips. However, since a comparatively brief prospecting campaign revealed twelve deposits and there is still plenty of scope for prospecting, it cannot be doubted that many more deposits remain to be discovered.

It should be noted that, with two exceptions the authors agree on the stratigraphical position of the deposits listed in the two foregoing tables and described in this section of the bulletin. The two exceptions are "Nahoo" and "Childers". The descriptions of these two deposits have been written by E.S.H. H.G.R. and H.B.O. have merely indicated briefly that they consider that these deposits occur on the same stratigraphical horizon as the other deposits.

B.—DESCRIPTION OF INDIVIDUAL DEPOSITS.

1. Napier's No. 1 Lease. (Refer Plates 10 and 11.)

(*a*) *Situation.*—The lease embraces parts of allotments 120B, 120C and 120E, Parish of Mirboo, and is about $1\frac{1}{2}$ miles north-north-east from the township of Mirboo North, which is the terminus of a branch railway from Morwell. The main road from Trafalgar to Mirboo North traverses the lease from north to south.

(*b*) *Topography.*—The area is hilly and the immediate vicinity of the lease is drained by the Little Morwell River which occupies a deep gully within the western lease boundary and parallel to the road mentioned above. A bauxite outcrop near the centre of the lease lies at about 600 feet above sea level and about 60 feet above the level of the river. Details of the surface relief are shown in Plate 10 by contours at a vertical interval of 10 feet.

The bauxite deposit has been divided into two sections by a gully near the centre of the lease. This gully has cut a gap nearly 500 feet wide through the bauxite and about 10 feet into the basalt. It is now partially filled with clay.

(*c*) *Workings.*—Two quarries have been opened on bauxite outcrops adjoining the road on the eastern side and a number of prospecting shafts had been sunk at various points on the lease prior to the start of the drilling campaign, the results of which form the subject of this report.

With the exception of two shafts mentioned below, all operations have been confined to that part of the lease which lies to the east of the road and river.

(*d*) *General Geology.*—The area has been mapped by the Geological Survey of Victoria as occupied by Post Volcanic Sediments with some older basalt exposed in the river channel. Since this survey was carried out new road works have revealed a greater area of basalt masked by a soil cover only a few inches thick. Boulders of comparatively fresh basalt embedded in basaltic clay are visible in the road cuttings both north and south of the southern quarry and near the northern quarry.

Bauxite outcrops about 10 feet north from the southern quarry and 20 feet east from the edge of the road and can be traced for about 150 feet to where it is obscured by soil.

At a point 800 feet west from the northern quarry and on the opposite side of the river valley, ferruginous bauxite outcrops on the slopes at an elevation of about 55 feet above the river. Shallow pits have indicated the extension of the bauxite as a thin bed to 160 feet south-west from the outcrop, but shafts at 200 feet and 300 feet respectively west-south-west are stated to have entered decomposed basalt at a depth of 20 feet without encountering any bauxite.

Sections across the deposit are given in Plate 11. Following are detailed logs of a few representative bores:—

Depth in Feet.		Depth in Feet.	
	BORE No. 9.		BORE No. 19.
0 – 2	Soil	0 – 3	Soil
2 – 6	Clay	3 – 8	White clay
6 – 28	Sand	8 – 24	Lignitic clay
28 – 29	Clay	24 – 30	Lignite and clay
29 – 31	Sand	30 – 46	Lignite
31 – 35	Clay	46 – 47	Grey clay
35 – 59	Bauxite	47 – 49	Lignite
59 – ..	Decomposed basalt	49 – 68	Bauxite
		68 – ..	Decomposed basalt

Depth in Feet.	
	BORE NO. 48.
0 – 1	Soil
1 – 19	Sand
19 – 25	Grey clay
25 – 28	Yellow sandy clay
28 – 34	Yellow sand
34 – 45	Grey sandy clay
45 – 60	Coarse grey sand
60 – 78	Brown clay and lignite
78 – 90	Fine grey sand
90 – 95	Yellow sand
95 – 101	Lignite
101 – ..	Decomposed basalt
	BORE NO. 93.
0 – 4	Yellow sand
4 – 8	Mottled clay
8 – 38	Brown and grey sand
38 – 42	Sandy clay
42 – 65	Yellow sand
65 – 66	Clay with bauxite
66 – ..	Decomposed basalt

Depth in Feet	
	BORE NO. 66.
0 – 2	Soil
2 – 7	Grey and mottled clay
7 – 30	Brown, yellow and grey sand
30 – 33	Grey clay
33 – 38	Lignite
38 – 45	White sand
45 – 51	Bauxite
51 – ..	Decomposed basalt
	BORE NO. 88.
0 – 2	Soil
2 – 12	Sand
12 – 19	Grey clay
19 – 41	Grey sand
41 – 50	White sand and clay
50 – 52	Grey clay
52 – 61	Lignitic clay
61 – 68	Alternating bands of sand and clay
68 – 77	Fine grey sand with clay
77 – 83	Coarse grey sand
83 – 95	Lignitic clay and lignite
95 – 98	Clay with traces of bauxite
98 – 100	Bauxite
100 – 108	Coarse quartz sand and fragments of bauxite
108 – ..	Decomposed basalt

The sections and bore logs show that, while the bauxite generally rests directly upon basalt, there are places where an appreciable thickness of sediments, generally coarse sand, is interposed.

The basalt which forms the bedrock of the bauxite deposits is decomposed to a smooth clay which retains the original basaltic texture presenting a finely mottled appearance, and contains small specks (0.2 mm.) of ilmenite.

In colour the basaltic clay is generally bluish but may be yellow, red, brown or nearly white.

The bauxite also possesses a wide range of colours but is commonly buff, pink, brown, red or, particularly if recovered from below the level of the water table, grey or bluish-grey. The grey bauxite is of poorer quality than the reddish or lighter shades and has a higher iron content due largely to the presence of siderite and pyrite (marcasite ?). However, the colour cannot be regarded as a reliable guide to the quality except for very limited areas. Some very pale pink bauxite has a high silica content.

The appearance of the bauxite in the hand specimen varies fairly widely. Much of it is earthy and apparently devoid of any characteristic texture while some is hard and granular. The higher grade material may be distinguished by its low density, finely cellular texture, and the presence of minute crystals of gibbsite which glitter in strong light. The grey varieties have a superficial resemblance to decomposed basalt, but are harsh to the touch in contrast to the smooth soapy feel of the basaltic clay.

Analyses of the bauxite suggest that the aluminium is present as the mineral gibbsite—$Al_2O_3.3H_2O$, the presence of which has also been demonstrated by F. L. Stillwell (August, 1943).

Petrological examination of mainly fine-grained types of bauxite indicates recognizable crystalline and cryptocrystalline gibbsite, ilmenite and iddingsite (?), suggesting that the bauxite was derived from volcanic ashes. In places the ore contains secondary pyrites of encrusting habit, and also veinlets of secondary siderite.

Bauxite which contains 50 per cent. or more of Al_2O_3 generally contains less than 7 per cent. TiO_2. In all the anlyses of bore samples that have been made, the iron content has been expressed as Fe_2O_3, but at least some of the iron present is in the ferrous state. The iron content (expressed as Fe_2O_3) of bauxite containing more than 50 per cent Al_2O_3 varies between 12.5 and 1.4 per cent. and averages 7.4 per cent. For bauxite of similar grade, the average titanium content is 5.3 per cent. The table shows some typical analyses on a moisture-free basis.

Bore No.	Thickness.	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Ignition Loss.
	Feet.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
(i) High Grade—Included in Reserves.						
4	9	50.5	8.0	6.7	6.9	27.9
12	13	53.5	5.7	5.8	6.5	28.5
38	10	53.4	7.6	4.0	6.8	28.2
43	21	53.2	2.4	12.5	4.5	27.4
65	7	53.7	5.2	7.7	4.5	28.9
74	24	52.0	4.9	8.9	5.3	28.9
81	7	54.3	7.7	3.5	4.9	29.6
92	7	53.5	4.4	7.7	6.5	27.9
94	11	55.6	4.8	5.6	4.9	29.1
(ii) Low Grade—Not Included in Reserves.						
11	20	40.9	4.7	20.7	5.7	28.0
16	15	43.3	10.3	13.7	6.1	26.6
19	19	32.1	9.1	24.7	5.6	28.5
27	33	36.3	7.3	22.3	6.9	27.2
34—	34					
Top 2 feet	..	40.4	13.5	5 1	6.5	34.5
Bottom 6 feet	..	22.7	26.5	28.5	3.2	19.1
50	9.5	40.3	10.0	21.6	4.6	23.5
76	23	33.0	7.3	28.0	4.0	27.7
85	2	40.9	10.3	15.5	7.5	25.8
89	3	38 5	29.0	4.7	6.5	21.3

The Post-Volcanic sediments overlying the bauxite consist of sand, clay and lignite and lignitic clay. Towards the south-eastern part of the southern section of the deposit, the lignite attains a thickness of 44 feet. Much of the lignite lies directly upon the bauxite, occupying depressions in its surface, and is practically restricted to the area occupied by bauxite. The surface soil is black in colour and contains much coarse angular white quartz sand. This forms a sharp contrast with the chocolate soil formed by weathering of the basalt and provides a useful guide for prospecting operations. The soil is poor in quality and is of little use for agriculture or grazing. Much of the sand, particularly that near the surface, is clean, coarse and angular. It is much used locally for surfacing roads and for building purposes. The clays vary widely in colour; some appear to be suitable for industrial application. The arenaceous clays contain varying proportions of fine yellow sand.

(e) *Structure.*—The basalt surface in undulating with a gentle dip to the south-east. The shape of this surface is shown by structure contours in Plate 10. The bauxite lies in depressions in the basalt.

Broadly the upper surface of the bauxite is not as irregular as that of the basalt, but where exposed in the quarries the surface bears holes and narrow gutters which suggest that it has been exposed to scouring.

From the western edge of the deposit the upper surface of the bauxite dips to the east and south-east at from 7 to 10 degrees. The central and eastern portions lie nearly horizontal, but from some places on the eastern margin the dip is gently towards the centre. These features are shown in the sections in Plate 11.

The marked differences in level of the bauxite penetrated by bores near the western margin of the deposit gave rise to the suggestion that several faults with a northerly trend and downthrow to the east had displaced the bauxite. Alternatively it was thought that the differences in level might be accounted for by slumping of the bauxite towards the centre of the basin and by erosion of the surface Two hand-bores were sunk between Bores 31 and 32 and they revealed a regularly dipping upper surface of the bauxite, thus demonstrating the absence of faulting. It is also noteworthy that no faulting has been disclosed in the quarries on this lease.

There was some evidence of stratification showing in the northern quarry, where horizontal bands of greyish bauxite are intercalated with the brown bauxite which forms most of the quarry face.

(f) *Reserves.*—The following table shows that reserves of high-grade bauxite proved by drilling amount to 182,850 tons. Of this total 37,950 tons lie in the northern body and 144,900 tons in the southern body.

The average composition of this bauxite, on a dry basis, is—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Ignition Loss.
Per cent. 52.1	Per cent. 5.5	Per cent. 7.4	Per cent. 5.3	Per cent. 29.9 (By diff.)

Examination of the sections in Plate 11 and of the analyses given in the table on page 22 shows that the bauxite falls into two groups—one with Al_2O_3 exceeding 50 per cent. and the other with Al_2O_3 below 42 per cent. Very few samples with an intermediate alumina content were found. For this reason very minor amounts of bauxite containing less than 50 per cent. alumina have been included in the calculated reserves. In these circumstances, although the aim was to demonstrate the tonnage of bauxite containing not less than 50 per cent. alumina, the virtual absence of bauxite of a composition between 50 and 42 per cent. alumina raised the average figure to 52.1 per cent.

It would be possible in the course of quarrying operations to strip about 31,000 tons of lower-grade bauxite, mainly from below the high-grade material, without removal of additional overburden. The inclusion of this quantity of lower-grade bauxite would increase the total tonnage to about 214,000 and lower the average composition to—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2
Per cent.	Per cent.	Per cent.	Per cent.
50	6	10	6

In calculating the tonnages given in the table below some quantities of ore containing in excess of 50 per cent. alumina have been disregarded on account of thickness of overburden or isolation from the main bodies. A small tonnage of bauxite easily available under thin overburden and situated near the southern quarry has also been omitted owing to its high silica content.

A density of 2.2, equivalent to 16 cubic feet to the long ton, has been allowed in converting the volume of bauxite *in situ* to long tons. For computing the tonnage of overburden the factor that has been used is 15 cubic feet to the ton or 1.8 tons per cubic yard.

It should be pointed out that the overburden figures refer to the volume standing vertically above the proved reserves of bauxite and no allowance has been made for batter. Where quarrying has been, or is being, carried out it has been found that a face cut in the overburden may be left standing nearly vertical for very long periods.

Details of reserves proved along the lines of sections shown on Plate 11 are given in the following tables:—

NAPIER'S No. 1.—NORTHERN BODY.

Line.	Bauxite.			Overburden.		Ratio.
	Tons.	Composition.		Cubic Yards.	Tons.	Overburden: Bauxite.
		Al_2O_3	SiO_2			
		Per cent.	Per cent.			
1300N ..	9,500	51.5*	5.0*	19,100	34,300	3.61
1200N ..	16,650	53.6	2.9	28,800	51,900	3.12
1100N ..	10,100	53.4	7.4	25,700	46,300	5.29
1000N ..	1,700	57.0	7.9	5,800	10,400	6.00
Total or Average	37,950	53.2	4.3	79,400	142,900	3.77

* Estimated.

NAPIER'S No. 1.—SOUTHERN BODY.

Line	Bauxite.			Overburden.		Ratio.
	Tons.	Composition.		Cubic Yards.	Tons.	Overburden Bauxite.
		Al_2O_3	SiO_2			
		Per cent.	Per cent.			
400N ..	15,000	52.0	4.9	12,390	22,300	1.5
300N ..	8,500	55.7	4.0	15,560	28,000	3.3
200N ..	3,750	56.2	6.8	26,800	48,300	12.9
100N ..	3,380	54.3	7.7	19,160	34,500	10.1
00 ..	22,750	52.8	4.9	92,800	167,000	7.3
100S ..	12,450	51.9	5.3	8,760	15,800	1.3
200S ..	25,000	51.7	8.4	43,600	78,600	3.1
300S ..	3,600	50.0	7.8	3,670	6,600	1.8
400S† ..	..	..	..	..	..	..
500S ..	6,060	53.8	4.2	11,200	20,200	3.3
600S ..	8,900	50.7	7.0	17,200	31,000	3.4
700S ..	32,030	52.1	6.0	36,900	66,200	2.1
800S ..	3,480	50.5	8.0	4,560	8,200	2.4
Total or Average	144,900	51.8	5.8	292,600	526,700	3.62

† Less than 1,000 tons under shallow overburden and containing 51.7 per cent. Al_2O_3, 13 7 per cent. SiO_2. Excluded from reserves on account of high silica.

Total reserves proved are therefore—

Body.	Bauxite.			Overburden.	Ratio.
	Tons.	Composition.		Tons.	Overburden: Bauxite.
		Al_2O_3	SiO_2		
		Per cent.	Per cent.		
Northern	37,950	53.2	4.3	142,900	3.77
Southern	144,900	51.8	5.8	526,700	3.62
Total or Average ..	182,850	52.1	5.5	669,600	3.66
Additional lower grade ..	31,000	50.0	6.0	..	..
Grand Total or Average	213,850	51.5	5.6	669,600	3.13

In addition to the reserves given in the above table 165,000 tons of low-grade bauxite have also been proved by boring. This ore averages 37 per cent. alumina and 12 per cent. silica.

2. **Greenwood's Lease.** (Refer Plate 12 and Plate 2, Fig. 1.)

(*a*) *Situation.*—This lease with an area of approximately 8 acres is the westernmost of the group of three leases held in the Parish of Budgeree and is situated in allotment 16B, 5 miles by road south-east from the small township of Boolarra. Boolarra lies in the valley of the Little Morwell River a mile above its junction with the Morwell River and is an intermediate point on the railway between Mirboo North and Morwell.

(*b*) *Topography.*—The summit of the ridge in the vicinity of the lease has an elevation (by aneroid) of 980 feet above sea level and rises slightly to the east. The southern flank falls steeply to Waratah Creek which flows west to join the Morwell River. On the north the hill is drained by Belbrook (or Sassafras) Creek which flows north into the Parish of Yinnar and joins the Morwell 2 miles below Boolarra.

Landslips are a common feature on the south side of the ridge.

(*c*) *Workings.*—Advantage has been taken of the partial removal of overburden by a landslip to open a quarry near the centre of the lease. The quarry now has an area of about 1/5th acre and some 400 tons of bauxite have been produced from it.

(*d*) *Geology.*—Dark grey sandy soil thinly covers the surface but exposures in the quarry and in road cuttings east from the lease indicate the usual sequence which has been demonstrated elsewhere.

Basalt, decomposed to mottled clay with a ferruginous capping, forms the bedrock. Bauxite overlies the basalt under a cover of sand and sandy clay. At the face of the quarry the thickness of the overburden is between 25 and 30 feet, consisting of 6 feet of yellow sand, immediately overlying the bauxite, and the remainder sandy clay.

In the quarry where the contact between basalt and bauxite can be seen, the bauxite rests directly upon clay still retaining the original basaltic texture, but the logs of bores sunk to the north-east of the quarry show several feet of clay between bauxite and decomposed basalt. This, however, is believed to represent completely decomposed basalt in which, where the clay is highly coloured, the texture is masked by iron stain; but some of it may be low-grade bauxite.

The bauxite is variable in texture from fine, soft, reddish material to types in which numerous hard lumps, up to a few inches across, are set in finer material. The bedding is indicated in places by the alinement of small white concretions of amorphous bauxite, as well as by the arrangement of coarse and fine material. The upper surface is slightly irregular, but not more so than the bedding in the overlying clays and sands. The sands are current-bedded, and contain kaolin pellets. The coarse fraction (0.5 mm. diameter) consists of quartz, kaolinized felspar, and tourmaline. The fine fraction (0.5 mm. diameter) consists of quartz and kaolinized felspar with abundant tourmaline occasional andalusite, zircon, bleached biotite, leucoxene, ilmenite, rutile, monazite, limonite, and topaz. Undulating limonite bands are present in the bauxite at outcrop, and are apparently of late development due to leaching and redeposition, since they are not so common in depth.

No traces of lignite or lignitic material are revealed in the quarry, but in one bore, No. 10, lignitic clay was recognized. The log of this bore and one other follow:—

BORE No. 6.

Feet.		
0 – 2	Grey sand	
2 – 4	Yellow clay	
4 – 19	Sandy clay	
19 – 22	Yellow sand	
22 – 24	Sandy clay	
24 – 39	Sand	
39 – 41	Grey clay	
41 – 56	Bauxite	
56 – 69	Red and grey clay	Basalt
69 – 70	Decomposed basalt	Basalt

BORE No. 10.

Feet.		
0 – 1	Loam	
1 – 13	Yellow and grey clay	
13 – 14	Gravelly clay	
14 – 47	Sandy clay with thin bands of sand	
47 – 61	Sand	
61 – 62	Grey clay	
62 – 69	Sandy clay	
69 – 71	Yellow clay	
71 – 73	Lignitic clay	
73 – 80	Yellow and grey clay	Basalt
80 – 81	Decomposed basalt	Basalt

(*e*) *Petrology.*—The fine-grained earthy bauxite, on washing, leaves a residue of clay pellets, leucoxene, quartz, plagioclase, and ilmenite. In the hard lumps, which appear in hand specimen to represent altered basalt, ilmenite is abundant, and detrital minerals such as quartz and plagioclase are absent. In places, subrounded concretionary pellets of white amorphous bauxite are numerous, and clay lenticles also occur. The bauxitic concretions are completely soluble in 1:1 sulphuric acid and are similar to the pure gibbsite concretions in the Boolarra deposit. The clay lenticles are composed either of halloysite or a mineral of the kaolin group, and since the clay loses 4.8 per cent. of its water below 100 degrees, it is probably in part, at least, halloysite. In addition, there are stem-like sub-cylindrical concretionary structures, which consist mainly of brown, microcrystalline gibbsite stained with ferric hydrates, with some pseudomorphs of iddingsite after olivine, and small ilmenite grains. The concretionary structure parallel to the outer surfaces of these bodies is outlined by differences in the intensity of iron-stain in the colloform gibbsite.

Under the microscope the fine-grained bauxite at Budgeree shows stratification, which is indicated by coarse and fine layers, and also by the alignment of platy ilmenite grains parallel to the bedding. It consists of amorphous bauxite, crystalline gibbsite, ilmenite, pseudomorphs of iddingsite (?) after olivine, and irregular clay masses

(*f*) *The Ore Body.*—The outline of the body is shown in the accompanying plan, which indicates that in general the body is oval in plan with its longer axis trending north-east. It is roughly symmetrical, the greatest thickness being developed centrally (*see* Plate 12.)

A narrow tongue protruding to the south has been proved by costeans which have picked up the western margin, and boring results indicate that a similar tongue under deep over-burden extends north-easterly beyond the lease boundaries.

(*g*) *Reserves.*—The attached table shows that proved reserves total 49,400 tons containing 50.0 per cent. alumina on a moisture-free basis. Information regarding the quality is not as complete as that used for determinations of the grade at Napier's No. 1 and Payne's leases, as only one analysis is available for bauxite in the quarry face, and none for the costeans, or the shaft between Nos. 1 and 2 Bores. The figures given for the average alumina and silica content for the whole tonnage are derived from analyses of fifteen samples from Bores 1 to 6 and 17, and the analysis of bauxite from a shaft sunk on the site of the present quarry.

GREENWOOD'S, BUDGEREE.

Line.	Bauxite.			Overburden.		Ratio.
	Tons.	Composition.		Cubic Yards.	Tons.	Overburden : Bauxite.
		Al_2O_3	SiO_2			
		Per cent.	Per cent.			
From quarry through bores 6, 5, 4 to 3	19,000	49.5	9.6	51,000	91,800	4.83
From quarry through bore 1, shaft to bore 2	20,000	50.0	5.6	71,000	127,800	6.39
Bore 17 ..	6,200	50.9	5.7	28,300	50,900	8.21
Costeans ..	4,200	..	..	5,000	9,000	2.14
Total or Average	49,400	50.0	7.3	155,300	279,500	5.66

3. The Pines Lease.

(*a*) *Situation.*—This lease (Appn. 6991, Parish of Allambee East) comprises a narrow strip extending to the north-east from inside the northern boundary of allotment 125A. It crosses allotments 97A, a corner of 98A, and 97, and terminates in allotment 96, 1¼ miles north from Payne's lease in allotment 99.

The lease is approximately 1 mile long by 20 chains wide and crosses several different farm holdings. Portions of the lease are known by the names of the holders of the land embraced, as, for example, bodies of bauxite in the centre of the north-eastern end of the property are known as Napier's No. 2 deposit and Watkin's deposit respectively.

(*b*) *Topography.*—The lease lies mainly on the north-western slope of the Lydiard Range, which is part of the divide between the drainage systems of the Morwell and Tarwin Rivers. The elevation is about 800 feet above sea level near the foot of the range at Parkins' and about 1,200 feet above sea level at Watkin's.

The south-western portion of the lease at Parkins' includes the head of a large creek which flows west to the western branch of the Tarwin River.

(*c*) *Geology.*—The following notes are based chiefly on an unpublished geological map of the Parish of Allambee East by O. A. L. Whitelaw of the Geological Survey of Victoria and the results of hand-boring conducted by Messrs. Sulphates Proprietary Limited.

Practically the whole area of the lease is covered with timber and dense bracken and undergrowth, but the eastern and southern portions of the lease border on cultivated ground consisting largely of basaltic soil, with, in places, decomposed basalt at a shallow depth below the surface.

At the north-western end of the lease, basalt and bauxite lie beneath a cover of sand and clay ranging from 3 feet to 35 feet thick over the area of 10 acres that has been tested by boring.

At about 20 chains south-west of the area bored the geological map shows an exposure of pre-volcanic Tertiary sediments over a width of 10 chains in a small saddle.

The map shows basalt occupying the area flanking the saddle on the south-west. In this area and ½ mile south-west from Watkin's, a small triangular area of 2½ acres has been bored revealing from 3 to 30 feet of sand and clay overlying bauxite and basalt. This deposit is known as Napier's No. 2.

The south-western extension of the lease in allotment 125A is occupied by basalt in the creek channels and basaltic soil on the lower slopes. Boulders of bauxite lie at the base of a low hill between two creeks, and the hill is capped with coarse sandy soil typical of the post-volcanic Tertiary sediments.

(*d*) *The Ore Bodies.*—(i) *Watkin's* (refer Plate 13).—Hand-boring and shaft sinking at the northern end of the lease have revealed bauxite underlying a triangular area of about 14 acres. Exploration of the body is not complete as at the northern apex of the triangle the thickness of overburden is too great for effective hand-boring.

Sufficient prospecting has been done to indicate the outlines of the body with fair accuracy and to prove the existence of 235,000 tons of bauxite under 400,000 tons of overburden. Two shafts were sunk at the positions shown on the plan for the purpose of recovering uncontaminated samples. The samples yielded the following results on analysis:—

Shaft No.	Thickness.	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Ignition Loss.
	Feet.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1	15	51.3	9.7	5.8	5.0	28.2
2	16	51.9	10.4	5.0	5.5	28.3

(ii) *Napier's No. 2.*—Hand-boring on this deposit has disclosed the presence of a small body of bauxite with a maximum thickness of 11 feet under shallow overburden. A total of 24 bores was sunk in an area of about 3 acres and only six bores entered bauxite. The deposit contains a total of 19,000 tons of bauxite lying under 21,000 tons or 11,500 cubic yards of overburden.

Samples taken from a shaft sunk near the centre of the deposit yielded on analysis:

Sample.	Thickness.	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Ignition Loss.
Feet.	Feet.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Bulk ..	11	50.8	10.0	7.6	4.8	26.8
8–15.. ..	7	50.2	12.8	4.8	5.2	27.0

(iii) *Parkins'.*—Prospecting by hand-boring on allotment 125A proved disappointing. Light coloured bauxite had been observed around the flanks of a rounded hill occupying the northern side of the allotment. A line of six hand-bores sunk along the crest of this hill penetrated decomposed basalt at shallow depth and failed to reveal the presence of bauxite. This area can, therefore, be disregarded as a potential source of bauxite.

4. Boolarra Deposits. (Refer Plate 14, Plate 3, Fig. 1, and Plates 4 and 5.)

(*a*) *Situation.*—Mineral leases held by Sulphates Proprietary Limited in the southern portion of the Parish of Narracan South enclose two deposits of bauxite. Of a group of leases two are here described. They are M.L. 6689 in allotment 116D and M.L. 6873 on the adjoining allotment 116C. The former, known as "Sulphates Open Cut", occupies 15 acres; the latter is known as Orgill's and has an area of about 8 acres.

These leases are about 2 miles west from the railway at Boolarra and are connected with the town by a motor track.

(*b*) *Topography.*—The two groups of workings on the leases are a few hundred yards north and east respectively from the junction of Burchell's Creek with the Little Morwell River, and M.L. 6689 partly occupies a bend of the river. East of this lease and within the boundaries of Orgill's lease, a small creek flowing west-south-west to the river has incised a steep walled gully to a depth of 30 feet. The southern and western portions of the former lease extend close to the river channel and enclose the lower slopes of the valley walls. The plan (Plate 14) shows topographic contours at a vertical interval of 10 feet and referred to a zero datum which is about 400 feet above sea level.

(c) *Geology.*—Basalt is exposed in the river bed below M.L. 6689, but at higher levels is masked by sand and clay which has slumped down to the river. According to the geological map of the parish, Jurassic rocks are exposed in the left bank of the river about half a mile downstream from Burchell's Creek. No. 2 Bore sunk in 1889 at a point about half a mile east from the quarry on M.L. 6689, at a surface elevation of 615 feet above sea-level encountered Jurassic rocks at 272 feet. This bore passed through 67 feet of post-Volcanic sediments and 105 feet of basalt before entering Jurassic sandstone (Plate 8).

The bauxite in allotment 116D is overlain by the Post-Volcanic Tertiary sands and clays, and underlain by mottled limonitic clays, which represent decomposed Older Basalt (Plate 3, Fig. 1). The bauxite is variable in texture and quality, a rough stratification being readily discernible in the face, as indicated by the occurrence of bands of different texture and colour. Some layers contain numerous hard sub-angular lumps, embedded in soft, friable material; others are fine textured, and range in colour from reddish to buff and grey; other layers are massive and earthy, while some are notably heterogeneous, and consist of small, soft lumps of dark brown, red-brown, grey and white material, set in a fine-grained base.

The clays on which the bauxite rests can readily be distinguished from the ore by a simple test for plasticity carried out in the fingers, the bauxite being non-plastic. The top of the clays is undulating, but the top of the bauxite does not rise or fall in sympathy with the elevations and depressions in its base. The clays exhibit spheroidal limonitic concretionary structures in places, and since they contain no detrital minerals and pass down into the underlying basalt, it is clear that they represent decomposed Older Basalt.

The bauxite is overlain by grey and white clays. Unlike the sub-bauxitic clays, the overlying clay is gritty, and an analysis by Mr. G. Baker shows that it contains nearly 5 per cent. of sand, which consists of quartz, ilmenite, tourmaline, zircon, anatase, rutile, brookite, apatite and leucoxene.

The cover of post-Volcanic sand and clay which constitutes the overburden averages 12 feet in thickness at the present quarry face on M.L. 6689 and is more than 40 feet thick at the opposite edge of the deposit 450 feet to the east. Lignite has not been encountered in the excavations on this lease.

On Orgill's lease the overburden is thinner, ranging from zero to 6 feet in thickness along the northern and north-western edge of the deposit to a maximum of 36 feet near the centre of the body.

The lithology of the overburden is shown by the two bore logs here given:—

M.L. 6689 (Sulphates Open Cut).		M.L. 6873 (Orgill's).	
	Bore No. 12.		Bore No. 6.
Feet.		Feet.	
0 – 3	Sand	0 – 1	Sand
3 – 5	Yellow sandy clay	1 – 4	Yellow clay
5 – 9	Clay	4 – 7	Red and grey clay
9 – 25	Sandy clay	7 – 11	Red and grey sandy clay
25 – 28	Grey sand	11 – 14	Red and grey clay
28 – 40	Grey sandy clay	14 – 20	Grey clay
40 – 44	Grey clay	20 – 23	Yellow sand
44 – 51	Bauxite	23 – 34	Grey clay
51 – ..	Decomposed basalt	38 – 39	Bauxite and clay
		39 – ..	Decomposed basalt

Reference to the plan and sections (Plate 14) will show the essential differences existing between the two deposits herein described. On the other hand there are certain marked similarities. Both deposits contain the same tonnage of bauxite and the ratios of overburden to bauxite are not dissimilar. Both bodies have been truncated by stream erosion on their western or north-western sides and both possess dips which bear a not unfavorable relationship to the surface slopes of the overburden.

(*d*) *The Ore Bodies.*—(i) M.L. 6689 (Sulphates Lease).—The deposit on this lease is roughly rectangular in plan and lenticular in section. The length from east to west approaches 600 feet, but approximately 150 feet has been removed from the western end by quarrying operations. The breadth of the deposit ranges up to 400 feet and averages 300 feet. The maximum thickness proved by boring is 15 feet and the average about 9 feet.

The body has the form of a thin nearly horizontal lens bounded by undulating surfaces, but possessing a predominant dip to the north-west. The upper surface is more nearly plane than the lower.

The salient features of the deposit are shown in Plate 14, which shows the body in plan with thickness contours added. It will be noticed that the greatest thickness of bauxite extends east from the southern side of the quarry as a sinuous tongue which lies in a depression in the basalt surface.

(ii) M.L. 6873 (Orgill's).—This body is more oval than rectangular in plan and has its longer axis 600 feet in length trending north-west. The breadth is 300 feet and the average thickness a little over 8 feet. The sections show that the bauxite lies on a relatively plane floor of basalt.

In section the body takes the form of a wedge-shaped lens which thins very gradually to the south-east and terminates abruptly on the opposite side where it outcrops along the top of a creek bank. The body dips west down the slope of the hill at an average angle of 4 degrees.

Exposure of the western edge of this deposit by a small quarry has shown that the body here terminates abruptly, tapering sharply from a thickness of 12 feet to one foot or less in a horizontal distance of approximately 10 feet. The upper surface of the bauxite is exposed in the quarry over an area of about 250 square feet. This surface is irregular and bears a shallow but sharp trough-like depression parallel to the strike, together with numerous holes. The under surface, which rests on basaltic clay, dips east at about 40 degrees. Sections compiled from the results of boring and shaft-sinking show that this steep dip is not maintained and that actually both the upper and lower surfaces of the bauxite rise gently to the east from points only a few feet east of the western edge of the deposit. These features appear to be the result of erosion.

(e) *Reserves and Composition of Bauxite.*—The following tables show that the total reserves proved by shaft sinking and boring on the two properties amount to 106,600 tons of bauxite under 141,000 cubic yards or 263,500 tons of overburden; in round figures 2.5 tons of overburden to 1 ton of bauxite. The total reserves of bauxite are divided almost equally between the two deposits, but Orgill's lease has the more favorable overburden-bauxite ratio.

Information regarding the composition of the bauxite on M.L. 6689 is not complete, but Messrs. Sulphates Proprietary Limited have advised that the average analysis of bauxite removed from the quarry over a period of four years is:—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Ignition Loss.
Per cent. 53.0	Per cent. 5.0	Per cent. 6.5	Per cent. 4.5	Per cent. 31.0

These figures have been accepted as representative of the whole deposit.

With regard to Orgill's deposit, figures are given in the table for each block of ore proved by a line of bores or shafts. These figures are averages of analyses of samples obtained from shafts or bores on or near the lines selected, but in some instances lower results have been obtained from samples from intermediate shafts and the following analyses are quoted:—

—	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Ignition Loss.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
(i)	53.2	5.3	6.9	5.7	28.8
(ii)	55.1	4.0	6.9	5.0	29.0
(iii)	49.2	4.1	13.2	4.6	28.2
(iv)	50.9	4.1	9.2	4.5	27.8

(i) Average of bores 4, 5, 7 and shaft 4, representing 20.900 tons of reserves.
(ii) Average of parcel of 40 tons from shaft. To a certain extent this ore would be selected for despatch to works.
(iii) Average of 39 samples from fifteen shafts representing total footage sampled of 158½ feet and including low-grade material.
(iv) Average of 26 samples from shafts representing 150 feet and excluding analyses showing less than 48.6 per cent. Al_2O_3.

It is considered that the grade shown in the table of reserves for Orgill's deposit may be slightly higher than could be actually recovered, but the above analyses tend to show that any reduction in grade will not bring the alumina percentage below 50.

SULPHATE'S LEASE, M.L. 6689, ALLOTMENT 116D, PARISH OF NARRACAN SOUTH.

PROVED RESERVES OF BAUXITE.

Line	Bauxite.	Overburden.		Ratio
	Tons.	Cubic Yards.	Tons	Overburden. Bauxite.
200W	13,100	28,480	51,200	3.92
100W	10,400	15,900	28,600	2.75
00	13,200	15,900	28,600	2.27
100E	8,800	12,880	23,200	2.64
150E	6,300	4,620	8,300	1.32
250E	1,200	1,560	2,800	2.33
Total or Average ..	53,000	79,340	142,700	2.70

The average analysis of bauxite won from this lease is Al_2O_3, 53 per cent.; SiO_2, 5 per cent.

ORGILL'S LEASE, M.L. 6873, ALLOTMENT 116C, PARISH OF NARRACAN SOUTH.

PROVED RESERVES OF BAUXITE.

Line	Bauxite.			Overburden.		Ratio
	Tons.	Composition.		Cubic Yards.	Tons.	Overburden: Bauxite.
		Al_2O_3	SiO_2			
		Per cent.	Per cent.			
300N ..	4,500	52.0	5.0	2,400	4,320	0.96
200N ..	25,400	52.1	4.8	20,200	36,360	1.24
100N ..	12,100	54.4	5.0	27,040	48,700	4.03
00 ..	8,800	51.5	6.0	10,000	18,000	2.23
100S ..	2,800	52.1	3.7	1,940	3,450	1.23
Total or Average ..	53,600	52.5	5.0	61,580	110,830	2.06

(*f*) *Petrology.*—(i) *Bauxite.*—Microscopic examination of the heterogeneous bauxite containing small fragments of various colours shows that many of the included fragments are composed of altered volcanic rocks, probably mainly basaltic. Figures 1 and 2, Plate 4, illustrate various kinds of such fragments, scattered through a fine-grained base. Selected specimens of the large hard lumps, moreover, are readily recognizable as altered basalts. These consist of pseudomorphs of crystalline gibbsite after felted plagioclase laths, the interstices between which contain a considerable amount of leucoxene, which in part has the form of pseudomorphs after small prisms, probably originally pyroxene. Leucoxene also occurs as an alteration product of ilmenite, but residual plates and skeletal crystals of unaltered ilmenite also occur. In some of the lumps, there are numerous phenocrysts of altered olivine, represented by iddingsite pseudomorphs, but such pseudomorphs are not present in all the basaltic fragments examined, and there is also considerable variation in the content of unaltered ilmenite grains, and also in the size of the felspar laths (Plate 4 and Plate 5, Figure 1). In one sample, small amounts of secondary pyrites are present, but this mineral is rare in the Boolarra bauxite.

In the softer bauxite, such as the grey bed of high-quality ore at the top of the deposit, only a few of the included pellets are recognizable as altered volcanic rock. Most of them reveal little structure, consisting almost entirely of cryptocrystalline gibbsite, with variable amounts of leucoxene and ilmenite. Gibbsite occurs in all stages of crystallinity from well-developed large euhedral crystals showing polysynthetic and sector twinning (Plate 5, Figure 2), through aggregates of fairly large flakes, to micro- and crypto-crystalline aggregates. In general, each recognizable altered rock fragment in the bauxite is fairly uniform as regards the grain size of gibbsite developed in it, this being connected probably with the original texture since more open textures would permit of readier metasomatism and hence result in large crystals of gibbsite. The base in which the various pellets are set varies in different specimens. In one slide, it is sensibly isotropic, but contains numerous minute, highly refringent granules, resembling the *poudre refringeant* described by de Lapparent (1930) in the French bauxites. This base is rich in TiO_2, indicating that the minute highly refringent granules are probably leucoxene (TiO_2, Aq.). On the other hand, the structureless cryptocrystalline pellets contain only a slight trace of TiO_2 and a little kaolinitic clay. Their water content (approximately 30 per cent.) and nearly complete solubility in 1:1 sulphuric acid and in NaOH agree with the microscopic evidence that they are practically pure gibbsite.

In a heterogeneous sample containing dark-brown fragments of altered basalt set in an earthy base, the fragments were found to contain more TiO_2 than the base, which consists in part of colloform amorphous gibbsite, containing only a trace of TiO_2. The base is a fairly uniform, yellowish, sensibly isotropic material, the colloform structure of which is indicated under the microscope by iron oxide staining.

In addition to pellets that may be recognized as altered basalt, there are, especially in the higher grades of ore, small ovoid or rounded white concretionary lumps of nearly pure amorphous gibbsite.

After leaching with 1:1 sulphuric acid and washing with water the residue of the soft earthy bauxite consists of clay pellets, with a few grains of quartz, plagioclase (oligoclase-andesine, An_{40}), ilmenite, numerous pseudomorphs of leucoxene in stumpy crystals, rare zircon, and a few large flakes of bleached biotite containing apatite crystals. The clay in this material is either halloysite or one of the kaolin group, as shown by staining tests (Faust, 1940).

(ii) *Basalt.*—Three samples of unaltered basalts from the Boolarra district were sectioned. All are olivine basalts, closely resembling in texture and mineralogy varieties of altered basalts that occur in the bauxite.

A sample from the ridge near Boolarra township consists of large phenocrysts of olivine, partially altered to serpentine, felted plagioclase laths zoned from basic labradiorite to oligoclase, small prisms of augite, and large ilmenite grains and plates. Large patches and interstitial areas of analcite are very numerous, and the rock is clearly related to the widespread crinanites and crinanite-basalts of the Older Volcanic series in Gippsland.

The basalt from allotment 116D, west of the bauxite pit, contains large phenocrysts of olivine, partly changed to iddingsite, ophitic titan-augite, and zoned plagioclase laths (labradorite to andesine) with large ilmenite crystals and smaller plates of the same mineral. Zeolites are absent.

Basalt from the railway section near the pit, stratigraphically beneath the bauxite, is generally similar to the above but contains in addition to analcite, a considerable amount of a fibrous zeolite, the optical properties of which agree with natrolite. In this rock the olivine is partially serpentinized, but no iddingsite is present.

5. Payne's Lease. (Refer Plate 15.)

(*a*) *Situation.*—The lease has an area of 11 acres and is situated in allotment No. 99, Parish of Allambee East, adjoining the northern boundary of the allotment. It lies about 3½ miles by road north from the township of Mirboo North which is the terminus of the branch railway from Morwell.

(*b*) *Topography.*—The lease lies on the crest of a small spur of the Lydiard Range and is flanked by steep slopes on the north, east and south. The summit of the spur is about 1,000 feet above sea-level and the fall to the Little Morwell River, 1 mile to the east, is 500 feet. The accompanying plan shows topographic contours at a vertical interval of 10 feet. Small creeks on either flank of the hill drain eastward to the river.

(*c*) *General Geology.*—Black clayey soil containing angular quartz grains obscures the surface on the crest and flanks of the hill, and the adjacent gullies are choked with dense and rotting vegetation. A thin band of cemented brown sand is exposed in wheel ruts and by upturned roots of fallen trees on the crest of the northern slope of the spur.

One small outcrop of bauxite occurs on the southern flank of the hill 35 feet below the crest. Large detrital boulders of bauxite lie below and to each side of the outcrop and scattered fragments can be picked up over a broad arc following the contours round the face of the spur. Similar fragments and large boulders embedded in soil lie in a group near the south-eastern corner peg of the lease.

As shown on the plan and sections there are two bodies of bauxite about 250 feet apart. The western deposit consists of two lenticular bodies with maximum thicknesses of 9 feet and 17 feet and joined by a thin sheet of bauxite.

The maximum thickness of the eastern section of the deposit is not known as it has not been found possible to drill through the bauxite with hand augers which have been used for the prospecting of this part of the lease, but the bauxite is known to be not less than 18 feet thick at one place, and not less than 15 feet and 12 feet thick at two others. The eastern limit of this body has not yet been defined.

Basalt does not outcrop on or in the immediate vicinity of the lease, but chocolate basaltic soil is evident on cultivated land near the foot of the hill on the southern side.

Landslips have carried down much sand and probably some bauxite on the southern and south-eastern flanks, and to a lesser extent on the northern side.

The overburden above the bauxite consists of sand and clay. The sand contains both coarse (3 to 5 mm.) and fine (0.5 mm.) angular and subangular grains of quartz. It derives the colours ascribed to it in the drilling logs (yellow and brown) from admixed clay or surface staining of the component grains.

The bauxite recovered from boring operations on the western deposit is buff or brownish pink in colour and is rather harder and more compact than that of other deposits. Analyses show the composition to be that of gibbsite, Al_2O_3, $3H_2O$, but only rarely can any crystalline component be observed by megascopic examination.

The following description is taken from a report by F. L. Stillwell (1943)—

The bauxite is buff to creamy coloured, and finely cellular. No. 1 specimen (from Bore No. 11) appears to consist of cemented fragments, but the other three (from below No. 1 in the same bore) appear uniform.

In thin section, No. 1 is seen to be irregularly ironstained, and it is the unequal distribution of the stain that gives it its fragmental appearance. Much of the rock shows a relic basaltic texture, and consists of finely cryptocrystalline gibbsite, with a little ilmenite more or less altered to leucoxene.

Specimen No. 2 is practically colourless in thin section and consists essentially of cryptocrystalline to microcrystalline gibbsite, with which are associated laths and skeletal crystals of ilmenite showing all stages of alteration to leucoxene.

The iron content, expressed as Fe_2O_3 for all bauxite containing not less than 49.8 per cent. Al_2O_3, averages 5.6 per cent. and ranges between 6.5 and 4.1 per cent. Titania (TiO_2) content averages 6.1 per cent., with a range between 6.5 per cent. and 4.8 per cent.

With one exception, the bores within the area of the western section of the deposit, where bauxite occurs in sufficient thickness to warrant quarrying, revealed bauxite containing more than 50 per cent. Al_2O_3 for the whole thickness of the bed at the point bored. In the one excepted instance, the figure is 49.8 per cent.

Traces of lignite were found in only one bore hole (No. 22) on the lease. These traces consisted of broken fragments of woody material embedded in finely mottled clay of greyish colour. This clay contains minor amounts of rounded grains of clear glassy quartz, ilmenite very finely divided, and small grains of amorphous bauxite. It rests upon decomposed basalt.

The completely decomposed basalt penetrated in each bore is generally greyish-white or pale brown in colour, with a finely stippled texture and containing small specks of a heavy black material which is probably ilmenite. Dr. Stillwell, in the report quoted above, has identified ilmenite and leucoxene in specimens of clay from immediately below the bauxite on this lease. The clay did not show any trace of basaltic texture and revealed an indistinct banded structure.

Typical bore logs which show the section above the basalt are—

Depth in Feet.

Bore No. 2.

From	To	
0	2	Soil
2	4	Grey sand
4	23	Brown sand
23	24	Sandy clay
24	41	Bauxite
41	..	Decomposed basalt

Bore No. 7.

From	To	
0	2	Soil
2	3	Grey sand
3	4	Brown sand and clay
4	9	Brown clay
9	11	Grey sandy clay
11	12	Clay with trace of bauxite
12	..	Decomposed basalt

Bore No. 3.

From	To	
0	2	Soil
2	4	Grey sand
4	24	Brown sand
24	27	Grey sandy clay
27	29	Yellow sand
29	50	Grey sandy clay
50	55	Grey clay
55	56	Brown clay
56	60	Grey clay
60	61	Clay with trace of bauxite
61	..	Decomposed basalt

Depth in Feet.

Bore No. 13.

From	To	
0	2	Soil
2	5	Grey sand
5	20	Brown sand
20	27	Yellow sand
27	31	Grey sand
31	35	Grey sandy clay
35	50	Bauxite
50	..	Decomposed basalt

Bore No. 22.

From	To	
0	2	Soil
2	23	Brown sand
23	30	Grey sand
30	32	Brown clay
32	35	Grey sand
35	38	Grey clay
38	50	Brown, grey and white sand
50	67	Thin bands of clay and sand
67	69	Sand and lignitic clay
69	71	Lignitic and bauxitic clay
71	..	Decomposed basalt

(*d*) *Structure.*—The bauxite which constitutes the western section of the deposit, lies in a depression in the basalt and dips at about 5 degrees to the east-northeast. Structure contours on the upper surface of the basalt are not shown on the plan as the shape of this surface is relatively simple and is evident from the sections. The basin is somewhat asymmetrical being deeper on the eastern side where the greater thickness of bauxite lies.

The large body which forms the eastern section of the deposit is lenticular in cross-section and has an average thickness of 16 feet for a distance of 300 feet along its long axis. The average width from east to west along this length is 200 feet. The body is nearly symmetrical about the north-south axis, but a short tongue projects to the north from the north-west corner.

Exploration of the eastern section of the deposit could not be completed, but results of boring to date indicate that the upper surface dips at about 15 degrees to the north-east. Assuming that the bauxite resulted from the alteration of volcanic ash the sections strongly suggest that the parental bodies were formed by deposition in separate basins around the margins of which wedge-shaped deposits accumulated.

(*e*) *Reserves.*—Figures in the following table indicate that boring has proved a total of not less than 111,500 tons of bauxite to exist on the lease.

Of this total 61,500 tons lies in the western section of the deposit and has been tested by power drilling which recovered uncontaminated samples for analysis. The whole deposit, including marginal areas which are too thin or too deeply buried to be recoverable, occupies an area of 5 acres and has been tested by 23 boreholes.

This bauxite is overlain by 198,500 tons of overburden and has the following average composition when dry.

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Ignition Loss
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
52.8	8.0	5.6	6.1	27.1

As this tonnage (61,500) represents virtually the whole of the bauxite which can be recovered from the western section of the deposit irrespective of the composition, the figure cannot be increased by lowering the acceptable grade except in minor amount and at the cost of greatly increasing the volume of overburden to be stripped.

The tonnage available in the eastern section of the deposit is shown as 50,000. Testing of this body has been conducted by hand-boring but on the eastern side the bauxite passed below the depth which can be reached by the method of hand-boring used. The extent of the deposit so far proved is shown in Plate 15.

Line.	Bauxite			Overburden.		Ratio.
	Tons.	Composition.		Cubic Yards.	Tons	Overburden · Bauxite.
		Al_2O_3	SiO_2			
		Per cent.	Per cent.			
	PAYNE'S WESTERN SECTION—WESTERN BODY.					
100N ..	6,000	52.2	10.4	20,280	36,500	6.08
200N ..	13,000	52.7	7.5	21,110	38,000	2.92
Total or Average	19,000	52.5	8.3	41,390	74,500	3.92
	PAYNE'S WESTERN SECTION—EASTERN BODY.					
100N ..	7,800	51.7	10.0	6,120	11,000	1.41
200N ..	9,940	56.0	5.0	14,450	26,000	2.61
300N ..	14,380	51.8	9.0	30,550	55,000	3.82
400N ..	10,380	53.0	7.1	17,770	32,000	3.08
Total or Average ..	42,500	52.9	7.9	68,890	124,000	2.92
Grand Total or Average	61,500	52.75	8.03	110,280	198,500	3.23
	PAYNE'S EASTERN SECTION (DATA INCOMPLETE).*					
200N ..	9,000	..	..	5,800	10,000	..
300N ..	14,000	..	..	6,700	12,000	..
400N ..	20,000	..	..	12,500	22,500	..
500N ..	7,000	..	..	4,200	7,500	..
Total ..	50,000	..	..	29,200	52,000	..

* Bauxite, if present, could not be reached by hand bores on eastern side of deposit.

(a) Rodda's or Childers. (Refer Plates 16 and 17.)

(*a*) *General.*—This deposit is situated in Allotment 148, Parish of Moe, on the south side of the road from Thorpdale to Childers.

Some bauxite has been produced from a small open cut from which ore has been raised with a windlass. This bauxite is siliceous and is used chiefly by the Ordish Firebrick Pty. Ltd., in the manufacture of firebricks.

The deposit is believed to be small. The composition of the bauxite won from the open cut shows a fairly wide range and averages approximately—SiO_2—11 per cent.; Al_2O_3—51 per cent.; Fe_2O_3—4.5 per cent.; TiO_2—6 per cent.

(*b*) *Geology.*—(i) *General.*—The occurrence is close to the western edge of an extensive area of Older Volcanic rocks (classified by the Geological Survey of Victoria as basalts, tuffs, clays, &c.) in the parishes of Moe and Narracan South (*see* Geological Map; Herman, 1922, Plate 11). It is situated on a ridge between the head-waters of the Narracan Creek and Little Narracan Creek, at an elevation of 1,250 feet above sea level. On the coloured geological Parish Plan of Moe, Post-Volcanic sands, clays and fine gravels are shown at the bauxite occurrence. The slopes on either side are indicated as Older Volcanic. A more detailed sketch geological map of the immediate neighbourhood is given in Plate 16.

(ii) *Sands and Clays.*—As usual in South Gippsland, the geological features are in large part masked by soils, but the information obtainable in the field is sufficient to cast strong doubt on the interpretation of the sands as post-volcanic, the indication being that they rest on a foundation of Jurassic sandstones and shales containing *Taeniopteris Daintreei* and (?) *Cladophlebis*, and underlie residual chocolate-brown soils and mottled clays, derived from formerly overlying basalt. The sands and clays at the bauxite pit, and also on the road to Mirboo North (MacDonald's Track), have a general dip in a south-easterly direction, probably of the average order of 5°–10°, so that the ridge on which the bauxite occurs is roughly parallel to the strike of the Tertiaries.

The Tertiary sediments consist of coarse and fine quartz sands, clays, and sandy clays, in places strongly cemented with limonite. The coarse sands are current-bedded, and contain white mica and grains and "pebbles" of kaolin. A heavy mineral analysis of these sands, made by Mr. G. Baker, shows that they contain less than 0.05 per cent. heavy minerals, these consisting of tourmaline, hematite, limonite, ilmenite altering to leucozene, zircon, biotite, bleached biotite, rutile, and very rare hornblende.

The mineralogy of the coarse sands, therefore, indicates their probable derivation from a parent granitic rock. The current-bedding, as well as the presence of prismatic tourmaline and zircon crystals in addition to rounded grains of these minerals, and also the presence of fresh biotite, indicate rapid transportation by the streams of the period, from a not far distant source.

The fine-grained white sandy clay overlying the bauxite contains 57 per cent. clay and 43 per cent. sand. In addition to quartz, the heavy minerals limonite, ilmenite, leucoxene, rutile, zircon, tourmaline, brookite and fresh biotite are present. It appears, therefore, that this sandy clay is of similar derivation to the coarse sand that overlies it. Interbedded with the sands and sandy clay are lenticular, mottled and speckled white, purple and red clays. In the coarse sands, a ferruginous cement is present, and ironstone bands are locally developed roughly parallel to the bedding. In some of these bands in the bauxite pit and on the hillside to the north, fragments of fossil wood preserved as limonitic replacements occur. These have been examined by Dr. R. T. Patton, who states that they are indeterminable.

The Tertiary sediments underlying the base of the bauxite and overlying the Jurassic rocks are not seen in exposure, but fragments in the soils on the northerly slopes of the main ridge indicate the presence of ferruginous grits, clays, and quartz gravels, the latter probably marking the base of the Tertiary succession.

(iii) *Older Volcanics.*—The volcanic rocks that overlie the Tertiary sediments are deeply weathered to chocolate-brown soils, many of which contain dispersed grit particles, perhaps originally derived from formerly overlying sands. The rotten rock (C soil horizon) is clayey and has a spheroidal structure marked by limonite staining and banding.

The unweathered rocks are dense basalts, a fresh specimen from the Yarragon-road near Childers being an ophitic olivine-titanaugite basalt, of moderately coarse grain size. The felspars are markedly zoned, with labradorite cores (An_{65}) and jackets of andesine (An_{45}). Small crystals of ilmenite occur in the ground mass, and the interstices are occupied by carbonates and serpentinous aggregates. The carbonates, which are present in fairly large amount, appear to be primary since they enclose unaltered felspar laths and augite prisms. The olivines are partially changed to serpentine along cracks, but otherwise the rock shows no sign of alteration.

(iv) *Bauxite.*—A detailed section at the bauxite pit is shown in Plate 17. The base of the deposit is not visible, but it appears from the occurrence of fragments in the paddock on the north-west of the pit that the bed is not more than 20 feet thick. The top of the bauxite is irregular, but although the overlying sandy clay thins out on the flanks of a ridge in the bauxite, it is doubtful if this is an initial feature, since the adjoining trough, in which the bauxite and the overlying beds are all involved in a minor fold, is clearly tectonic. Disturbances such as this, and the marked increase in dip near the southerly end of the pit, indicate that locally observed dips have little regional significance. Nevertheless, a low regional dip towards the south-east or south-south-east is indicated by the general geology and the prevalence of such dips in exposures. This regional dip is affected by local disturbances.

The bauxite *en masse* has a rubbly texture, consisting of hard rounded to sub-angular fragments up to about 2 inches across, intermingled with finer yellowish-red material. A rough bedding is discernible in places, but at this locality the bauxite is, in general, massive. In conformity with the bedding, undulating bands of hard limonite about 6 inches thick are interbedded with the bauxite near the outcrop. A similar concentration of limonite is usually found in bauxite outcrops in South Gippsland, indicating that solution and redeposition of iron has gone on by vadose waters in the present erosion cycle.

Unlike the occurrences at Mirboo North and Boolarra, the bauxite at Childers cannot be shown from the available field evidence to overlie Older Basalt or its decomposition products; it apparently rests on Cainozoic sediments. It does not come into direct field relationship with the basalt, but the sediments with which the bauxite is interbedded pass beneath the basalt on MacDonald's Track, and rest directly on the Jurassic basement.

As shown in the map, exposures are poor in the vicinity of the bauxite, and in drawing the accompanying section, it has been necessary to project data from points off the line A—B. The very small residual shown as basalt on the ridge-top is of considerable significance in the interpretation of the structure. This material occurs as a mottled clay, with concentric limonitic banding well marked in places. It contains irregularly dispersed altered iron oxide grains, and white blotches of kaolinitic clay which are regarded as altered felspars. Detrital minerals are absent, and the material is thus identical with clays undoubtedly derived from the weathering of basalt in other parts of South Gippsland. On this interpretation it is regarded as a basaltic residual, overlying the sands and clays with which the bauxite is interbedded.

(There are no exposures of the rocks below the bauxite in the immediate vicinity of the Childers quarry. The section above the bauxite is similar to that revealed at several other localities, e.g., at Napier's near Mirboo North, and it is considered that the "mottled clay" referred to in the preceding paragraph is not derived from the Older Basalt. H.G.R. and H.B.O.)

(*c*) *Petrology*.—Under the microscope, the bauxite is seen to consist of recognizable fragments of altered olivine basalt, set in a base of variable composition and texture. The basaltic fragments consist of pseudomorphs of crystalline gibbsite after plagioclase laths, pseudomorphs of iddingsite after olivine, pseudomorphs of leucoxene after ilmenite and probably also after titanaugite, some residual grains of ilmenite, and an interstitial base containing numerous minute, highly refringent grains of leucoxene. In one sample, which is more coherent than the average bauxite, the altered basalt fragments are surrounded by banded colloform masses which vary from amorphous bauxite to coarsely crystalline gibbsite (Plate 6, Figure 1). In the hand specimen, it can be seen that these colloform masses encrust cavities in the bauxite, the lining of crystalline gibbsite having grown on a base of amorphous or cryptocrystalline bauxite (probably also gibbsite) of earlier deposition (Plate 6, Figure 2). Less coherent samples contain a smaller amount of colloform bauxite.

After grinding and treatment with 1:1 sulphuric acid, the residue of the average bauxite consists mainly of clay, with some rounded detrital quartz grains, a little partially altered oligoclase, ilmenite, and rare zircon and tourmaline.

7. "Nahoo," Parish of Narracan South. (Refer Plate 18.)

(*a*) *Situation*.—The bauxite deposite now opened up at this locality is situated in allotment 8, Parish of Narracan South. Macdonald's Track, leading from Morwell toward Nyora and Koo-Wee-Rup Swamp along the summit of the ridge between Tenmile Creek on the east and Narracan Creek on the west, passes on the north boundary of the property. The pit lies at an elevation of about 1,000 feet above sea level, on a spur between two small creeks.

(*b*) *Geology*.—On the coloured geological Parish Plan issued by the Victorian Geological Survey, the area is shown as occupied by older volcanic rocks, i.e., basalts, tuffs, and variegated clays with chocolate soils, so that at first sight one would expect the bauxite to be post-volcanic, or interbedded between lava flows. Actually, however, Jurassic sandstones, mudstones and shales, with abundant plant remains, chiefly *Taeniopteris Daintreei*, occur a few feet beneath the bauxite. The Jurassic sediments are exposed in small creeks on either side of the spur on which the deposit occurs, and also on the spur itelf, below the bauxite (*see* sketch geological map, Plate 18). As indicated on the map, the country to the north-east of the pit is disturbed by landslips, and much of the neighbourhood, at the time of investigation, was covered with very dense bracken. Sufficient information was obtained, however, to permit the construction of the cross-sections shown in Plate 18. The top of the Jurassic rocks, beneath the bauxite, dips towards the south-east. Extrapolation of this dip to the north-west would bring the top of the Jurassic rocks to the surface on the northern slopes of the main ridge, but they do not appear there, perhaps because of intervening warping or faulting. Resting on the Jurassic rocks, there is a thin bed of quartz gravel, usually cemented by limonite, associated with ferruginous sands. These deposits form characteritic marker beds by which the base of the Cainozoic formations may be traced.

The base of the bauxite is not far above the ferruginous grit, but the section in the workings shows white clay at the bottom, the succession being as follows:—

Coarse current-bedded red sands—20 ft.

White sandy clay—8 ft.

Quartzite—1 ft.

Bauxite with halloysite masses—3 ft. 6 in.

Bauxite—12 ft.

Red granular bauxite clay with limonite bands—2 ft.

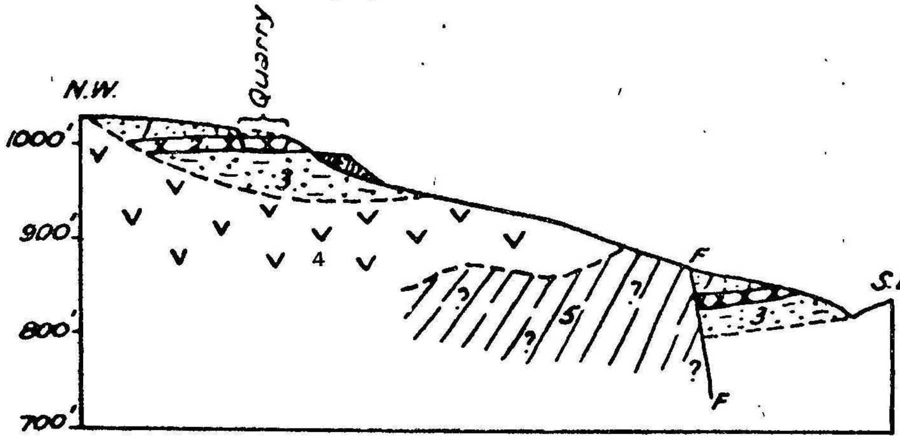
White clay—Base not seen.

The current-bedded sands, like those at Childers, contain kaolin pellets, and consist of quartz, together with small amounts of leucoxene, limonite, ilmenite, tourmaline, zircon, rutile and biotie. The similarity of the two sands, and the occurrence of white sandy clay beneath them and resting on the bauxite at both localities, is notewothy, and the presence of ferruginous grits, sands, and a basal quartz pebble bed beneath the bauxite is a further indication of the similarity of the two successions, which is so close as to warrant bed to bed correlation. The bauxite at "Nahoo" is distinctly bedded, the stratification being defined by buff and whitish laminae, or by layers containing subrounded to angular hard fragments (Plate 3, Figure 2). Where the stratification is ill-defined, the ore is massive with a rubbly texture.

The interpretation here given to the available data at "Nahoo" is that the bauxite is interbedded with pre-Older Volcanic sediments, as at Childers. The bauxite does not rest on the Older Basalt; a possible alternative explanation is that it is on the same horizon as that rock, which has thinned out and is represented by tuffs only. This, however, is unlikely in view of the considerable thickness of solid basalt exposed nearby. Furthermore, if the bauxite represents the basalt, the post-bauxite sandy clay, quartz grits and quartzites must be post-volcanic Tertiaries, and as such should presumably be represented above the basalt nearby. There is, however, no trace of such deposits. It is, therefore, maintained that the bauxite represents the alteration of a bedded deposit, stratigraphically beneath the neighbouring Older Basalt. Support to this conclusion is given by the occurrence of quartzite and bauxite containing large halloysite masses, at the top of the main deposit. The quartzite represents a secondarily silicified sand and is of the typical "Grey Billy" type, which occurs in its usual position beneath the basalts at Wanke's and many other places in South Gippsland. Its position above the bauxite at "Nahoo" is therefore a clear indication that the bauxite is on a lower horizon than the neighbouring basalts. Furthermore, the production of a clay mineral such as halloysite by the re-silication of gibbsite under lateritizing conditions has been postulated by Harrison (1910) and by Hardy and Rodrigues (1939). With conditions definitely favouring silicification as is indicated by the formation of the quartzite at "Nahoo", the formation of large masses of pure halloysite by a similar chemical process may perhaps be explained.

On the assumption that all the bauxites in South Gippsland represent a single period of lateritization, the basalts overlying the bauxite at "Nahoo" and Childers must be considerably younger than those underlying the ore in the Mirboo North, Boolarra and Callignee districts. However, it is suggested below that the Gippsland bauxites may not be the products of lateritization, and that they could have formed fairly rapidly under the requisite physical and chemical conditions, at various times during the one major geological episode which included the vulcanicity of the Older Volcanic Series and the deposition of the brown coals. On this view, the bauxites would not constitute an absolute index of one particular geological horizon. Whitelaw (1921) came to the same conclusion, and his work was probably the original source of the statement made by Herman (1922, page 15) that, "At the base of the flows in fine-grained material, which was probably originally ash, beds of bauxite clay have been located". As already pointed out in this bulletin, the geological relationships of the bauxite at Childers and "Nahoo" are unusual, since at all the other occurrences examined the ore is stratigraphically above the Older Basalt. It is perhaps significant that the Older Basalt near "Nahoo" is altered towards its base to ochreous clays which yield 17–18 per cent. of Al_2O_3 on leaching with 20 per cent. sulphuric acid, and are therefore bauxitic. This suggests that the bauxitization at "Nahoo" may perhaps have taken place after the basalt covered the area rather than before this event.

Our interpretation (H.G.R. and H.B.O.) of the section at "Nahoo" is shown in the following figure:—



Text Figure 1.—Sketch Section at "Nahoo".
Horizontal scale—1 inch equals 400 feet.
Vertical scale—1 inch equals 200 feet.

1. Sand, gravel, clay ⎫
2. Bauxite .. .. ⎬ Tertiary.
3. Clay, cemented grit ⎪
4. Basalt .. .. ⎭
5. Mudstone, sandstone—Jurassic.

It will be seen that on this interpretation the only difference between this and sections of the other deposits is the greater thickness of sediments beneath the bauxite than has been noted elsewhere.

(*c*) *Petrology.*—(i) *Red Bauxite Clay.*—This unusual material is bright red and sandy-looking, with limonite bands parallel to the bedding. The junction with the overlying bauxite is sharp. The rock consists of iron-stained clay granules, and on leaching with 20 per cent. sulphuric acid it yields 44–45 per cent Al_2O_3, leaving a clay residue. It is, therefore, definitely bauxitic, and was indeed treated as part of the commercial ore for certain purposes. In addition to the above, the bed contains some rounded quartz grains, and the heavy minerals brookite, tourmaline, ilmenite, leucoxene, rutile, zircon, white mica and zoisite. No minerals indicative of the incorporation of basaltic material are present, the ilmenite being readily derivable from granitic or other bedrock types, as in the associated fluviatile sands and grits. There seems no doubt that the clay is of sedimentary origin, and it is thus of considerable importance since it affords the only known occurrence of a bauxitized rock other than volcanic ash and basalt in South Gippsland.

(ii) *Bauxite.*—Unlike most other bauxites in South Gippsland, the "Nahoo" deposit contains few large lumps of altered basalt, being in general fine-grained and earthy. The coarser scoriaceous-looking varieties, however, may be seen under the microscope to contain numerous small pellets of altered olivine basalt, consisting of pseudomorphs of crystalline gibbsite after olivine, a little leucoxene, and numerous partially altered or fresh ilmenite grains. The dark-reddish bauxites are stained with ferric hydrates, probably limonite, since no crystalline forms are observable. In places, masses of crystalline gibbsite replace the original constituents of the groundmass. The finely bedded bauxite from this locality also contains readily recognizable altered volcanic rock fragments, and in places small veinlets of crystalline gibbsite of a second generation traverse the already bauxitized rock (Plate 7, Figure 1). No detrital minerals such as quartz, zircon, tourmaline, &c., were found in the bauxite at this locality.

(iii) *Hard Bauxite with Halloysite Masses.*—This material is rejected for commercial purposes owing to the high silica content. It contains irregular masses a few inches across of homogeneous duck-egg blue clay, which is believed to be halloysite. The clay is non-plastic, and breaks with a smooth, conchoidal fracture, but nevertheless adheres strongly to the tongue. It is optically amorphous and isotropic, with a low refractive index, about 1.535, which is typical of hydrated halloysite. Pure material air-dried in the laboratory for a year showed a loss of water below 80° C. of 7.48 per cent., and an additional loss at red heat of 13.71 per cent. The properties of the mineral thus indicate that it is halloysite. An X-ray diffraction pattern was obtained, which differs slightly from both pure hydrated halloysite and pure halloysite, but the presence of a strong line at about 10Å degrees indicates the presence of some hydrated halloysite. It may be suggested that the mineral was originally hydrated halloysite, but that owing to heating on exposure in the quarry to temperatures greater than 50° C., some of it has changed by dehydration to halloysite. The associated bauxite is harder than the average, consisting of a heterogeneous aggregation of completely altered volcanic rock fragments (none containing recognizable olivine pseudomorphs), irregular masses of amorphous bauxite, with a little crystalline gibbsite lining cavities and scattered through the groundmass. The groundmass contains a considerable amount of clay, and also numerous scattered ilmenite grains.

(iv) *Quartzite.*—Associated with the above-described hard bauxite and apparently overlying it, is a lenticular grey quartzite, formed by the silicification of the base of the overlying sandy clay, and resembling "grey billy". It consists of residual grains of quartz, brown tourmaline, and ilmenite, set in a base of micro- to crypto-crystalline secondary silica.

(*d*) *Reserves and Composition of Bauxite.*—Messrs. Sulphates Pty. Ltd. have worked the deposit for some years as a source of bauxite for chemical purposes. The average composition of the bauxite won is SiO_2—15 per cent.; Al_2O_3—52 per cent.; Fe_2O_3—3.5 per cent.; and TiO_2—4 per cent.

Proved reserves are small but there are possibly 50,000 tons in the deposit.

8. Bond's, Parish of Budgeree.

The south-west corner of this lease is separated from the north-east corner of Greenwood's lease (M.L.6717) by the width of a road. The corner peg and two bores are shown on Plate 12. To date three bores have been sunk on this lease and one of them has penetrated 4 feet of bauxite at a depth of 120 feet from the surface. This body appears to be an extension of that proved on M.L.6717. The quality of the bauxite is good. The bores are interesting in that they encountered lignite and lignitic clay. The log of Bore 14 is quoted---

Depth in Feet. From	To	
0	1	Soil
1	21	Yellow, grey and red clay
21	36	Sandy clay
36	39	Grey clay
39	57	Sandy clay
57	97	Sand
97	102	Brown clay
102	120	Lignite and lignitic clay
120	124	Bauxite
124	133	Decomposed basalt

9. Roy's, Parish of Budgeree.

Roy's lease adjoins Bond's on the east. No bores have been drilled on this lease, but bauxite fragments are embedded in slumped material towards the southern side of the lease. Three bores drilled half a mile to the east of this holding and at a slightly higher elevation entered decomposed basalt at a shallow depth.

10. Crutchfield's, Parish of Mirboo.

Crutchfield's farm is situated on allotments 61 and 59 about 5 miles south-west from Boolarra and 4 miles south-east from Mirboo North. Two outcrops of bauxite are known on allotment 61. One occurs on the crest of a rounded hill and the other in the bank of a creek about 20 chains to the east and 60 feet below the top of the hill.

It is thought that the higher body is only a small residual. There is insufficient exposure of the bauxite in the creek bank to form a basis for any estimates.

11. De Hais's, Parish of Mirboo.

Messrs. Sulphates Pty. Ltd. have reported that a deposit of bauxite exists on allotment 34 and that the ore is approximately of similar composition to that from M.L. 6689, Parish of Narracan South, i.e. 53 per cent. alumina, 5 per cent. silica, but alumina might be a little lower. The company considers it doubtful if any considerable tonnage could be obtained from this deposit.

12. Fox's, Parish of Mirboo.

Fragmental bauxite has been found on the slopes below the crest of a high ridge in allotments 10c, 10E, 18 and 131 near the eastern boundary of the parish. The ridge has an elevation of 1,000 feet above sea-level and is capped with post-volcanic sands underlain by basalt. Landslips have carried sand down the slopes and mixed it with basaltic soil on allotment 18. The bauxite fragments in a shallow road cutting on the western slope of the ridge were probably carried there by slumping.

No information is available about the extent of the deposit on this lease.

13. Foy's, Parish of Mirboo.

Foy's property lies about ½ mile east from the railway station at Mirboo North. Two occurrences of bauxite are known on this farm and Messrs. Sulphates Proprietary Limited have carried out some test boring on the southernmost of the deposits, about ½ mile south of the main road from Mirboo North to Boolarra. As the company was unable to come to any satisfactory agreement with the owner of the farm, the boring was not carried to a conclusive stage. Four bores encountered bauxite at an average depth of 8 feet from the surface and indicated the presence of 10,000 tons. The ore is high grade averaging 56 per cent. alumina and 4 per cent. silica.

About 100 yards south of the Mirboo North-Boolarra road, boulders of bauxite are showing on Foy's farm in a patch of thick bracken. It is not known whether they are *in situ* but the large size of some of them suggests that they mark the edge or top of an outcropping deposit.

14. Lovell's, Parish of Mirboo.

Pebbles and boulders of bauxite can be picked up for a distance of about 200 yards near the crest of a large hill ¾ mile west from Darlimurla railway station. No further information is at present available about this deposit.

15. Sargent's, Parish of Mirboo, in Darlimurla Township.

Bauxite occurs on the slopes of a low hill about 200 yards north of the railway station at Darlimurla and a lease has been taken up by Messrs. Sulphates Proprietary Limited. No further information is available.

16. Tierney's, Parish of Mirboo.

This is an area adjoining Crutchfield's farm on the east and occupying high uncleared ground in allotment 53. Fragments of bauxite picked up on the surface were analysed with the following results:— SiO_2—1.9 per cent.; Al_2O_3—36.3 per cent.; but to date the area has not been further prospected.

17. Harrison's Allotment 103, Parish of Allambee East.

Bauxite outcrops, which appear to be part of a flat-bedded deposit occur on the south side of a creek a few chains upstream (west) from the road from Mirboo North to Payne's. A few hand bores have been put down by Messrs. Sulphates Proprietary Limited on the south side of the outcrop, but no bauxite was encountered. It is impossible on present information to form any estimate of the extent of this deposit.

18. King's, Parish of Allambee East.

This lease lies to the south of Payne's and is at about the same elevation, namely 1,000 feet above sea level. The lease is in allotment 101 and as originally pegged contained about 45 acres, but the area has been reduced by the exclusion of barren ground at the northern end of the holding.

A road runs north outside the western boundary of the lease and turns in an easterly direction crossing the lease near the centre. Bauxite is exposed in a shallow cutting at the side of this road a few yards southwest from the south-west corner peg, and in the table drain of the road within the lease boundaries.

Two bodies of bauxite, one on either side of the road, occur on the lease.

North of the road three prospecting shafts and a few hand-bores have been sunk. One of the shafts was sunk a few yards north from the bauxite exposed in the table drain of the road, and the other two 600 feet and 900 feet further north respectively. Only the first shaft encountered bauxite; the others entered decomposed basalt at less than 20 feet from the surface.

Where intersected by the shaft the upper surface of the bauxite is steeply inclined, but as the shaft was not continued through the bauxite it cannot be stated whether an erosion or bedding surface was encountered.

Hand-boring of this deposit is not complete but suffices to indicate that the body of bauxite is not large.

On the south side of the road at 600 feet south from the shaft mentioned above hand-boring has revealed the presence of 21,400 tons of bauxite in a lenticular body dipping to the east down the slope of a gentle hill. The dip which is steeper than the hill slope averages 19 degrees and the thickness of the overburden ranges from 3 feet on the western edge to 30 feet on the eastern side where the depth became too great for hand-boring.

A shaft has been sunk in the north-west quarter of the southern deposit. Samples of bauxite, representing a thickness of 11 feet disclosed in the shaft, gave the following average analysis:—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2
Per cent. 51.7	Per cent. 10 0	Per cent. 4.9	Per cent. 7.0

19. Polley's, Parish of Allambee East.

A large lease, 2½ miles north-west from Mirboo North takes in portions of Allotments 91, 124A and 124B. The presence of bauxite at the northern end of the lease is known, but this area has not yet come under review and nothing further is known about it.

20. Smith's Mill, Parish of Allambee East.

A small outcrop of bauxite in allotment 124A (adjoining Polley's) at a point about ½ mile north-east from Smith's Mill (an abandoned timber mill) was investigated by hand-boring. One shaft sunk near the centre of the deposit for sampling purposes passed through 17 feet of bauxite of the following composition:—

Al_2O_3	SiO_2	Fe_2O_3	TiO_2
Per cent. 45.8	Per cent. 7.0	Per cent. 13.5	Per cent. 7.2

The bauxite lies horizontally and outcrops on a steep hillside which slopes to the north. It lies on decomposed basalt which shows in outcrop immediately beneath the bauxite.

Owing to the increasing depth of overburden, exploration of the body by boring is incomplete to the south, but it is improbable that much bauxite additional to that already revealed exists in this direction. The bauxite lies in a trough in the basalt surface.

The total tonnage indicated by hand-boring amounts to approximately 19,000 tons.

21. Wanke's, Parish of Allambee East. (Refer Plate 19.)

Bauxite outcrops over a small area, approximately 100 feet by 200 feet, on the slopes of a creek bank in allotment 104. The bauxite overlies the Older Basalt, with intervening mottled blue clays probably representing weathering products of the basalt, which itself rests on lenticular ferruginous sands, locally altered to quartzites. The Jurassic bedrock forms a range of hills to the north-west of the property. Overlying the basalt is a thick series of sands, clays and grits, together with the bauxite, which forms bouldery outcrops between the post-Volcanic sediments and the basalt.

The deposit has been opened by a quarry at a level about 10 feet above the creek and its extent has been proved by boring. The body has the form of a lens, roughly circular in outline, 16 feet thick near the centre and 200 feet in diameter. This lens dips south-east at about 35 degrees. Probably as much as a quarter of the original deposit has been removed by erosion. (*See* Plate 2, Figure 2.)

This locality is interesting chiefly for the reason that tilting of the beds has exposed fairly clearly a section from the Jurassic to the sands immediately above the bauxite. (*See* Plate 19.)

Owing to the high angle of dip a large part of the bauxite lies beneath deep overburden and is below the level of the nearby creek. The grade of bauxite recovered from the quarry averages about SiO_2—6 per cent.; Al_2O_3—50 per cent; Fe_2O_3—9 per cent.

The bauxite exposed in the pit has a rubbly texture, with a very rough indication of bedding. Hard lumps from the outcrop were sectioned, and found to consist of (1) very coarse-grained bauxitized olivine basalt (Plate 7, Figure 2), and (2) fine-grained bauxitized olivine basalt, rich in ilmenite. Both rocks contain crystalline gibbsite, but in the finer-grained type a considerable amount of amorphous colloform bauxite is also present. The very marked difference between these two types, and the notably fragmental character of the coarser variety, indicate that the original rock was a basalt tuff.

22. Martin's, Parish of Mirboo.

Bauxite outcrops near the crest of a hill in allotment 69A, about ¾ miles south-west from Crutchfield's deposits. The deposit is believed to be very small and may consist of residual boulders only.

XI.—ORIGIN OF THE BAUXITE.

This problem is discussed under the following headings:—

A.—Parent Rock.
B.—Form of the Deposits.
C.—Process of Bauxitization.
D.—Conditions and Date of Bauxitization.

A.—PARENT ROCK.

Petrological examination and observations in the field show that all the bauxites examined, with the single exception of the red bauxitic clay from "Nahoo", are derived from clastic stratified rocks consisting of recognizable fragments of altered volcanic rocks admixed with finer grades of material. The identity of the latter is not immediately obvious. All the samples examined contain clay, and usually a small proportion of detrital grains of quartz and acid plagioclase felspar, accompanied, in some samples, by a little bleached biotite, tourmaline, and zircon—minerals that are also present in the sedimentary sands and clays with which the bauxite is associated. Although a majority of the fragments of volcanic rocks present are shown on sectioning to be altered olivine basalts, it is possible that other types were originally present, since there is a tendency to select the hardest lumps for sectioning, and some of the softer volcanic fragments show no trace of the former presence of olivine. All, however, are free from quartz and contain felted plagioclase laths, and the variations in grain size and mineralogy are such as would be expected in the materials of a volcanic field in which olivine basalt was the dominant rock type.

The bauxite in the several deposits examined differ in their texture and stratification. Thus, at "Nahoo", the bauxite is in part finely stratified. It contains few large pieces of basalt and no detrital minerals, but under the microscope minute basaltic fragments are recognizable. The Boolarra deposit, on the other hand, is less distinctly stratified, and contains numerous large lumps of altered basalt, some up to 2 lb. in weight, together with smaller fragments dispersed through a fine earthy base. At Wanke's, Greenwood's and Childers, the stratification is even less well defined. The bauxite has a practically uniform rubbly texture, with some microsopically recognizable fragments of olivine-basalt. The bedding is indicated chiefly by secondary limonite bands, and by clay lenticles or bauxite nodules, but traces of fine stratification are visible in some specimens under the microscope, and it seems likely that the indistinctness of the bedding in the pits is due to haphazard distribution of the cementing materials, which results in the partial obliteration of the original stratification.

It will be seen that these various occurrences are alike in that they all contain dispersed fragments of altered volcanic rocks, chiefly olivine basalt; that they are bedded, either roughly or in fine stratification; and that the Boolarra deposit contains large pieces of altered basalt. These features are all consistent with the idea that the bauxites were derived from volcanic ashes and tuffs, the pyroclastic representatives of the Older Volcanic lavas with which they are associated. An alternative view is that the parental rocks of the bauxites were accumulations of basaltic detritus, washed into relatively low-lying parts of the lava plain by the streams of the period. This view is rejected, firstly, because of the ubiquitous occurrence of iddingsite in the altered oviline basalts of the bauxites, whereas the olivine in the associated lava flows is in general either fresh or altered to serpentine (see discussion below); secondly, basaltic detritus has not been recognized in the overlying Tertiary sediments, which must have been carried by the streams over exposed basalt surfaces; and, thirdly, the basaltic lumps in the bauxite are not waterworn, nor are they aggregated in any way according to size, as in pebble-beds or conglomerates. It is, therefore, preferred to regard the parental rocks as pyroclastic.

The presence of small amounts of detrital minerals such as quartz, acid plagioclase, bleached biotite, and tourmaline in the majority of the bauxites, raises the question of the mode of deposition of the parental ashes and tuffs. At "Nahoo", it can be definitely established that the bauxite rests on a sedimentary clay, very probably of lacustrine origin, and since the bauxite is, itself, very well bedded, it seems clear that it also was laid down under lacustrine conditions. At Boolarra, the bauxite rests directly on an uneven surface of decomposed basalt, but the fact that the top of the bauxite is bedded in apparent conformity with overlying sedimentary clays from which volcanic fragments are absent, indicates that the original deposit was probably water-laid. The large basaltic lumps in this deposit, however, point to the proximity of a centre of eruption.

The detrital minerals occurring in the bauxites may, therefore, have been washed into the deposits concomitantly with the explosive vulcanicity; they may have been carried up from the sub-basaltic sands and clays and ejected together with the volcanic fragmental material; or they may have entered the deposits by way of cracks and crevices, when the overlying sediments were laid down.

At the time of the Older Volcanic activity, South Gippsland was a relatively low-lying area of subdued relief, with lakes and swamps, receiving detritus from neighbouring high land which probably lay to the north. After the extrusion of the basalts, a similar condition must have existed, and one may imagine that the Older Volcanic lava plain would have resembled the younger portions of the Newer Volcanic lava plain of Western Victoria to-day. The pyroclastic materials, under these conditions, could have been laid down in a number of ways. In the higher parts they would be deposited subaerially; in the river beds, lakes, and swamps, they might rest directly on basalt, or on fluviatile, lacustrine or paludal deposits. Ashes redistributed by the streams would also have been deposited in these latter environments, and the admixture of relatively small amount of quartz, felspar, and other detrital minerals with the ashes may thus be accounted for, but the freshness of the detrital felspar grains, in contrast with the completely altered felspars of the volcanic rock-fragments may raise some doubt on this point. However, in view of the fact that all samples of the earthy bauxites, exclusive, of course, of the lumps of basalt, contain detrital minerals, it is extremely unlikely that these minerals could have been introduced into the bauxites after they were deposited. It is, therefore, necessary to assume that the detrital acid plagioclase resisted alteration to gibbsite, while the basic and intermediate plagioclases of the volcanic ejectamenta were completely altered to this mineral. The conclusion has been reached in studies of soil-formation that felspars containing a relatively large amount of SiO_2, such as potash felspar and acid plagioclase, are altered more readily to kaolin than to gibbsite (Hardy and Rodrigues, 1939). Mohr (1909) and Harrison (1910) believe that plagioclase felspars are more readily bauxitized than alkali felspars, and analyses of the bauxitized rocks of the Gold Coast (Cooper, 1936) show that lime and magnesia are more readily parted from silica than are the alkalis.

As regards both silica content and alkali content, acid plagioclase is more closely allied to potash felspar than to basic plagioclase, so that on chemical grounds one would expect it to react like potash felspar in resisting alteration to gibbsite. The fact that the majority of bauxite deposits are derived from lime-rich rocks, especially basic igneous rocks, lends support to this conception.

B.—FORM OF THE DEPOSITS.

The shape of many of the deposits has been clearly revealed by boring. Isopachous lines appear on several of the plans accompanying this Bulletin and in studying them the shape of the cross-sections should not be overlooked. In other words the isopachs should not be mistaken for structure contours. The deposits are all relatively small lenses, many of which have the typically wedge-shaped form of subaqueous deposits built out from the shores of lakes or laid down by slow-moving streams. The possibility is, therefore, not excluded that at some place a large lake or swamp may have existed in which an extensive and uniform sheet of ashes may have been laid down, subsequently to yield a more extensive and uniform deposit of bauxite than has yet been discovered in Gippsland.

Some of the small-scale irregularities in the upper surfaces of the deposits (which can be seen in several of the quarries) might have been caused at the time of deposition by small lateral streams scouring away the tuffs. However, all the irregularities shown on the sections cannot be explained in this way and some erosion after consolidation is also clearly indicated by local disconformities such as those illustrated in the sections in Plates 11 and 15.

More will be learned about the deposits as they are developed; to date we have seen only a very small proportion of their total volume. One important feature which may be revealed is the relationship of the bedding (true or false) to the upper and lower surfaces of the deposits.

C.—PROCESS OF BAUXITIZATION.

(i) Mineralogical Changes.

Although the bauxite was derived largely from the constituents of olivine basalt, it is possible that there were marked variations in the mineralogical constitution of the original volcanic ashes, owing to the separation of the various minerals during the volcanic eruptions and also during deposition in water. In addition to the essential minerals of the crystalline basalt (among which only basic plagioclase, olivine, titanaugite and ilmenite need be considered) it is very likely that there was in the original ashes a considerable amount of glass, which may be considered simply as a source of all the chemical elements entering into the process of bauxite development. Among the crystallized minerals in the basalt, the changes observed are as follows:—

(*a*) *Plagioclase* (originally mainly labradorite-andesine).—Plagioclase occurs entirely as laths, which have been replaced by apparently pure masses of crystalline gibbsite. A similar replacement has been reported by many workers elsewhere (*see*, e.g., Cooper, 1936; van Bemmelen, 1940). In the process of replacement, although the original form of the laths is excellently preserved, the crystals suffer some distortion, developing slight twists and bends, probably connected with adjustments in the rock mass as a result of changes in volume (Plate 5, Figure 1). The change from plagioclase to gibbsite involves the addition of Al and (OH) to the felspar pseudomorphs, so that redistribution of the Al content of the original rock must have occurred.

(*b*) *Olivine.*—The olivine crystals in the fresh basalts associated with the bauxite are generally partially changed to serpentine; olivine altered to iddingsite has been found only in the Boolarra district. In the bauxite, however, the olivines are all altered to iddingsite.

It has been shown (Ross and Shannon, 1925; Edwards, 1938) that the formation of iddingsite occurs under hydrothermal oxidizing conditions in the late magmatic stages of the crystallization of olivine basalts. That iddingsite should form in the bauxite might, therefore, be taken to indicate that similar conditions obtained during the bauxite formation, but it is difficult to concede this in view of the field evidence for the deposition of the original ashes in lakes, swamps and streams. It is more likely that the olivine became altered to iddingsite in the usual way by late magmatic processes, perhaps as a result of some accession of water to the magma chamber. This may also have had the effect of causing a sudden change in the vulcanicity from effusive to explosive eruptions. It is clear that iddingsite was stable under the conditions obtaining during the transformation of plagioclase to gibbsite, since even in the freshest lumps of basalt in the bauxite the felspars are completely altered. In the highest grades of bauxite, however, all traces of iddingsite are absent, and it seems most probable that this mineral was not originally present in those bauxites which do not now contain it. No evidence has been found of the transformation of iddingsite into any other mineral during bauxitization.

(*c*) *Pyroxene.*—The original pyroxene was probably mainly titanaugite, which occurs in various forms in the fresh basalt, ranging from large ophitic crystals to small, regular prisms and irregularly shaped grains. In many of the sections of bauxite examined it is difficult to recognize pseudomorphs after pyroxene, but in some of the altered basaltic lumps prismatic and platy pseudomorphs of gibbsite, with ramifying veinlets of leucoxene that serve to show the general form of the original crystals, appear to be definite pseudomorphs after pyroxene.

(*d*) *Ilmenite.*—The original ilmenite remains in part unchanged in the bauxite, but leucoxene also developed from it. Leucoxene has been shown to consist of $TiO_2.n\ H_2O$ (Coil, 1933), and an analysis by Edwards (1942) of leucoxene from the Boolarra bauxite agrees with this.

(*ii*) Chemical Changes.

Analyses of bauxites and ferruginous bauxites from Boolarra and Callignee have been published by Ferguson (1936 *a, b*), and a large number of commercial analyses of the ores are included in this bulletin. On the basis of these commercial analyses, the average compositions shown in Table II. (1 and 3) have been calculated. All analyses show that the MgO, CaO, K_2O, and Na_2O originally present in the parent rocks have been removed in the process of bauxitization, while in addition, a large part of the SiO_2 and much of the iron have also been leached out.

Unfortunately, there is no means of obtaining the original chemical composition of the parental volcanic ashes, but, since these contained a number of different types of basaltic rocks, it has been assumed for the purposes of the following discussion that their composition approximated to that of the average for older basalts in southern Victoria. This average, based on seven analyses, is given in Table II., Column 5.

The only substance definitely known to be added to the parental rocks during bauxitization is water. The average bauxite analyses have therefore been re-calculated on a water-free basis in Table II. (2 and 4). If from the average basalt all the CaO, MgO and alkalis are removed, together with most of the SiO_2, and iron oxide as shown in Table III. (6), and the remainder re-calculated to 100 per cent., the figures shown in Table III. (8) are obtained. These figures, it will be seen, approximate so closely to those for the average bauxites that it is unnecessary to postulate the operation of any major factor other than leaching to account for the chemical composition of the ores.

It is clear, however, that within the bauxitized rock the aluminium did not remain entirely *in statu quo,* but was re-distributed. This is shown by the replacement of plagioclase felspars by pure gibbsite, which can come about only if Al is added to the felspars, since their original content of this element was insufficient to yield complete gibbsite pseudomorphs: and also the formation of nodules and veinlets of gibbsite and of gibbsite crystals lining cavities indicates that re-distribution of the available Al was of considerable significance. Titanium, too, probably reacted in a similar way, being precipitated as gelatinous titanic acid. Artificial preparations of this compound, on ageing, have been shown to yield anhydrous TiO_2 as minute crystals of rutile or anatase, together with adsorbed water (Weiser, 1935). The mineral leucoxene, which is the only secondary titanium mineral known to occur in the bauxites, is reported to be amorphous hydrous TiO_2 (Coil, 1933; Edwards, 1942), which may be regarded as colloform titanic acid. Other examples of leucoxene, however, have been shown to contain minute crystallites of rutile or anatase as in aged titanic acid. (Tyler and Marsden, 1938).

As has been shown in an interesting way by Goldschmidt (1937) Al and Ti are the typical elements of the group which forms hydrolysates in the processes of weathering and transportation. Elements of low ionic potential $\frac{Ve}{r}$, where $V =$ valence, $e =$ the charge on the electron, and $r =$ the ionic radius, remain in true ionic solution, while those which intermediate ionic potential such as Al and Ti are precipitated by hydrolysis, their ions being associated with hydroxyl radicals derived from aqueous solutions. This principle affects the fate of iron in the process of bauxitization. Ferric iron has an ionic potential that places it with Al and Ti in the hydrolysates; the ionic potential of ferrous iron, however, is sufficiently low to cause it to remain in ionic solution. Thus, under reducing conditions one would expect most of the iron to be removed during bauxite formation, while with oxidizing conditions it would be precipitated as hydrated ferric oxide. With neutral conditions, the original valency state of the iron would affect the relative proportions of the amount removed and that remaining.

Generally speaking, the main bodies of bauxite, as shown in Tables II. and III., retained an amount of iron of the same order of magnitude as the original content of the parental rock in ferric iron, and lost an amount comparable to the original content of ferrous iron. This indicates that the conditions pertaining at the time of bauxite formation were probably almost neutral, i.e., neither oxidizing nor reducing. There are, however, many ferruginous patches in the ore with Fe_2O_3 up to 30-40 per cent. These patches probably resulted from the local incidence of oxidizing conditions during bauxitization, but they may also be due in part to secondary changes involving the selective solution and re-deposition of iron oxides.

Owing to the antiquity of the Gippsland bauxites, all possibility of obtaining direct evidence of the chemistry of the processes of solution and selective leaching in the formation of the ore must be ruled out. It is certain, however, that the bauxite developed in what might be termed an aqueous environment, and that the waters involved were acid, since the removal of Na, K. Mg and Ca as kations is an essential part of the process of bauxitization.

In view of the apparent absence of mineral acids during bauxitization, and considering the wide areas over which bauxite occurs in south Gippsland, it seems most likely that the acidifying agents responsible for the leaching of the parental ashes were substances of general distribution such as CO_2 and humic acids. Harrison (1910) and Cooper (1936) have concluded that CO_2 is chiefly responsible for lixiviation during laterization and bauxitization, but humic acids have been invoked by van Bemmelen (1940) and others.

TABLE II.

—	(1) Average Bauxite. Napier's No. 1.	(2) (1) Recalculated. Water-free.	(3) Average Bauxite. Boolarra.	(4) (3) Recalculated. Water-free.
	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	5.5	7.8	5.0	7.2
H_2O	29.7	..	31.0	..
Al_2O_3	52.1	74.2	53.0	76.8
Fe_2O_3	7.4	10.5	6.5	9.4
TiO_2	5.3	7.5	4.5	6.6
	100.0	100.0	100.0	100.0

TABLE III.

—	(5)* Average Older Basalt Recalculated to 100 per cent.	(6) Presumed Losses from Basalt.	(7) Remainder (in Bauxite).	(8) Remainder Recalculated to 100 per cent.
SiO_2	47.7	45.7	2.0	8.5
Al_2O_3	16.1	..	16.1	68.5
Fe_2O_3	4.4	9.0	3.0	12.8
FeO (as Fe_2O_3) ..	7.6			
MgO	8.3	8.3	..	..
CaO	9.1	9.1	..	..
Na_2O	3.0	3.0	..	..
K_2O	1.4	1.4	..	..
TiO_2	2.4	..	2.4	10.2
	100.0	76.5	23.5	100.0

* Average of seven analyses quoted by Edwards (1939).

D.—CONDITIONS AND DATE OF BAUXITIZATION.

The authors of this bulletin have not been able to reach complete agreement on interpretation of the conditions under which the bauxite deposits were formed and on the time involved in their formation. It is agreed that the parental rocks were bauxitized under conditions of high rainfall and (probably) hot climate, and that a land surface of low relief existed, but while two of us (H.G.R. and H.B.O.) regard the available evidence as consistent with the view that the bauxites are all on one horizon and are lateritic in origin, one of us (E.S.H.) stresses the evidence against this interpretation, and indicates other possibilities that, in his view, cannot be excluded. It is admitted that the available data do not yet permit a final solution of the problem.

(1) **Hypothesis of Lateritization.** (By H.G.R. and H.B.O.)

It is considered that the South Gippsland bauxite deposits are all on the one horizon and that they are essentially lateritic in origin. Nevertheless it is freely admitted that there are features of the deposits which are difficult to explain on this (or any other) hypothesis. The feature most difficult to explain is the apparently selective action of the process of bauxite formation.

The formation of bauxite under lateritizing conditions requires favorable rock types lying within the zone of rise and fall of the groundwater table. (Alternating wet and dry seasons such as are experienced in monsoonal climates provide the ideal conditions.) Typical laterites are relatively thin sheets of considerable horizontal extent. Also gradation downwards from laterite to parent rock can usually be demonstrated.

One of us (H.G.R.) has studied, in considerable detail, most of the bauxite deposits of eastern New South Wales. All these deposits were derived from Tertiary Volcanic rocks, chiefly basalts and it is clear that they are laterites. Where the basalt flows were thick, a gradation downwards from lateritic bauxite to basalt can be observed, and where the flows were thin the underlying bedrock types are lateritized. Also where the topographic profile was suitable the adjacent bed-rock types are lateritized. Thus in New England, the granite sides of basalt-filled leads are lateritized and in the Wingello district both Hawkesbury sandstone and Tertiary sediments beneath the basalt are lateritized.

When we compare these profiles with the typical profiles in south Gippsland, the feature most difficult to explain is the selective bauxitization of tuffs resting (in most places) on a rock (basalt) which the evidence in eastern New South Wales shows is readily amenable to the lateritizing process.

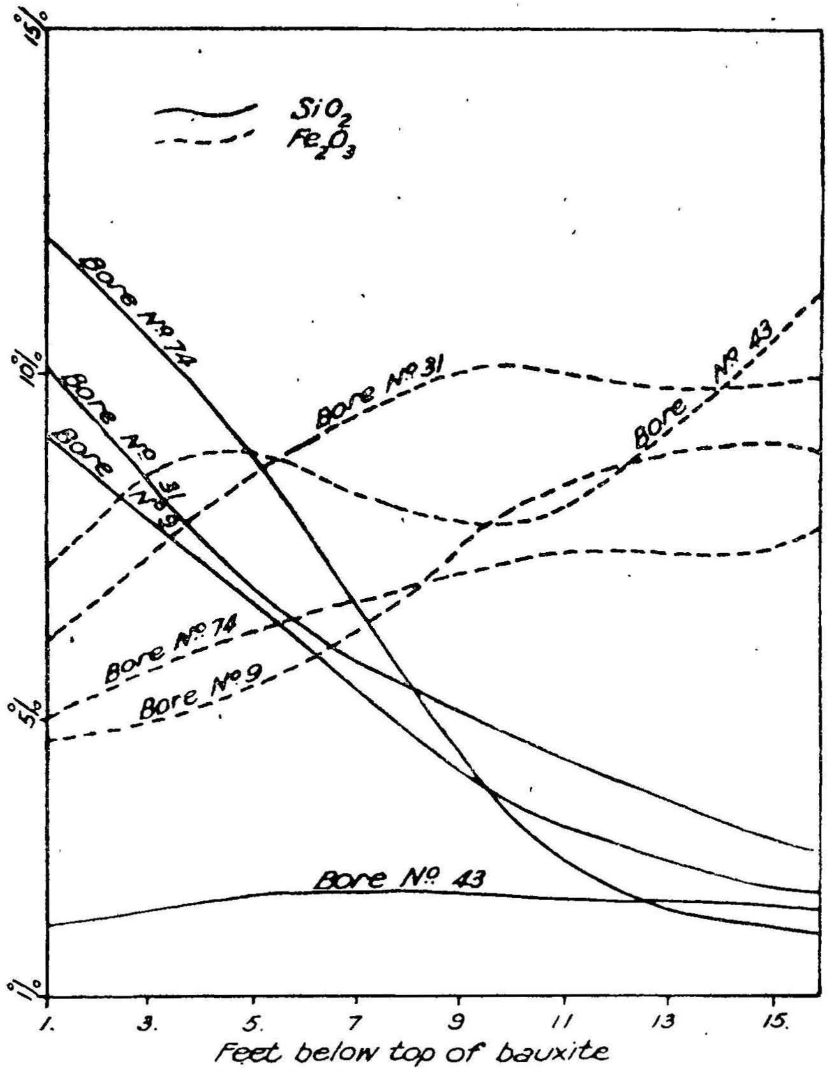
Most of the Gippsland bauxites rest upon a clayey surface of decomposed basalt which it is considered is the result of normal sub-aerial weathering, before the tuffs parental to the bauxite were laid down. In some places, e.g., at Nahoo and Paynes, the bauxites rest upon clayey sediments. It is possible, therefore, that the conditions at the time of formation were that lenses of highly permeable tuff (breccia, agglomerate) were resting upon relatively impermeable clays with the result that lateritization proceeded in a series of isolated aquifers rather than in a zone within a more or less continuous water table. F. L. Stillwell

(1943), who has studied specimens collected during our investigation, has independently put forward a somewhat similar view. If this is a reasonable explanation, the absence of the normal vertical succession of rock types in a lateritized profile need occasion no surprise; indeed the lower grade sections of a deposit such as Napiers may represent part of a lens which was less pervious than the rest or which came within the zone of rise and fall of the water table to a less extent, or less often, than the rest of the deposit. Some support can be obtained for this hypothesis from the fact that in several of the New South Wales deposits the base of the bauxite is irregular, indicating that physical differences in the parent rock have had some effect on the shape of the lateritized zone.

It is realized that this hypothesis requires a time interval between the outpouring of the basalt and the formation of the tuff, &c., parental to the bauxite, of sufficient length to permit the weathering of the basalt. It is clear that there was a lapse of time between these two episodes during which sediments were deposited in hollows in the basalt surface, e.g., at Napier's No. 1, Payne's and Nahoo. On our interpretation of the evidence at Nahoo probably 50 feet of sediments were laid down during that time. At present we know very little about the bauxite-basalt contact because so far nearly all natural exposures and all the quarries reveal only a limited part of this contact and, moreover, nearly everywhere the part revealed is at the edges and not the thickest portions of the bauxite deposits. As future mining operations expose more of the contact it is probable that clayey or siliceous sediments will be found to be common between the basalt and the bauxite.

A relatively high silica zone has been noted at the top of some of the deposits. For a time it was thought this was due to contamination of the samples by sand or clay from the overlying beds, but it now seems that although some contamination did occur, most of the silica is inherent in the bauxite. This is a feature common to bauxite deposits in many parts of the world and is believed to be due to concentration at the surface by evaporation of silica-bearing solutions. The concentration of silica near the surface of the bauxite is shown graphically in Text Figure 2 in which the silica content of high-grade bauxite from four bores at Napier's No. 1 is plotted against depth below the upper surface of the ore. The curves show that, with one exception, there is a steady decline in silica content to a depth of about 10 feet into the bauxite.

Total iron (expressed as Fe_2O_3) shows an increase with depth, but is less regular in its occurrence than silica. The state of valency of the iron was not determined by the anaylst, but it is believed that much of the iron existing near the base of the bauxite is in the ferrous condition, and has undergone reduction from the higher valency through the action of organic matter and probably bacteria. While the present distribution of silica is considered to be an original feature of the bauxite, the downward migration of iron is considered to result from secondary changes in the bauxite brought about by leaching during the present day.



Text Figure 2.—Graph showing changes in content of silica and iron in bauxite at Napier's No. 1 deposit, Mirboo North.

We have briefly referred (page 55) to the views expressed by other workers that carbonated ground water, with, perhaps, humic acid, is the main chemical reagent in bauxite formation. It is necessary to stress here that until the boring was done, not one deposit of bauxite was known to have lignite above it and it is apparent from the sections accompanying this bulletin that acids derived from overlying lignite cannot have played a very important part in the formation of bauxite. There is the further point that much of the lignite is enclosed or underlain by impervious clays.

There is little doubt, however, that humic acid was available at the time of formation of the bauxite. This could have been derived from lignite deposits beneath the bauxite or from contemporaneous swamps.

The part this humic acid may have played in the chemical change from tuffs to bauxite cannot be gauged.

Dr. W. G. Woolnough has recently brought to notice and supplied a translation of part of a paper by A. V. Volkov (1933) on bauxite deposits in the Tikhvin district of the Union of Soviet Socialist Republics which are somewhat like those of South Gippsland. "Lenticular beds of bauxite occur at points where the Upper Devonian bedrock consists of fine felspathic clays, apparently occupying second order depressions in a peneplain surface" and are disconformably overlain by Lower Carboniferous freshwater sediments. These deposits have apparently been studied by several workers whose conclusions are discussed in some detail by Volkov. Volkov tentatively considers that the deposits are essentially laterites in origin.

It has been pointed out on page 19 of this bulletin that opinions on the geological period during which the bauxite was formed will vary accordingly to the length of time accorded to the bauxite-forming interval. This arises because, to date, our most reliable criterion of age is the determination of foraminifera in the beds overlying the bauxite and in their marine equivalents east of the Mirboo-Boolarra area. There is little doubt that the bauxite was formed during the Miocene; probably early in that period.

If the hypothesis put forward here that the Gippsland bauxites are laterites is correct, the conclusions reached would support the thesis put forward by W. G. Woolnough (1927) that lateritizing conditions were widespread (virtually ubiquitous) in Australia in Miocene time.

(2) Alternative Hypotheses. (By E.S.H.)

Although the stratigraphy of the Cainozoic deposits of Gippsland is not yet known in sufficient detail to permit precise conclusions as to the date and duration of the bauxitization to be drawn, it can be said that the major events in the geological history of the district were as follows:—

A land surface of low relief—locally of the nature of a peneplain —was formed in Oligocene or Lower Miocene times. Warping (and probably block faulting) of this surface then occurred, accompanied by sedimentation. Marine conditions developed in East Gippsland, passing to paralic, paludal, lacustrine and fluviatile conditions in South Gippsland and the Great Valley.

During this episode, the brown coal deposits were laid down and the Older Volcanic eruptions occurred. In places, brown coals and lignitic clays underlie the Older Basalts, but elsewhere the relations are the reverse, and it is legitimate in our present state of knowledge to regard the basalts as having been extruded during the period in which the earlier brown coals were laid down in various places (*see* Hills, 1938; Edwards, 1938). At this time, the bauxitization of the associated volcanic ashes also took place. According to Singleton (1941), the Yallournian brown coals are of Oligocene age, but in a recent work by Miss Crespin (1944) they are regarded as ranging from Lower Middle Miocene to Lower Pliocene.

The evidence for luxuriant vegetation afforded by the thick lignite deposits indicates abundant rainfall, but until detailed palaeontological examination of the flora has been made, no definite statement as to the climate can be made. Nevertheless the probabilities are that the conditions were warm to hot. It is, therefore, a natural assumption that the bauxites are essentially lateritic in origin, by analogy with those formed in Africa, India and Malaya under tropical conditions of weathering. This conception is, however, difficult to reconcile with the following data:—

(*a*) The bauxites are derived, so far as is known, only from volcanic ashes, not from the Older Basaltic lavas themselves, which chemically are quite as amenable to bauxitization as the ashes. Similar basalts have been altered to bauxite and laterite in other regions. Very probably the open and porous texture of the ashes, which would permit ready circulation of waters, was a critical factor, but the uniform alteration of the sub-bauxitic basalts to clay rather than to bauxite is nevertheless difficult to explain. As pointed out above (by H.G.R. and H.B.O.) it may be that the basalts were deeply weathered before the tuffs parental to the bauxites were laid down, but this would necessitate a period of widespread explosive vulcanicity, long after the basalts themselves were extruded, and not represented, so far as is known, by lava flows. Furthermore as buried vegetation, weathered residual boulders, or the like have NOT been noted at the base of the bauxite, to the present writer, the *a priori* grounds for separating the flows from the tuffs by a long time-gap do not, therefore, appear to be strong.

(*b*) At each locality, the whole thickness of the layer of volcanic ashes was bauxitized; there is, in general, no vertical succession of "soil" horizons such as is found in connexion with bauxites formed under conditions of lateritization, unless the sub-bauxite clays are to be regarded as part of a very deep soil. Unfortunately, insufficient is known of the mineralogy of these clays to indicate whether or not they might be related to the bauxites, e.g., by containing a relatively greater proportion of clay mineral to gibbsite than obtains in the commercial bauxites.

(*c*) Many of the textural features of the bauxites appear to be inconsistent with a lateritic origin. In particular, the development of large gibbsite crystals in vugh-like cavities (Plate 6, Figure 2), indicates that the precipitation of this mineral took place in a highly porous medium that was completely saturated with the solutions from which the crystals were deposited and, in view of the large size of the crystals, that these solutions were strongly concentrated. It is suggested that such textural features as the above, and also the crystalline gibbsite veinlets in the "Nahoo" deposit (Plate 7, Figure 1), point to more intense chemical activity than would occur in pedogenic processes.

(*d*) The bauxites, so far as is known, occur only in South Gippsland; they have not been recognized in other Older Volcanic fields in Victoria.

In view of the close association of the basalts and bauxites with the Yallournian lignites, it is suggested that waters containing relatively high concentration of humic acids, and perhaps also bacteria, were chiefly concerned in the formation of the bauxites. The process may have gone on in the lake and swamp beds of the period, being thus analogous with the formation of kaolin deposits under similar conditions in more temperate climates. It may also, however, have been carried out, in part at least, by ground waters deriving organic acids from the lignites, after a cover of sediments had been laid down on the bauxites. The presence of 17–18 per cent. of free alumina in the base of the Older Basalt at "Nahoo", where this rock has been altered to ochreous clay, lends support to such a conception of sub-surface bauxitization.

It is also suggested that the absence of concretionary re-deposited iron oxides from the bauxite lenses is explicable on one or other of the above hypotheses since they involve the possibility of lateral migration of considerable volumes of water, which is not so readily mineralized under lateritizing conditions on a land surface of low relief.

The hypotheses suggested are also consistent with the evidence for continuous deposition of sediments in South Gippsland during the period in which the bauxites were presumably formed. The post-Volcanic Tertiaries of the official maps are represented by fluviatile, lacustrine and paludal deposits, including brown coals, with local marine intercalations as shown by Miss Crespin (1943) extending at least as far as Budgeree.

Although it appears probable that local scouring of the tuffs parental to the bauxites went on before the overlying sediments were deposited, in general, the formations are conformable in their stratification, and in the view of the writer, there is no incontrovertible evidence for any prolonged cessation of deposition in South Gippsland after the Older Basalts were extruded; nor would such be expected to result merely through the intervention of a period of volcanic activity, which certainly would not have cut off the supply of detritus from the neighbouring high land. The only direct evidence indicative of a marked time-break is afforded by the duration assigned to the period of bauxite formation, which may not have been long, and which as suggested above may have continued after a cover of sediments had been laid down on the volcanic ashes. On this view, therefore, the bauxites do not necessarily represent one geological horizon only.

At a later date, generally assigned to the Pliocene, strong block faulting and monoclinal warping, accompanied by minor faulting, affected the Jurassic and Tertiary rocks of South Gippsland (Hills, 1935). As a result, the bauxite deposits have been much disturbed by both large and small scale movements, which makes the interpretation of local geological details a matter of some difficulty, especially in view of the usual lack of good exposures, and the prevalence of landslips.

XII.—SECONDARY CHANGES IN BAUXITE.

Evidence for secondary changes in the bauxite is afforded by the concentration of limonite in the vicinity of outcrops, indicating a tendency for the iron to be leached from the ore in the present erosion-cycle, resulting in secondary enrichment. Similar leaching and enrichment have been noted by Cooper (1936) in the bauxites of the Gold Coast. There is, however, no indication that any of the various forms of crystalline gibbsite, colloform amorphous bauxite, or gibbsite nodules, are other than primary. Some introduction of alumina into adjacent rocks might be expected if secondary redistribution of Al had been important, but no such impregnation is found.

The presence of secondary pyrites in the bauxite at Napier's and, very rarely, at Boolarra, indicates the former presence of sulphur-bearing anions, and free $Al_2(SO_4)_3$ occurs in the Boolarra bauxites.

Tests for the presence of this compound were made at the suggestion of R. G. Thomas, and it was found to be present in two bauxite samples, and also in the overlying and underlying clays. High quality bauxite at the top of the deposit contains 0.030 per cent., while fine-grained earthy bauxite below this contains only 0.002 per cent. The sub-bauxitic clay tested contains 0.005 per cent., and the overlying clay 0.025 per cent. This water-soluble $Al_2(SO_4)_3$ contains no iron and only a trace of titanium.

Owing to the improbability that such free $Al_2(SO_4)_3$ would have been retained in the bauxite since the time of its formation, it is believed that it has resulted from the leaching of the ore by acid waters derived from the oxidation of the small amounts of pyrites present. This pyrites is of encrusting habit and is clearly secondary. It may be compared with the secondary pyrites that occurs in deep leads, and there is no suggestion that it has any relation to the primary bauxitization.

The formation of pyrites and siderite in certain of the bauxites at Boolarra and also at Napier's is a secondary effect of little economic significance.

XIII.—BENEFICIATION TESTS.

Some rough beneficiation tests have been carried out by Sulphates Pty. Limited, on ore from five of the deposits with the results given in the table hereunder. In these tests the bauxite was crushed to $\frac{1}{4}$-in. mesh. Fines were removed by agitation in water, suspended material being decanted and the operation repeated till clear washings were obtained.

Deposit.	Per cent.	SiO_2	Loss on Ignition.	Al_2O_3	Fe_2O_3	TiO_2
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
(1) (*a*) Boolarra Open Cut—						
Crude Ore ..	100	6.5	28.0	53.6	6.9	5.0
Fines	30	13.0	23.1	45.3	9.7	9.0
Coarse	70	3.6	30.0	57.1	5.6	3.2
(*b*) Boolarra Open Cut—						
Crude Ore ..	100	8 75	28.5	51.35	4.9	6.5
Fines	32	13.65	25.8	47.5	5.56	7.5
Coarse	68	4 8	30.5	56.92	3.63	4.25
(2) (*a*) Napier's Northern Quarry—						
Crude Ore ..	100	6.15	29.0	54.7	5.4	4.75
Fines	20	13.1	23.0	43.1	12.1	8.7
Coarse	80	4.4	30.5	57.6	3.7	3.75
(*b*) Napier's Centre Quarry—						
Crude Ore ..	100	8.8	30.0	54.2	2.3	4.7
Fines	20	20.4	24.0	44.6	2.3	8.7
Coarse	80	5.9	31.5	56.6	2.3	3.7
(*c*) Napier's Centre Quarry—						
Crude Ore ..	100	10.0	28.4	54.66	2.16	4.46
Fines	30	27.5	27.0	42.0	..	2.7
Coarse	70	2.5	29.0	60.1	3.2	5.2

Deposits.	Per cent.	SiO_2	Loss on Ignition.	Al_2O_3	Fe_2O_3	TiO_2
(3) Watkin's Deposit—		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Crude Ore ..	100	8.15	28.3	55.9	3.2	4.75
Fines	38	13.9	24.9	50.4	4.3	6.5
Coarse	62	5.25	29.9	58.1	2.5	4.25
(4) Nahoo Quarry—						
Crude Ore ..	100	13.0	26.9	52.23	3.12	4.75
Fines	37	13.3	25.7	50.1	4.4	6.5
Coarse	63	12.85	27.2	52.7	3.0	4.25
(5) Napier's No. 2—						
Crude Ore ..	100	10.0	26.8	50.8	7.6	4.75
Fines	32	13.2	24.3	44.4	11.5	6.0
Coarse	68	8.5	28.0	53.8	5.8	4.25

The results obtained indicate that, with the exception of the ore from Nahoo, the grade of the bauxite may be greatly improved by the simple method adopted in these tests, but it will be noted that there are also considerable losses entailed. At the present time it is not possible to make much further useful comment on these results. Refinement in procedure might result in greater percentage recovery of the high grade product; on the other hand it might be found that chemical industry could absorb such quantities of the lower grade product as might be produced by the simple method used in the tests, having regard to the tonnage of high grade ore required for the manufacture of aluminium.

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XV.—DESCRIPTION OF PHOTOGRAPHIC PLATES.

Plate 1—

X-ray diffraction patterns optically amorphous (gibbsite) nodules (Fig. 1) of gibbsite crystals (Fig. 2) and bauxite (coarse) from tuffaceous bauxite, Boolarra (Fig. 3). Note the absolute correspondence of the lines and intensities in Fig. 1 and Fig. 2, showing the gibbsitic nature of the amorphous concretionary nodules; also the gibbsite lines, which mask all other constituents, in the bauxite (coarse).

Plate 2—

Fig. 1.—Bauxite and overburden exposed in quarry face, Greenwood's deposit, Budgeree. The figure is standing on the top of the bauxite. (W.S. Curteis, Photo.)

Fig. 2.—Quarry at Wanke's deposit showing outcropping bauxite in background. The strike of the bauxite is approximately from the boulders in the left foreground to the tree, and the dip to the right can be seen at the rear of the quarry. Scale is provided by the nearest fence post, which is about four feet high. (W.S. Curteis, Photo.)

Plate 3—

Fig. 1.—Bauxite overlying limonitic basaltic clay with onion structure. Boolarra. Scale is provided by the geological hammer in the foreground. (E.S.H. Photo.)

Fig. 2.—Bedded bauxite with fragments of altered basalt. "Nahoo" Scale is provided by the pocket knife, bottom right corner. (E.S.H. Photo.)

Plate 4—

Fig. 1.—Altered olivine basalt fragment from bauxite. Boolarra. Note plagioclase laths altered to gibbsite, iddingsite after olivine (O), and interstitial ilmenite and leucoxene. X21

Fig 2.—Altered basalt fragment from bauxite, Boolarra. Altered olivine phenocrysts are absent. X21

Plate 5—

Fig. 1.—Altered basaltic fragment in agglomeratic bauxite, Boolarra. Note pseudomorphs after plagioclase laths. X13

Fig 2.—Gibbsite crystal in high quality bauxite. Boolarra. X214

Plate 6—

Fig. 1.—Banded colloform bauxite (C) and crystalline gibbsite masses (G) in ferruginous bauxite, Childers. X21

Fig. 2.—Prismatic gibbsite crystals lining cavities in ferruginous bauxite. Childers. X68

Plate 7—

Fig 1.—Veinlet of crystalline gibbsite in bauxite. "Nahoo" affording evidence of bauxitization *in situ* X215

Fig 2.—Altered olivine basalt in bauxite Wanke's, Mirboo North. Note deformation of plagioclase pseudomorphs (now gibbsite). X21

PLATE 1.

Pure Amorphous Bauxite.

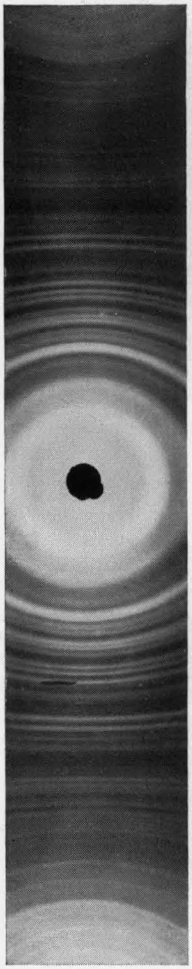


Fig. 1 .

Gibbsite Crystals.

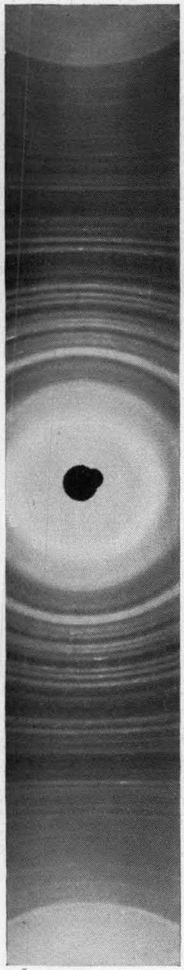


Fig. 2.

Bauxite (Coarse).

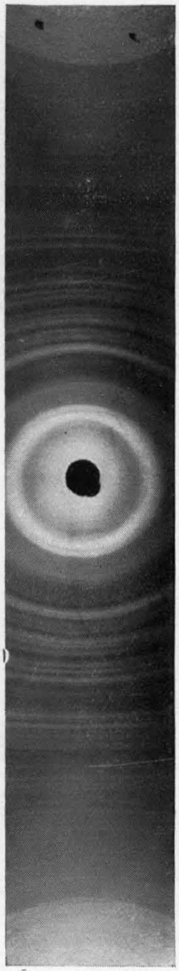


Fig. 3.

PLATE 2.

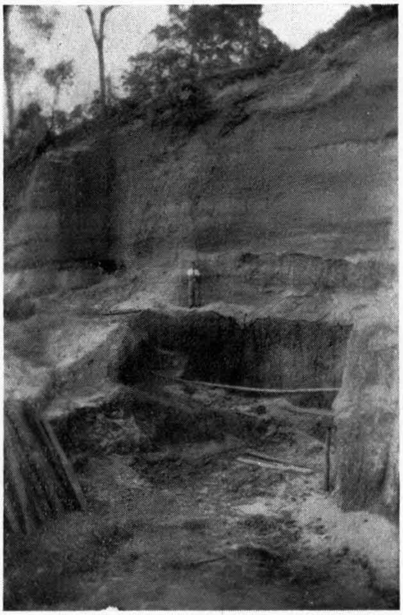


Fig 1.

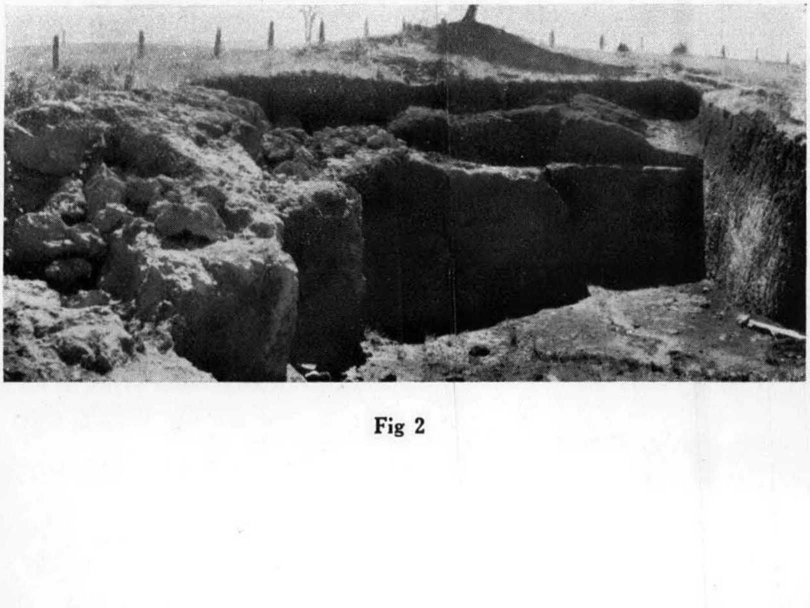


Fig 2

PLATE 3.

Fig. 1.

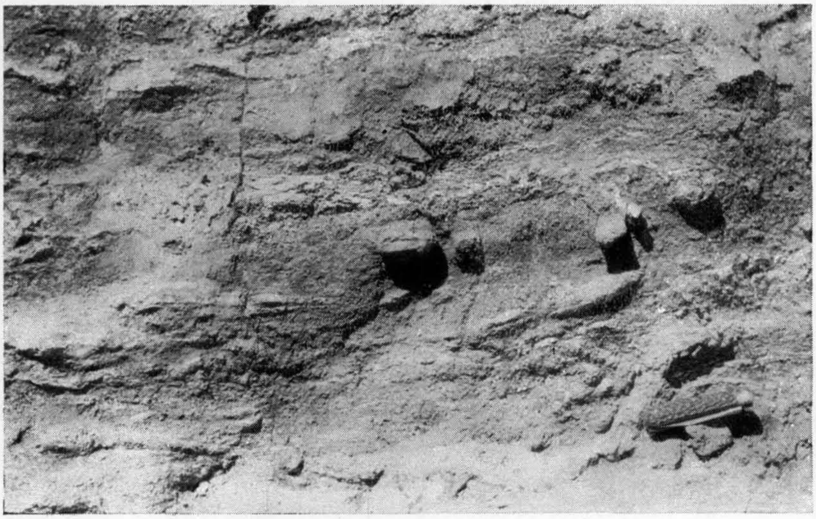


Fig. 2.

PLATE 4.

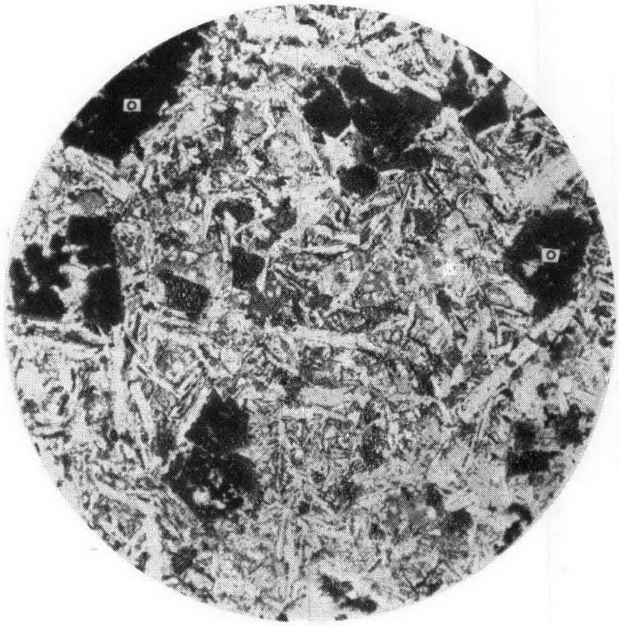


Fig. 1.

Fig. 2.

PLATE 5.

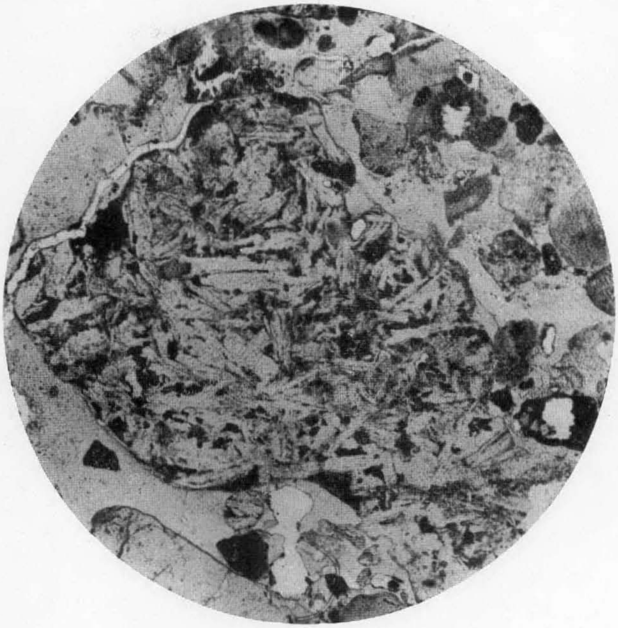


Fig. 1.

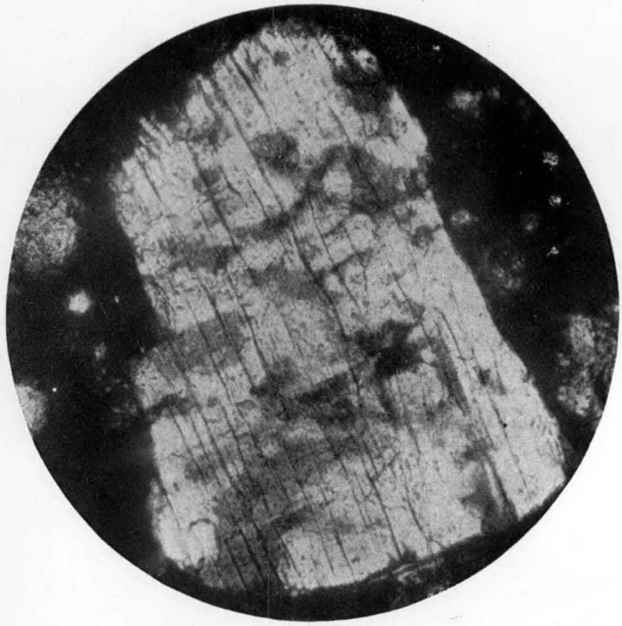


Fig. 2.

PLATE 6.

Fig 1.

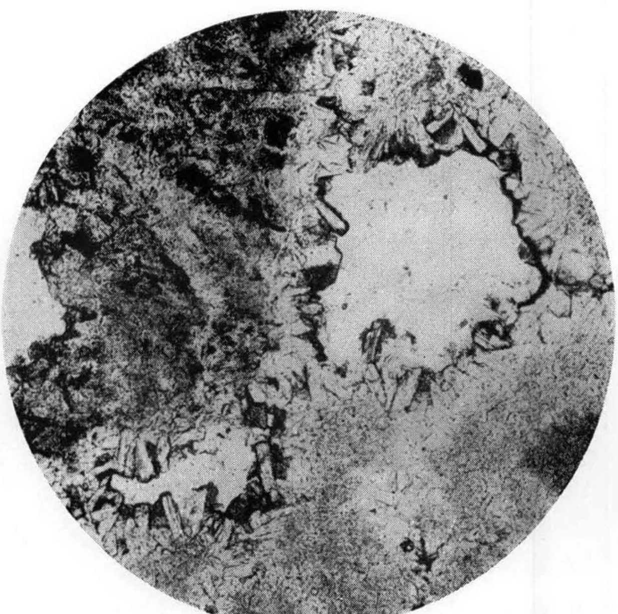


Fig 2.

PLATE 7.

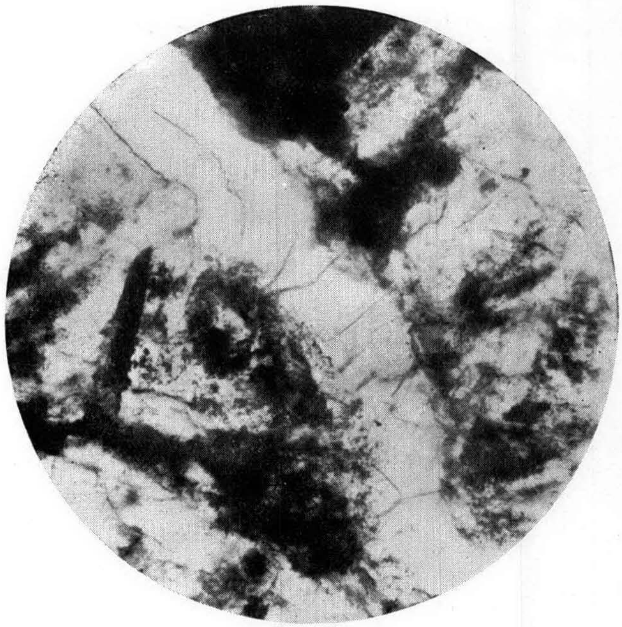
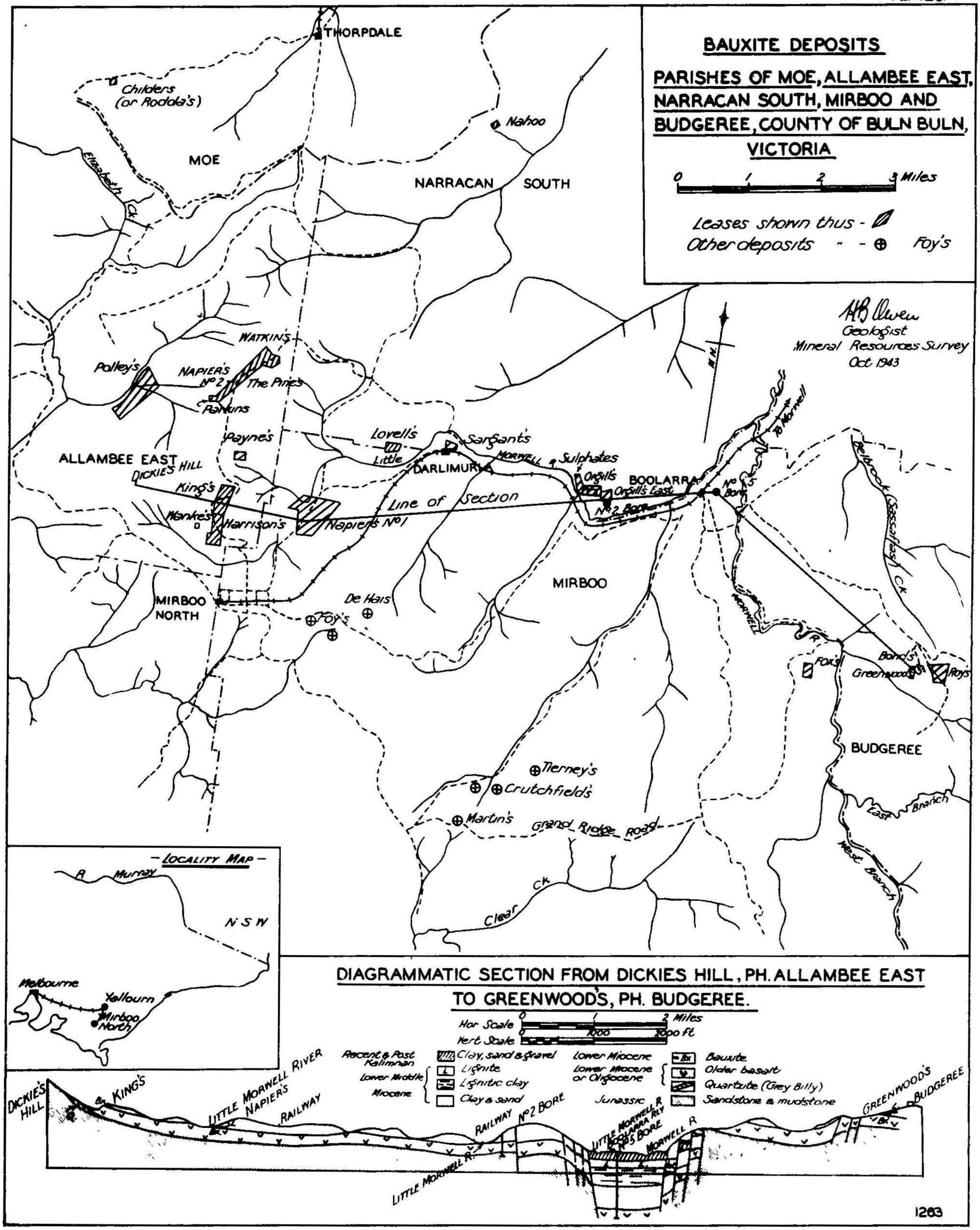
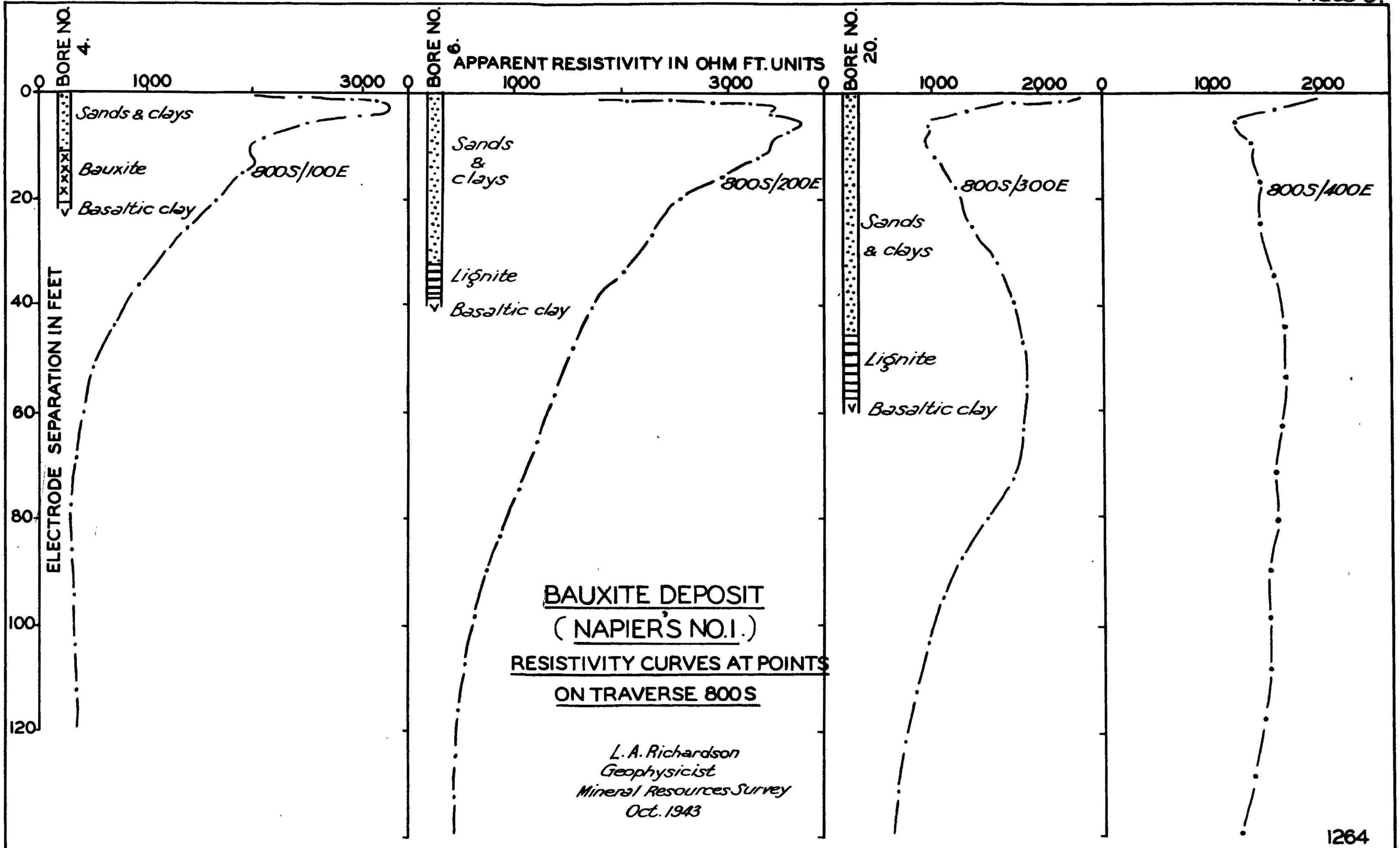


Fig. 1.

Fig. 2.


BAUXITE DEPOSITS
PARISHES OF MOE, ALLAMBEE EAST, NARRACAN SOUTH, MIRBOO AND BUDGEREE, COUNTY OF BULN BULN, VICTORIA
0 1 2 3 Miles
Leases shown thus -
Other deposits - - ⊕ Foy's
H.B. Owen
Geologist
Mineral Resources Survey
Oct 1943
THORPDALE
Childers (or Rodda's)
Nahoo
MOE
NARRACAN SOUTH
Elizabeth Ck
WATKIN'S
Polley's
NAPIER'S No 2
The Pines
Parkins
Payne's
Lovell's
Little
Sargant's
DARLIMURLA
MORWELL
Sulphates
Orgill's
BOOLARRA
Orgill's East
No 2 Bore
No 5 Bore
To Morwell
ALLAMBEE EAST
DICKIES HILL
King's
Wanke's
Harrison's
Napier's No 1
Line of Section
MIRBOO NORTH
De Hais
Foy's
MIRBOO
MORWELL R
Sassafras Ck
Fox's
Bond's
Greenwood's
Foy's
BUDGEREE
Tierney's
Crutchfield's
Martin's
Grand Ridge Road
East Branch
West Branch
Clear Ck
LOCALITY MAP
R Murray
N S W
Melbourne
Yallourn
Mirboo North
DIAGRAMMATIC SECTION FROM DICKIES HILL, PH. ALLAMBEE EAST TO GREENWOOD'S, PH. BUDGEREE.
Hor Scale 0 1 2 Miles
Vert Scale 1000 2000 ft
Recent & Post Kalimnan — Clay, sand & gravel
Lower Middle Miocene — Lignite; Lignitic clay; Clay & sand
Lower Miocene — Bauxite
Lower Miocene or Oligocene — Older basalt; Quartzite (Grey Billy)
Jurassic — Sandstone & mudstone
DICKIE'S HILL
KING'S
LITTLE MORWELL RIVER
NAPIER'S
RAILWAY
No 2 BORE
LITTLE MORWELL R
BOOLARRA RLY
No 5 BORE
MORWELL R
GREENWOOD'S
BUDGEREE
LITTLE MORWELL R.
1283



BAUXITE DEPOSIT

(NAPIER'S NO.1.)

RESISTIVITY CURVES AT POINTS ON TRAVERSE 800S

L. A. Richardson
Geophysicist
Mineral Resources Survey
Oct. 1943

1264


PLATE II.
TRANSVERSE SECTIONS
BAUXITE DEPOSIT. (NAPIER'S NO. 1.)
SCALE HOR. & VERT. 1 INCH = 50 FT.
REFERENCE
SAND CLAY ETC.
LIGNITE & LIGNEOUS CLAY
BAUXITE OVER 50% Al_2O_3
" UNDER " "
DECOMPOSED BASALT
AREA OF BAUXITE USED IN QUANTITY CALCULATIONS SHOWN IN FULL LINES.
FIGURES INDICATE THICKNESS & COMPOSITION OF BAUXITE THUS:-
16' = Thickness of bauxite
51·0 = Percentage of Al_2O_3
8·2 = " " SiO_2
(Note:- No SiO_2 figures are shown where Al_2O_3 does not exceed 50%.)
NOTE:- NO BAUXITE BETWEEN 400 N & 1000 N
1300 N
QUARRY
1200 N
1100 N
1000 N
400 N
300 N
200 N
100 N
00
100 S
200 S
300 S
400 S
500 S
600 S
700 S
SHAFT NO. 8
800 S
Trace
Hand Bores
Lignite
3' Quality unknown.
H. B. Owen
Geologist.
Mineral Resources Survey.
Oct. 1943.
1266

PLATE II.

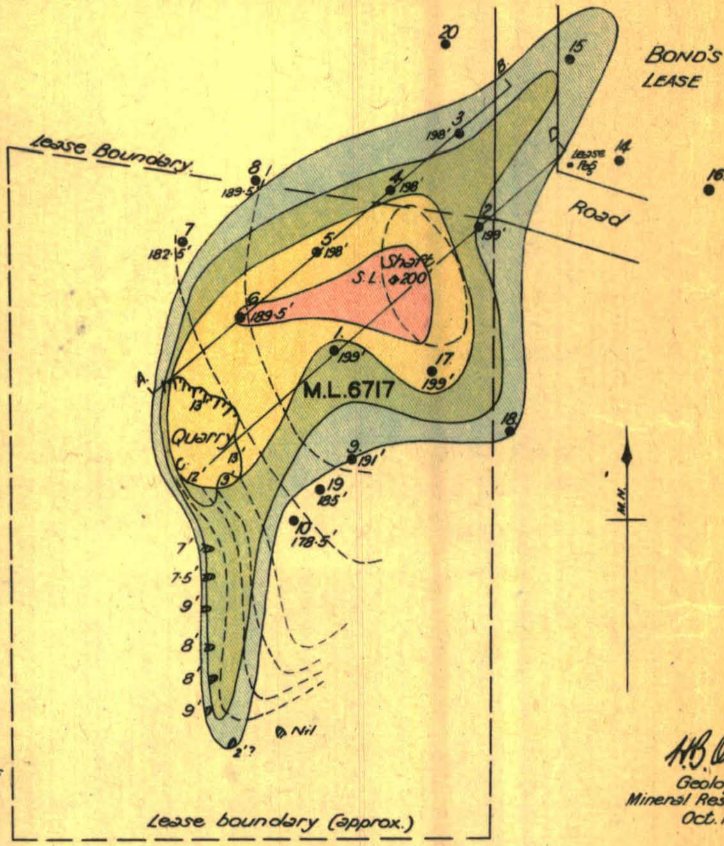
1266

PLAN
BAUXITE DEPOSIT
(GREENWOOD'S)

Allot. 16. Ph. of Budgeree, Vic.
Showing lines of equal ore thickness, bores, etc.

0 100 200 300 ft.

Bore No.	Thickness of Overburden	Thickness of Bauxite
1.	65	8
2.	98	4?
3.	95	Tr.
4.	67	8
5.	55	11
6.	41	15
7.	43	Nil
8.	49	Nil
9.	86	Nil
10.	80	Nil
14.	124	Nil
15.	122	3
16.	131	Nil
17.	85	13
18.	104	1
19.	82	Nil
20.	97	Nil
Shaft	75	20



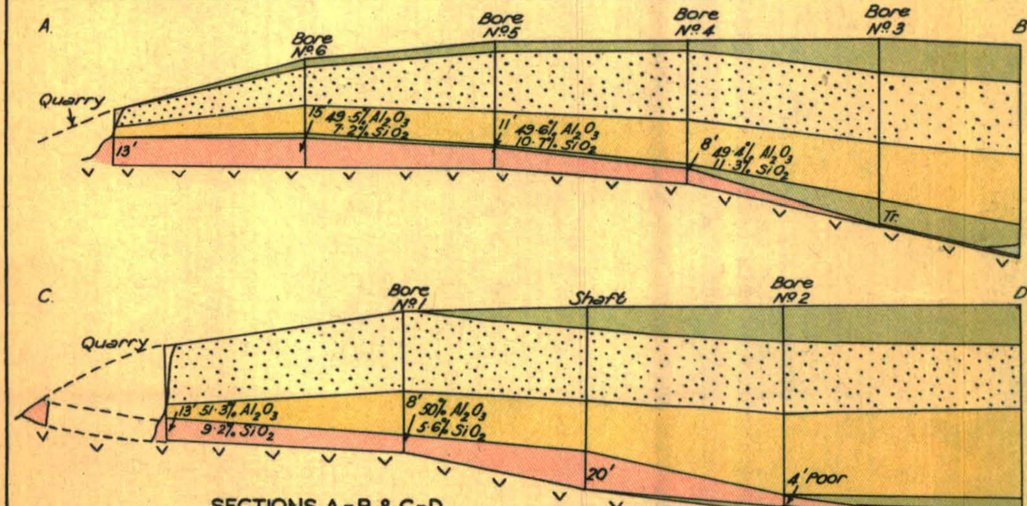
Reference

Thickness of Bauxite
- > 15'
- 10' - 15'
- 5' - 10'
- Trace - 5'

8' Costeans. Where 8' = thickness of Bauxite

Spot levels & contours above assumed zero datum approx. 800 ft. above Sea Level.

H. B. Owen.
Geologist
Mineral Resources Survey.
Oct. 1943.



SECTIONS A-B & C-D

0 50 100 150 ft.

Note:- Scale of Sections is twice scale of Plan.

Reference
- Clay
- Sandy clay
- Sand
- Bauxite
- Basalt
- Lignite

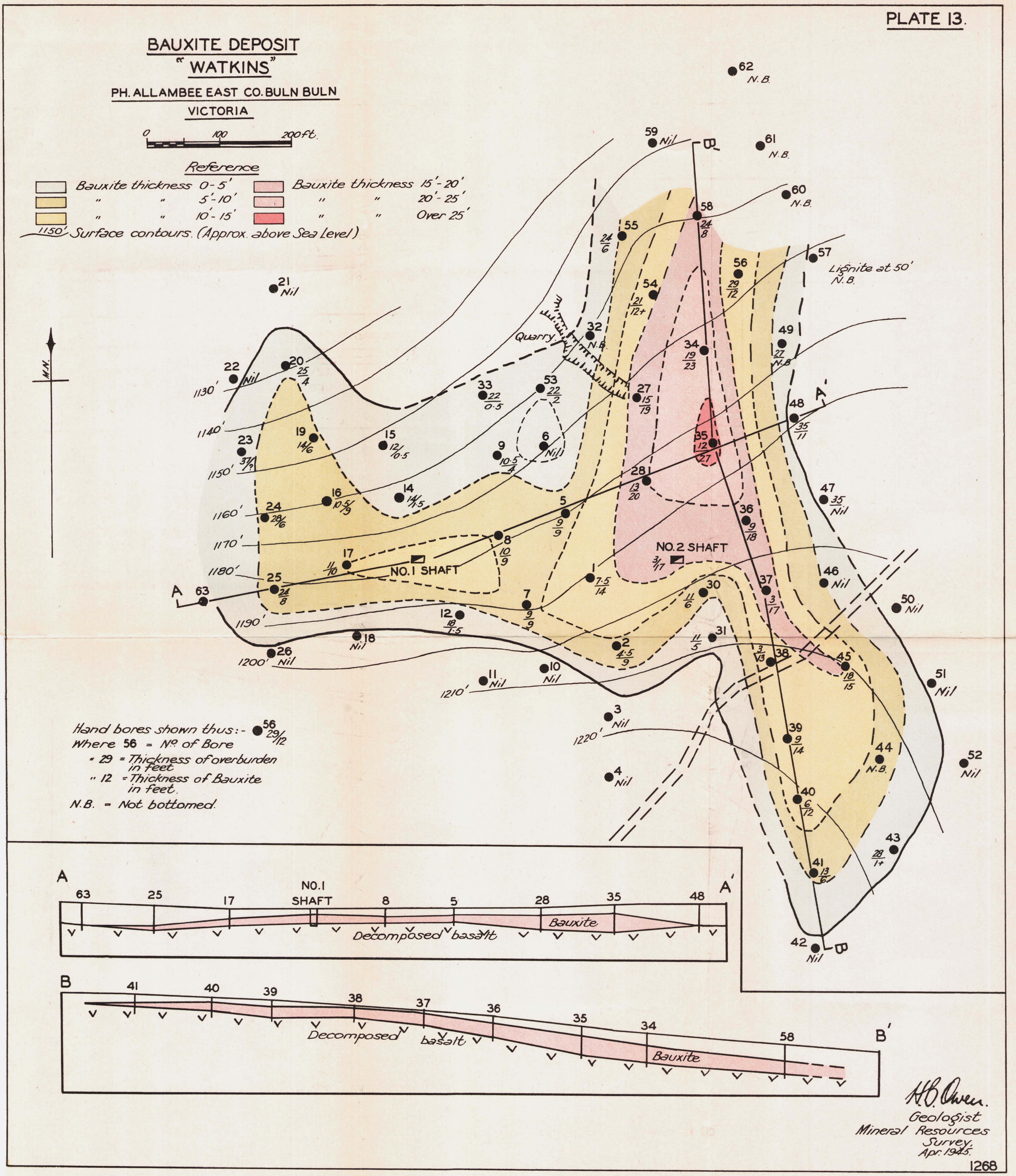
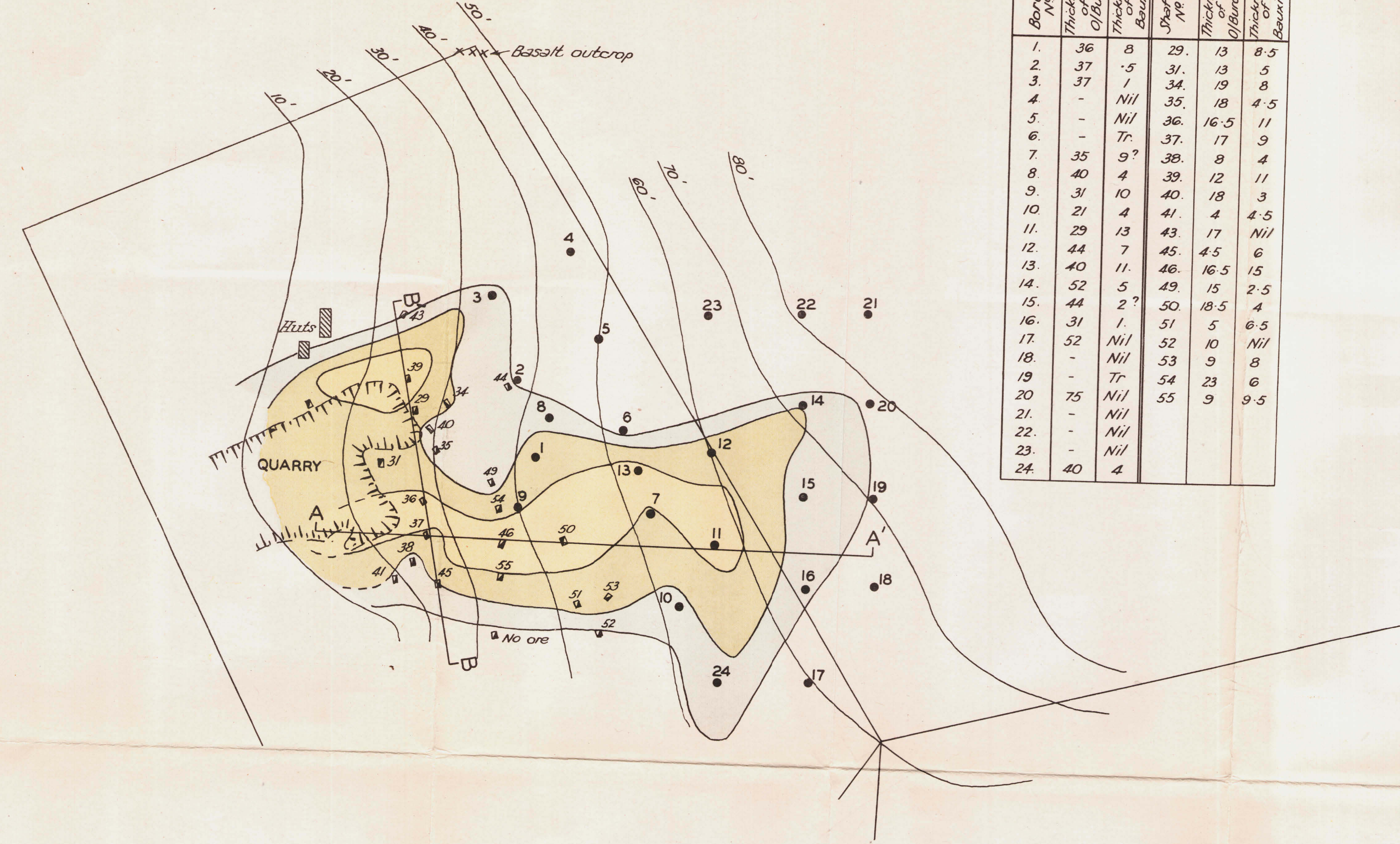


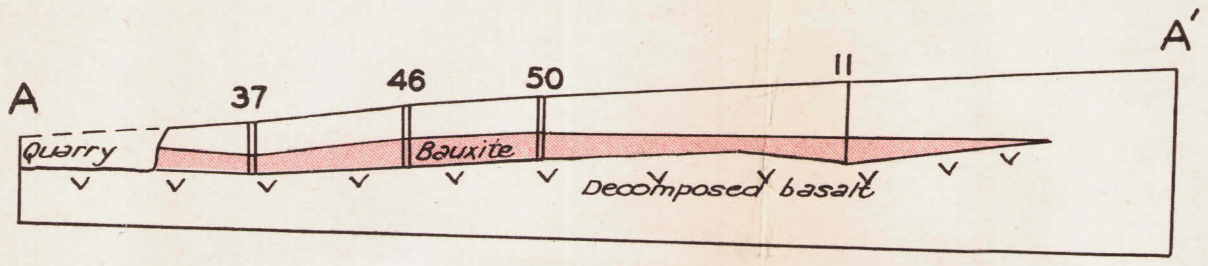
PLATE 13.
BAUXITE DEPOSIT
"WATKINS"
PH. ALLAMBEE EAST CO. BULN BULN
VICTORIA
0 100 200 ft.
Reference
Bauxite thickness 0-5'
" " 5'-10'
" " 10'-15'
Bauxite thickness 15'-20'
" " 20'-25'
" " Over 25'
1150' Surface contours. (Approx. above Sea Level)
M.N.
Quarry
NO. 1 SHAFT
NO. 2 SHAFT
Lignite at 50' N.B.
Hand bores shown thus:- 56 29/12
Where 56 = No. of Bore
" 29 = Thickness of overburden in feet
" 12 = Thickness of Bauxite in feet.
N.B. = Not bottomed.
A
A'
B
B'
NO. 1 SHAFT
Bauxite
Decomposed basalt
H.B. Owen.
Geologist
Mineral Resources Survey.
Apr. 1945.
1268

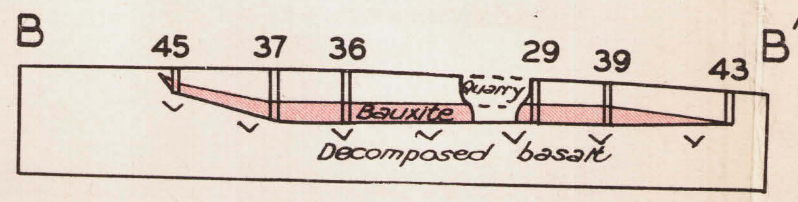
PLATE 14.

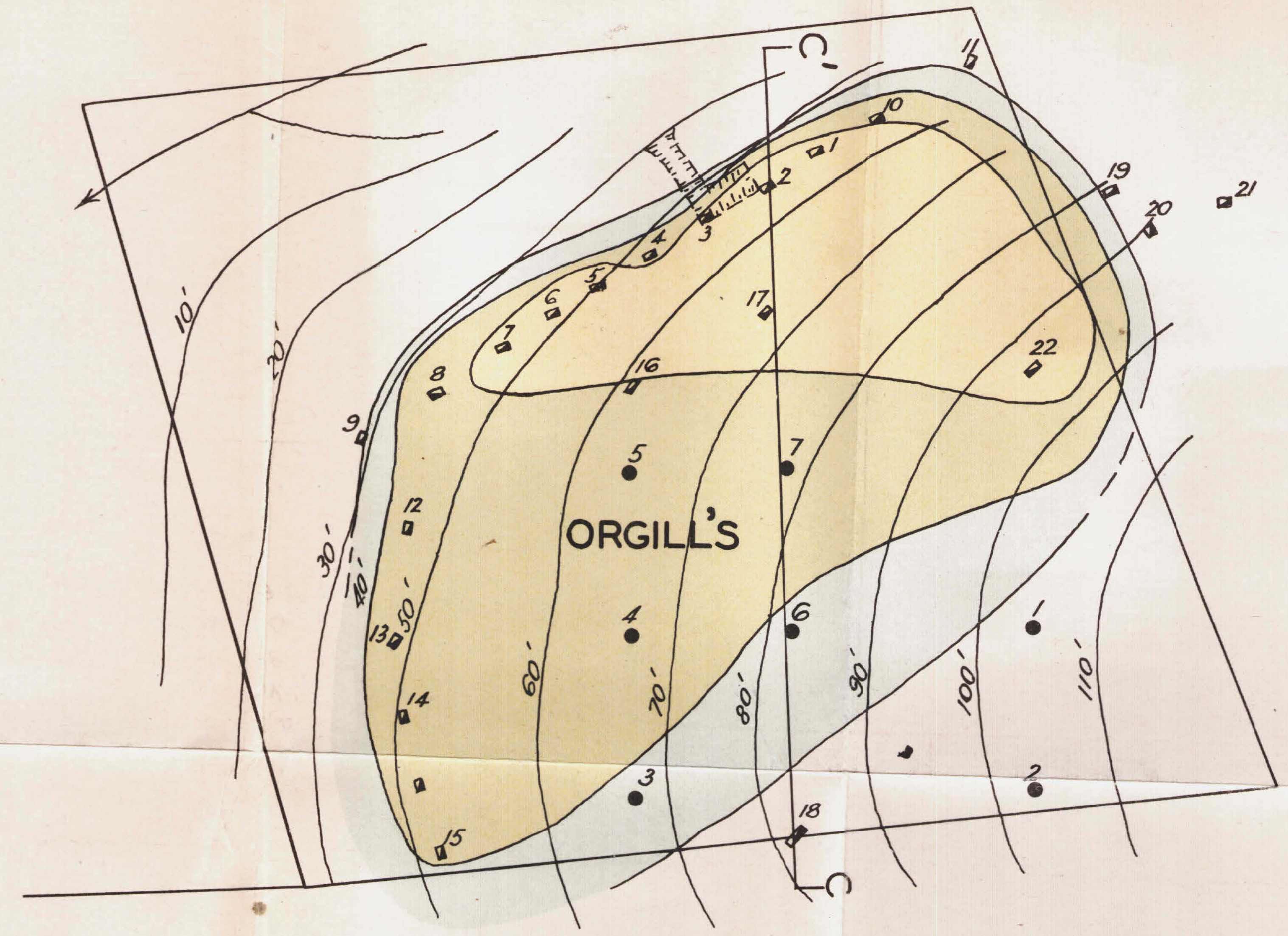


Bore No.	Thickness of O/Burden	Thickness of Bauxite	Shaft No.	Thickness of O/Burden	Thickness of Bauxite.
1.	36	8	29.	13	8·5
2.	37	·5	31.	13	5
3.	37	1	34.	19	8
4.	-	Nil	35.	18	4·5
5.	-	Nil	36.	16·5	11
6.	-	Tr.	37.	17	9
7.	35	9?	38.	8	4
8.	40	4	39.	12	11
9.	31	10	40.	18	3
10.	21	4	41.	4	4·5
11.	29	13	43.	17	Nil
12.	44	7	45.	4·5	6
13.	40	11.	46.	16·5	15
14.	52	5	49.	15	2·5
15.	44	2?	50.	18·5	4
16.	31	1.	51	5	6·5
17.	52	Nil	52	10	Nil
18.	-	Nil	53	9	8
19	-	Tr	54	23	6
20	75	Nil	55	9	9·5
21.	-	Nil			
22.	-	Nil			
23.	-	Nil			
24.	40	4			

Bore No.	Thickness of overburden in feet	Thickness of bauxite in feet	Shaft No.	Thickness of overburden in ft.	Thickness of bauxite in ft.
1.	-	Nil	1.	1·5	11·5
2.	-	Nil	2.	1	16·0
3.	23.	3.	3.	5	12
4.	17.	10.	4.	5	7
5.	26.	7.	5.	5	14
6.	34.	4.	6.	6	12
7.	30.	6·5	7.	3·5	13·5
			8.	5	8
			9.	-	Nil
			10.	3	10
			11.	-	Nil
			12.	4	6
			13.	4	6·5
			14.	4	6
			15.	4	6
			16.	18.	9
			17.	18	12
			18.	-	Nil
			19	-	Nil
			20.	-	Nil
			21.	--	Nil
			22.	30	15







BAUXITE DEPOSITS
SULPHATES OPEN CUT AND ORGILL'S

NEAR BOOLARRA, PH. NARRACAN SOUTH, CO. BULN BULN, VICTORIA.

0 100 200 300

Reference

Bauxite thickness. Trace to 5'

" " 5' - 10'

" " 10' - 15'

H.B. Owen.
Geologist
Mineral Resources Survey.
Oct. 1943.

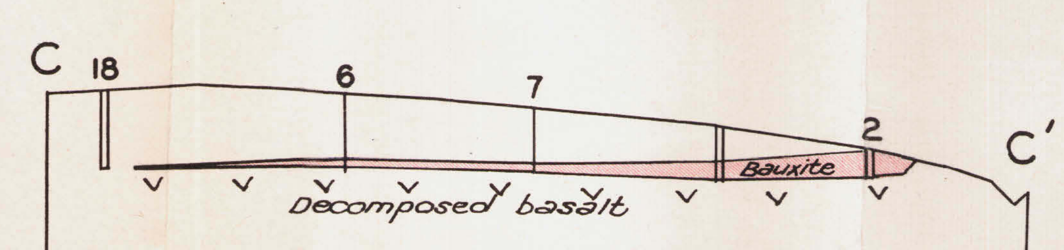


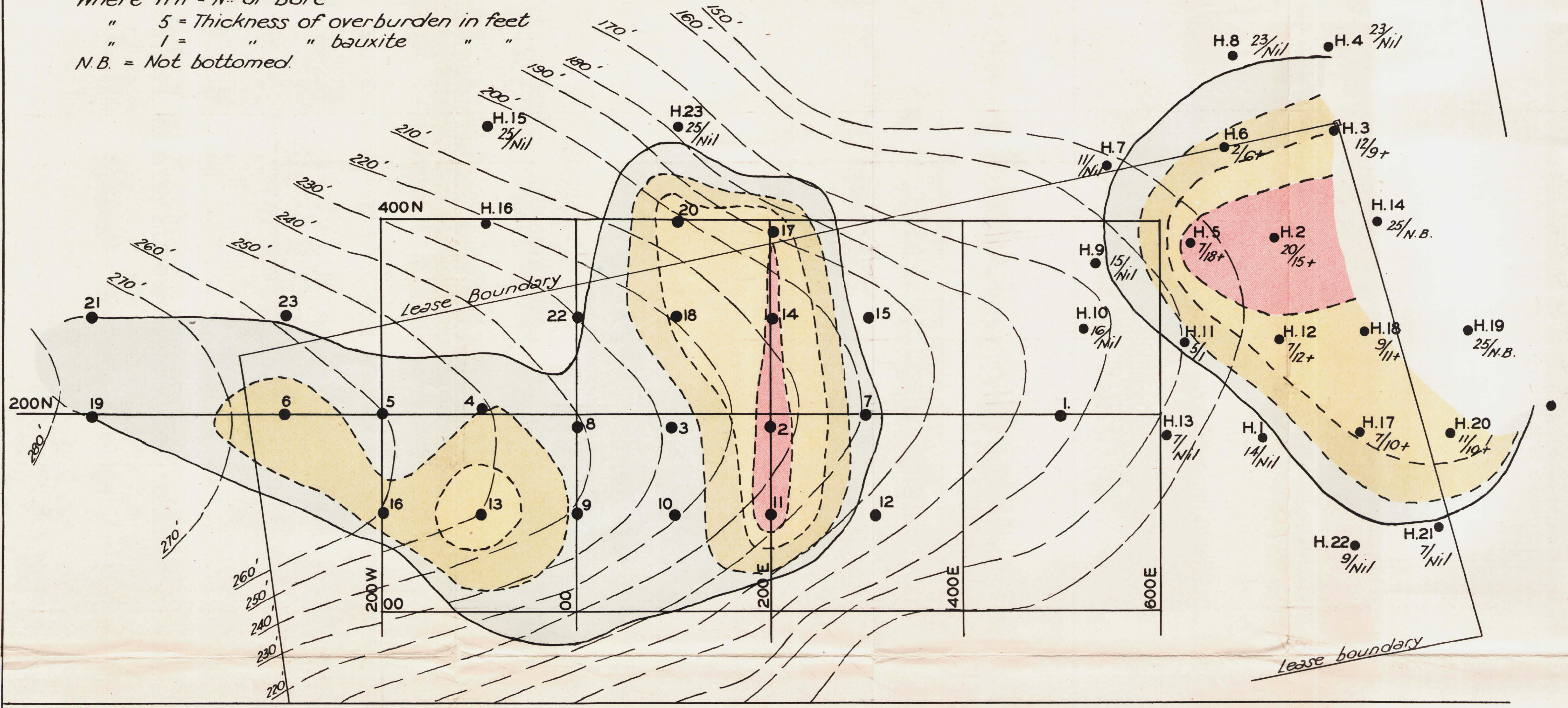
PLATE 15

BAUXITE DEPOSIT - PAYNES LEASE
PH. ALLAMBEE EAST CO. BULN BULN
VICTORIA

SCALE 1 INCH = 100 FT.

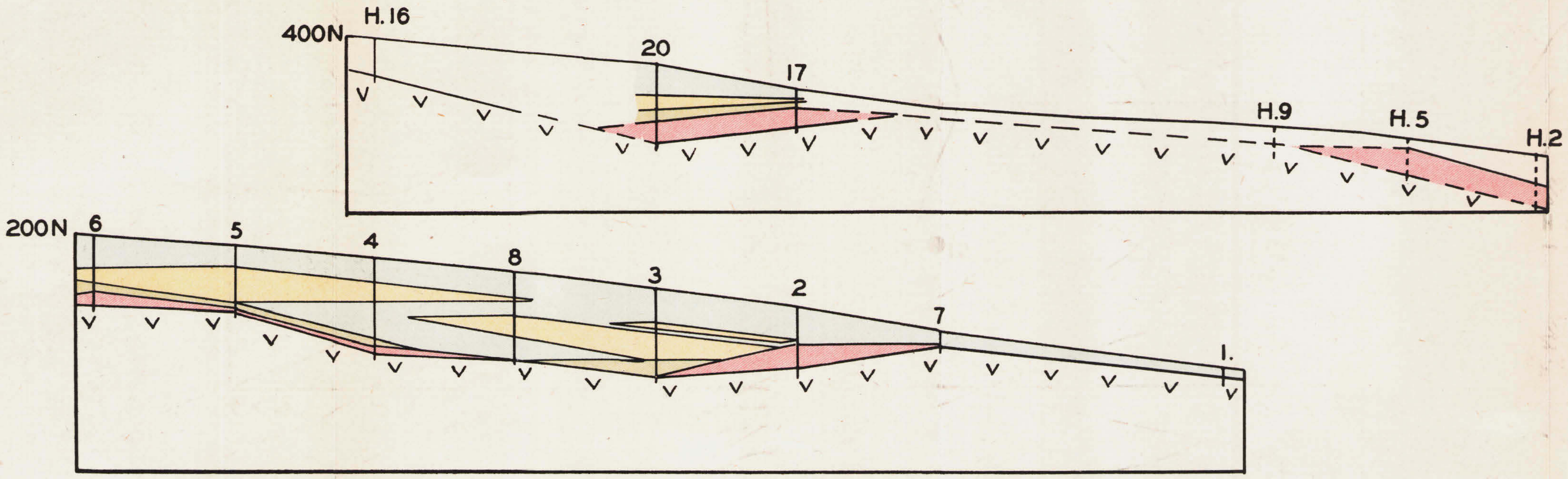
Reference

- Bauxite thickness - Trace to 5 feet.
- " " 5 ft. to 10 ft.
- " " 10 ft. to 15 ft.
- " " Over 15 ft.
- 150' Surface contours. (Above assumed datum.)
- Hand bores shown thus:- ● H11. 5/1.
- Where H11 = No. of Bore
- " 5 = Thickness of overburden in feet
- " 1 = " " bauxite " "
- N.B. = Not bottomed.



MACHINE BORE DATA

Bore No.	R.L. Feet.	Thickness of Overburden Feet	Thickness of Bauxite Feet
1.	173·5	11	Nil
2.	213·5	24	17
3.	228·5	60	Tr.
4.	251·0	62	5
5.	260·5	47	2
6.	266·5	39	9
7.	199·0	11	Tr.
8.	240·5	61	Tr.
9.	239·5	49	3.
10.	223·0	37	Tr.
11.	202·0	10	17
12.	185·0	9	Nil
13.	250·0	35	15
14.	206·0	26	15
15.	195·0	22	Nil
16.	259·0	23	5
17.	187·0	12	15
18.	219·0	51	13
19.	278·5	47	Tr.
20.	203·0	42	11
21.	276·0	47	Tr.
22.	229·0	71	Nil
23.	259·0	64	Nil



Reference to Sections

- Brown sand.
- Grey sand & sandy clay.
- Clay
- Bauxite
- Decomposed Basalt

H. B. Owen.
Geologist
Mineral Resources Survey
Apr. 1945.

1270

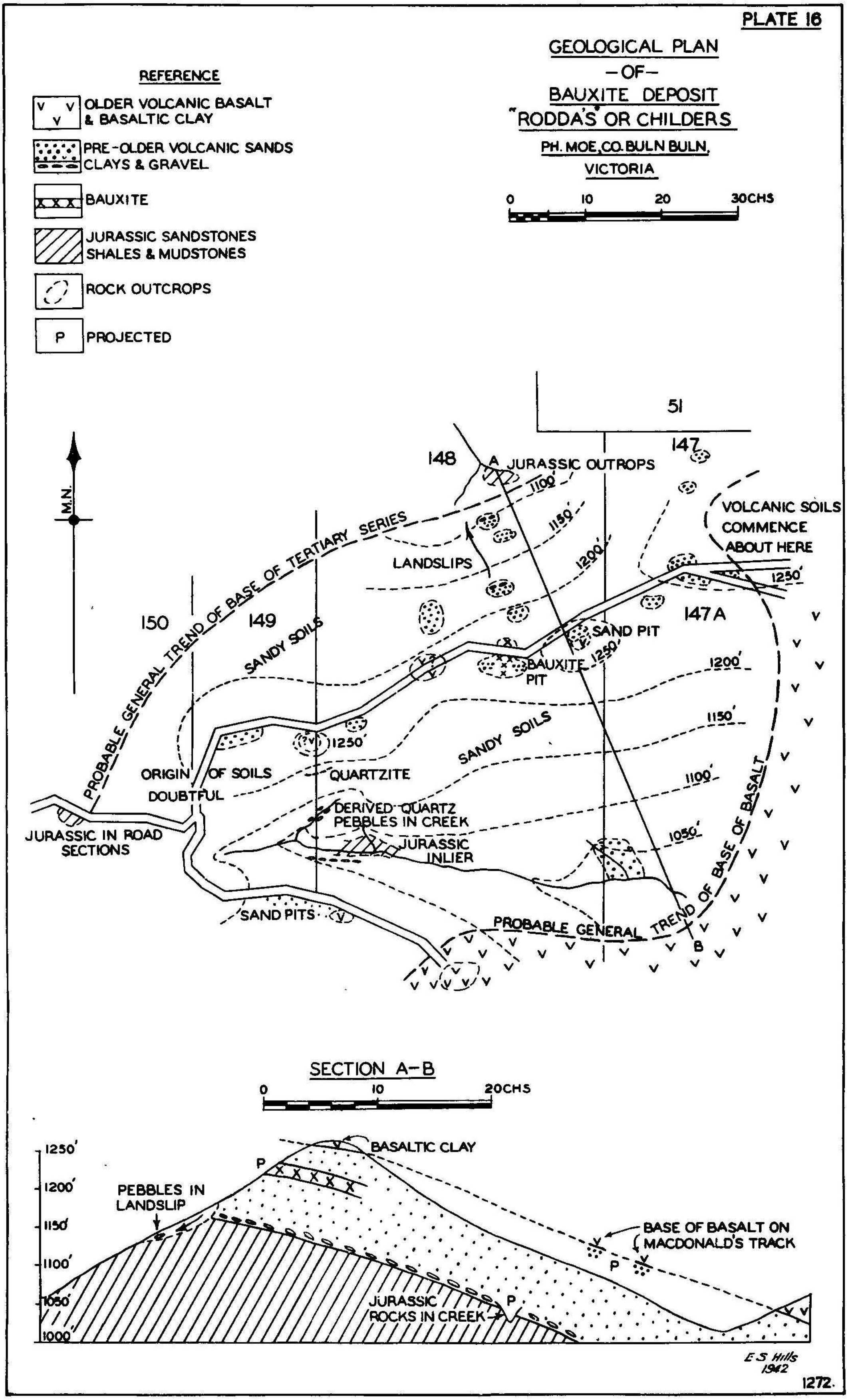
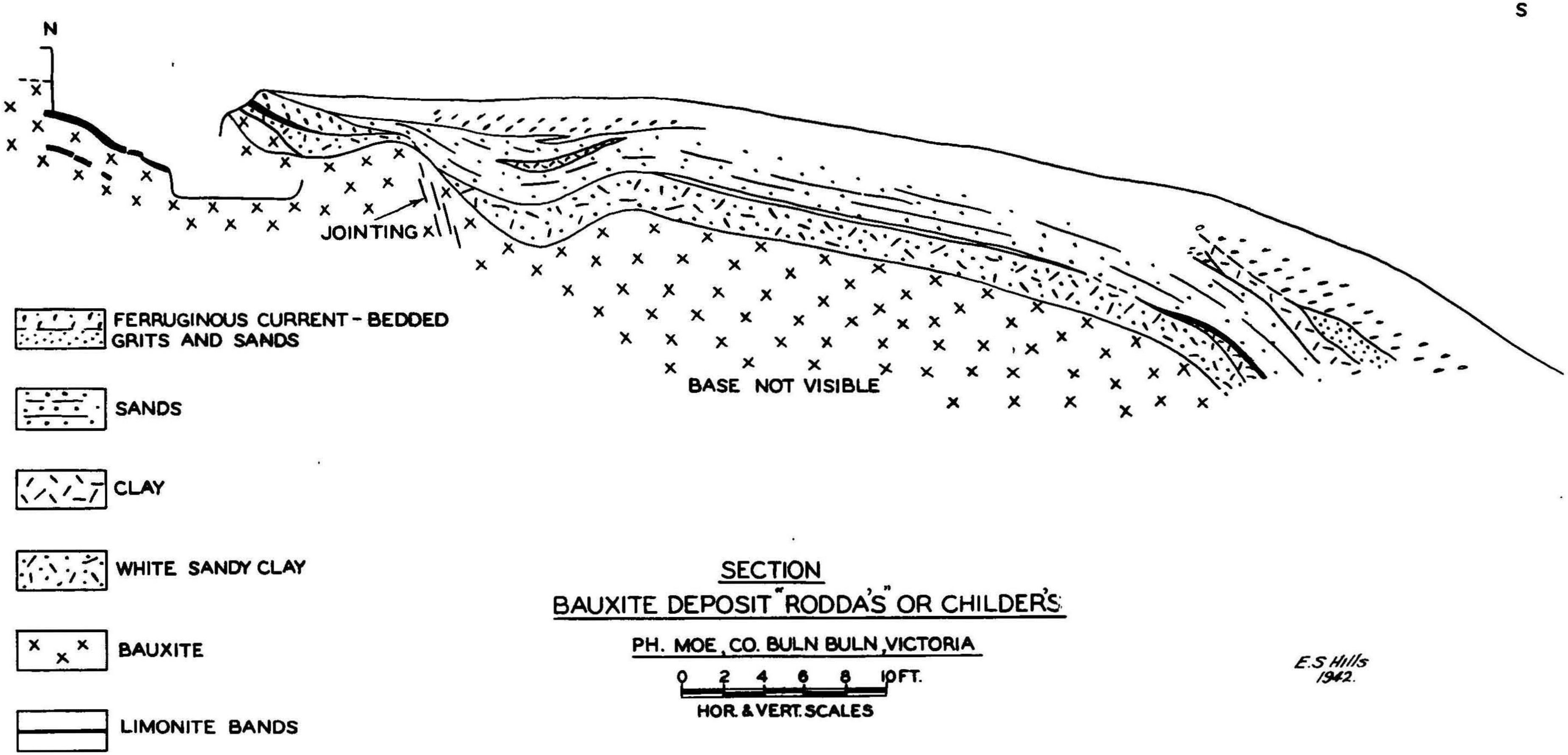


PLATE 16
GEOLOGICAL PLAN
-OF-
BAUXITE DEPOSIT
"RODDA'S" OR CHILDERS
PH. MOE, CO. BULN BULN,
VICTORIA
0 10 20 30CHS
REFERENCE
OLDER VOLCANIC BASALT & BASALTIC CLAY
PRE-OLDER VOLCANIC SANDS CLAYS & GRAVEL
BAUXITE
JURASSIC SANDSTONES SHALES & MUDSTONES
ROCK OUTCROPS
P PROJECTED
M.N.
51
148
147
150
149
147 A
A
B
JURASSIC OUTROPS
PROBABLE GENERAL TREND OF BASE OF TERTIARY SERIES
LANDSLIPS
VOLCANIC SOILS COMMENCE ABOUT HERE
SANDY SOILS
SAND PIT
BAUXITE PIT
1100'
1150'
1200'
1250'
1050'
ORIGIN OF SOILS DOUBTFUL
QUARTZITE
DERIVED QUARTZ PEBBLES IN CREEK
JURASSIC INLIER
JURASSIC IN ROAD SECTIONS
SAND PITS
PROBABLE GENERAL TREND OF BASE OF BASALT
SECTION A-B
0 10 20CHS
BASALTIC CLAY
PEBBLES IN LANDSLIP
BASE OF BASALT ON MACDONALD'S TRACK
JURASSIC ROCKS IN CREEK
1000'
E.S. Hills 1942
1272.

PLATE 17



SECTION

BAUXITE DEPOSIT "RODDA'S" OR CHILDER'S

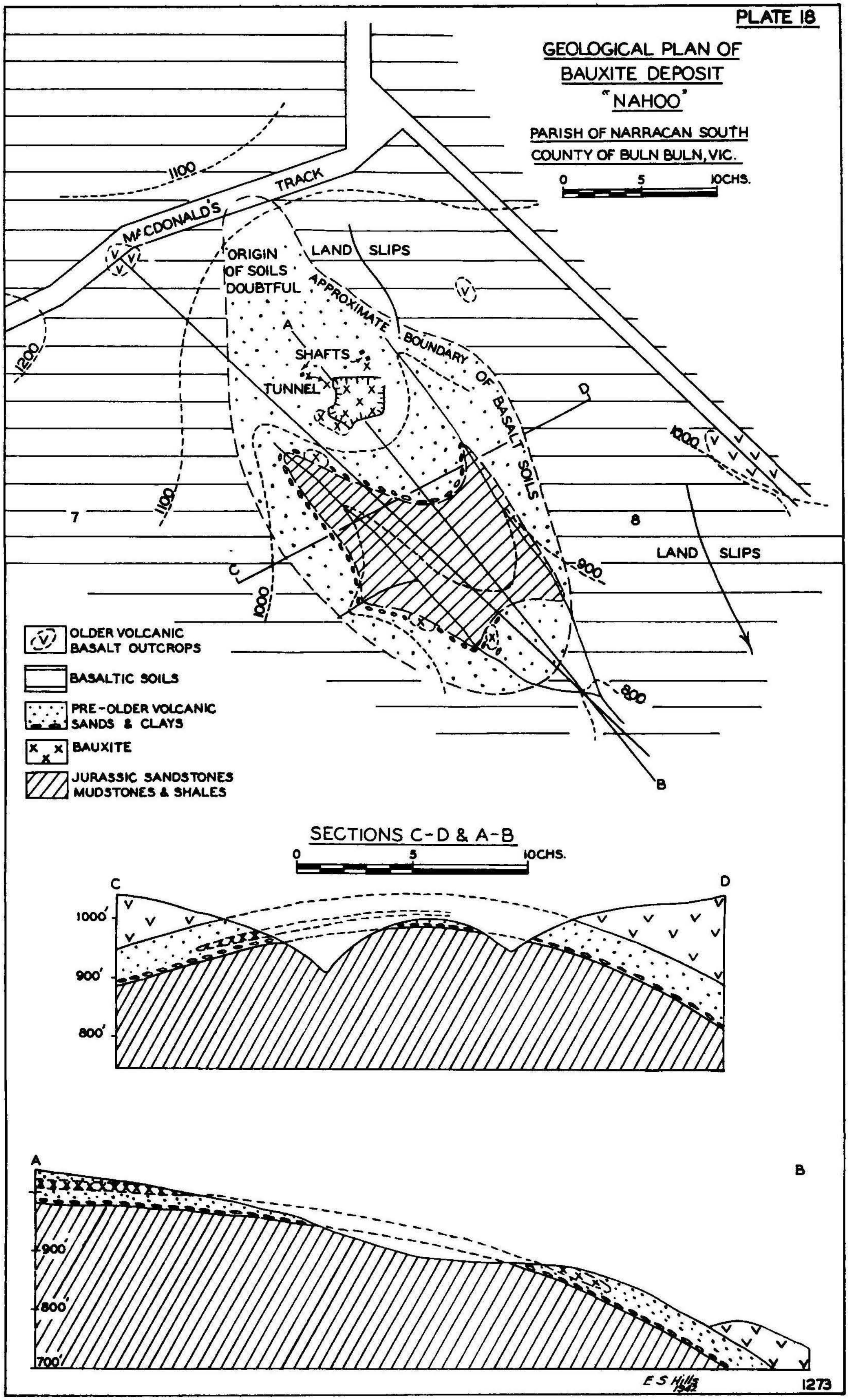
PH. MOE, CO. BULN BULN, VICTORIA

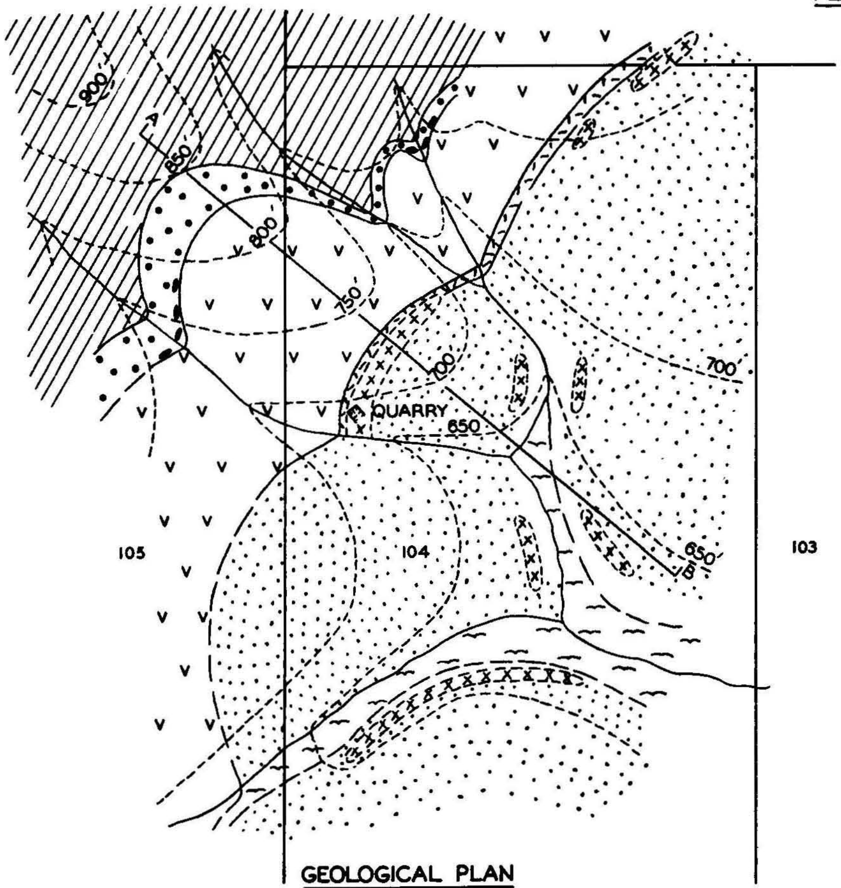
0 2 4 6 8 10 FT.

HOR. & VERT. SCALES

E. S. Hills
1942.

1271


GEOLOGICAL PLAN OF
BAUXITE DEPOSIT
"NAHOO"
PARISH OF NARRACAN SOUTH
COUNTY OF BULN BULN, VIC.
0 5 10CHS.
MCDONALD'S TRACK
1100
1200
ORIGIN OF SOILS DOUBTFUL
LAND SLIPS
APPROXIMATE BOUNDARY OF BASALT SOILS
SHAFTS
TUNNEL
A
B
C
D
7
8
900
1000
800
OLDER VOLCANIC BASALT OUTCROPS
BASALTIC SOILS
PRE-OLDER VOLCANIC SANDS & CLAYS
BAUXITE
JURASSIC SANDSTONES MUDSTONES & SHALES
SECTIONS C-D & A-B
0 5 10CHS.
1000'
900'
800'
900
800
700'
E S Hills 1942
1273



GEOLOGICAL PLAN
-OF-
BAUXITE DEPOSITS
"WANKES"

PH. ALLAMBEE EAST, CO. BULN BULN, VIC.

0 5 10 15 CHS.

REFERENCE

ALLUVIUM

BAUXITE

OLDER VOLCANIC BASALT

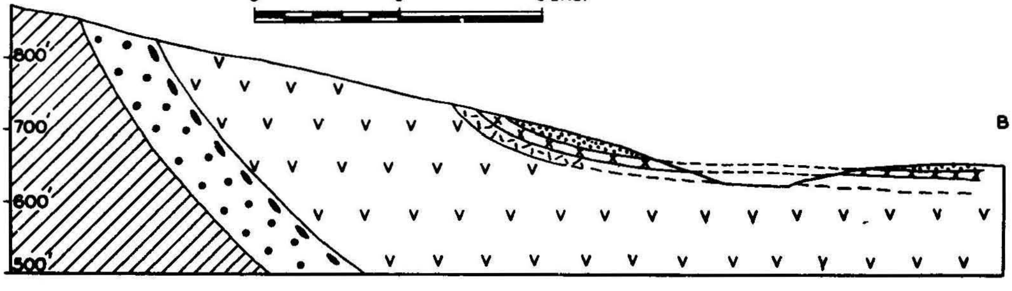
POST - OLDER VOLCANIC SANDS AND CLAYS

MOTTLED BASALTIC CLAY

PRE-OLDER VOLCANIC SANDS & QUARTZITES

JURASSIC SANDSTONES MUDSTONES & SHALES

SECTION A - B



E S Hills
1942

1274