COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN No. 35

THE INVESTIGATION OF DEEP LEADS BY THE SEISMIC REFRACTION METHOD

by

D. F. URQUHART

sued under the authority of Senator the Hon. W. H. Spooner, M.M.
Minister for National Development

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Minister—SENATOR THE HON. W. H. SPOONER, M.M.
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ABSTRACT.

Deep alluvial leads of Recent, Pleistocene, and Tertiary age have been of considerable economic importance in Australian mineral production. Numerous basalt-covered and alluvium-covered auriferous leads have been worked in New South Wales and Victoria, but are quite rare in other states. However, important stanniferous deep leads have been worked at Herberton in North Queensland.

Several geophysical methods can be applied to the investigation of alluvium-covered leads, the seismic refraction method being generally the most suitable. In the case of basalt-covered leads the geophysical problem is more difficult, although satisfactory results have been obtained by the magnetic method at Gulgong, New South Wales, and at Herberton.

More recently (1948-49) the seismic refraction method has been applied to problems of this nature at Kalgoorlie, Western Australia, and Wellington and Ardlethan in New South Wales.

At Kalgoorlie, geological evidence indicates that deep auriferous leads may extend for some distance to the south of the main Kalgoorlie lodes. At the request of the Western Mining Corporation, seismic refraction profiles were obtained along two 7-mile traverses. The first traverse (A) was about 15 miles south of the mines and the second (B) about 2 miles to the south of the "golden mile". The refraction profile revealed two deep channels crossing traverse A and two channels crossing traverse B; the depth to bedrock on both traverses was, however, much greater than anticipated.

For some years alluvial gold has been dredged along the banks of the Macquarie River near Wellington, New South Wales. In order to plan the course of the dredge, a considerable amount of advance drilling and sampling has to be done by the company concerned. It was considered that the seismic method might be employed in order to reduce the amount of test drilling which has to be done. In 1949, the method was tried in this area but it was found to be too costly in this application, due to the poor transmission qualities of the overburden which necessitated the use of large charges or the drilling of deep shot holes. However, the limited amount of work which was done did indicate the unexpected presence of deep ground in a part of the area which had not been tested by boring.

In the past, small stanniferous lodes have been worked about 6 miles to the north-west of Ardlethan. The geological evidence suggested that alluvial tin, shed from the Bygoo deposits, might be found at shallow depth. The seismic refraction method was used once again, but it was found that the depth to bedrock was much greater than had been anticipated. However, the presence of a deep gutter, running in a north-easterly direction from the old workings, was fairly well established and drilling recommendations were made to the company concerned.

INTRODUCTION.

Alluvial gold deposits of Recent, Pleistocene, and Tertiary age have been of considerable economic importance in Australian mineral production. When the more easily won gold from the Recent and Pleistocene deposits gradually became scarcer, the metal was traced by the more enterprising workers into the deep alluvial leads. These leads represent the beds of old rivers which formed the surface drainage system in middle and late Tertiary times. Many of the leads are covered by a thick layer of basalt and/or alluvium and the depth of the drifts below the surface is therefore considerable, ranging up to several hundred feet, hence the term " deep leads ". To the author's knowledge the term was first applied to such gold deposits in New South Wales and Victoria, and is not in general use. Deep leads have also been the source of most of Australia's tin production. A description of the manner in which deep leads are formed, including details of the mechanism by which gold-bearing gravels and drifts are deposited, has been given by Kenny (1924).

There are several geophysical methods which can be applied, under certain circumstances, to the location of deep leads or to the location of the channels in bedrock in which the leads are found. By the application of these methods, much time-wasting and costly exploratory drilling can be eliminated.

This report gives a brief outline of the occurrence of some deep leads in Australia and of the geophysical work which has been done up to the present time. Three fairly recent geophysical investigations of deep leads are described in detail and an outline is given of the theory and application of the seismic refraction method which was used in these surveys.

OCCURRENCE OF DEEP LEADS IN AUSTRALIA.

Many deep leads have been worked for gold in Australia, particularly in Victoria and New South Wales.

In Victoria, numerous gold-bearing leads occur in the Bendigo-Ballarat-Stawell area and in the Rutherglen-Beechworth area. Other leads occur in Central Victoria and on the Dargo High Plains. The leads range in age from Recent to Tertiary and many of the earlier ones are covered by basalt flows. The leads are as much as 700 feet below the present surface, but few have been worked below 300 feet.

In New South Wales, deep leads have been worked over a wide area of New England and the central and southern tablelands. In general, the valleys of the rivers flowing westward have been the most productive, but appreciable quantities of gold have also been won from coastal rivers such as the Clarence and the Shoalhaven. As in Victoria, many of the earlier Tertiary leads have been covered by basalt flows. Example of basalt-covered leads are to be found at Trunkey, Kiandra, and Gulgong, and alluvium-covered leads have been worked in the Forbes-Parkes district and in the upper parts of the Shoalhaven River. At Grenfell, and in the Corowa and Albury districts, leads have been worked at depths of 300 feet and more.

In Queensland, most of the alluvial gold has come from Recent shallow deposits, and there are few of the deep basalt-covered leads which are so common in Victoria and New South Wales.

Deep leads have been of relatively little economic importance in the other States of Australia, although some have been worked in Western Australia, e.g., at Kanowna and Kurnalpi, and in the Norseman area. Some gold has also been won from deep Tertiary leads at Lefroy and Back Creek in Tasmania.

Most of the tin produced in Australia has come from Recent and Tertiary alluvial deposits, one of the most important deposits being in a sub-basaltic, deep lead system at Herberton, North Queensland.

In New South Wales, tin has been obtained from deep leads covered by basalt and alluvium. Shallow leads have also been worked in the Ardlethan district.

A system of deep leads, some of them basalt-covered, in the Ringarooma River area of North-East Tasmania, has yielded significant quantities of tin. Other, but less productive, leads occur in the north-east and north-west of the State.

Tin has also been won from deep leads in Western Australia, principally in the Greenbushes Field, in the south-west of the State.

GEOPHYSICAL METHODS USED IN THE INVESTIGATION OF DEEP LEADS.

The geophysical methods which can be applied to the investigation of deep alluvial-covered leads, are the seismic refraction, resistivity, gravity and magnetic methods. The seismic method is described later in this report, and descriptions of all methods can be found in any standard text book on geophysics. By means of these methods it is sometimes possible to locate and trace the course of buried channels in an older land surface. The seismic and resistivity methods may provide quantitative information about the depth and extent of such channels. The seismic method can, however, be applied more generally than the resistivity method, and the interpretation of the results is usually more straightforward. The main disadvantages of the seismic method are that it is more costly and usually slower than the other methods.

If there is sufficient density contrast between the alluvium filling a buried channel and the surrounding rock, a detectable anomaly in the earth's gravitational field may be produced at the surface. It may therefore be possible to locate such a channel by mapping the gravitational field intensity over the area to be investigated. If reliable figures are available for the average density of the bedrock and the alluvium, it may even be possible to estimate the depth and extent of the channel. However, reliable quantitative results are not likely to be obtained by the use of the gravity method alone.

In some instances, magnetite or ilmenite is associated with metalliferous leads, and may be present in sufficient quantity to produce a measurable anomaly in the earth's magnetic field intensity at the surface.

When leads are covered by basalt flows, the direct location of the channel is more difficult. In some instances, however, the basalt flows have been restricted to the old river channels, and a method of delineating the basalt covering could be a useful guide in the investigation of a system of deep leads. This is so with the Gulgong lead system (see page 10).

Where conditions are suitable, the use of geophysical methods may result in substantial savings in the time and cost involved in the preliminary stages of an exploratory programme for deep leads. The final testing for gold or tin values can, of course, be done only by drilling and sampling.

SEISMIC REFRACTION METHOD

The seismic method is based upon the fact that the velocity of propagation of mechanically generated waves through the earth's crust varies according to the elasticity of the media traversed, with the result that the direction of propagation may be altered at a boundary between two different media.

The wave velocity is given approximately by the expression :—

$$V = \sqrt{\frac{3N}{D}}$$

where V = wave velocity
N = rigidity modulus
D = density of the medium traversed.

Fermat's principle of minimum time paths for light waves can also be applied to seismic waves. Thus, "in travelling between two points the wave will follow a path along which velocities are of such magnitude that the travel time is a minimum".

The laws of reflection and refraction of light are also valid for the seismic ray. Hence in passing across a boundary between two media in which the velocities of propagation are V_1 and V_2, the angle of refraction of the ray will be given by the expression :—

$$\frac{\text{Sin } i}{\text{Sin } r} = \frac{V_1}{V_2}$$

where i = angle of incidence
r = angle of refraction.

To illustrate the application of the method, consider a simple geological section (Fig. 1) in which there are three layers with velocities of propagation V_1, V_2 and V_3, where V_3 is greater than V_2 and V_2 is greater than V_1.

An elastic disturbance is produced at S, by the explosion of a charge of gelignite and the resulting wave is picked up at points along a straight line by detectors (geophones) G_1, G_2, G_3, &c. The instant at which the shot is detonated and the time of arrival of the wave at each of the geophones are recorded (as will be described later), and thus the minimum travel times between S and G_1, G_2, G_3, &c., are known. The figure shows the paths which would be followed by the shortest ray from the shot to each geophone, for particular values of V_1, V_2 and V_3 under ideally uniform conditions. At an interface the rays will be incident at the critical angle so that the refracted ray will be along the interface between the two media.

If the recorded times are plotted against the corresponding (surface) distances, the points will lie on a curve of the form shown in Fig. 1. The points of discontinuity on the curve correspond to distances between shot and geophone such that the time path through one medium is equal to that via the faster underlying medium. These are known as "critical distances."

The different slopes of the curve clearly represent the corresponding layer velocities; thus the curve becomes "flatter" as the rays penetrate to the lower and faster layers.

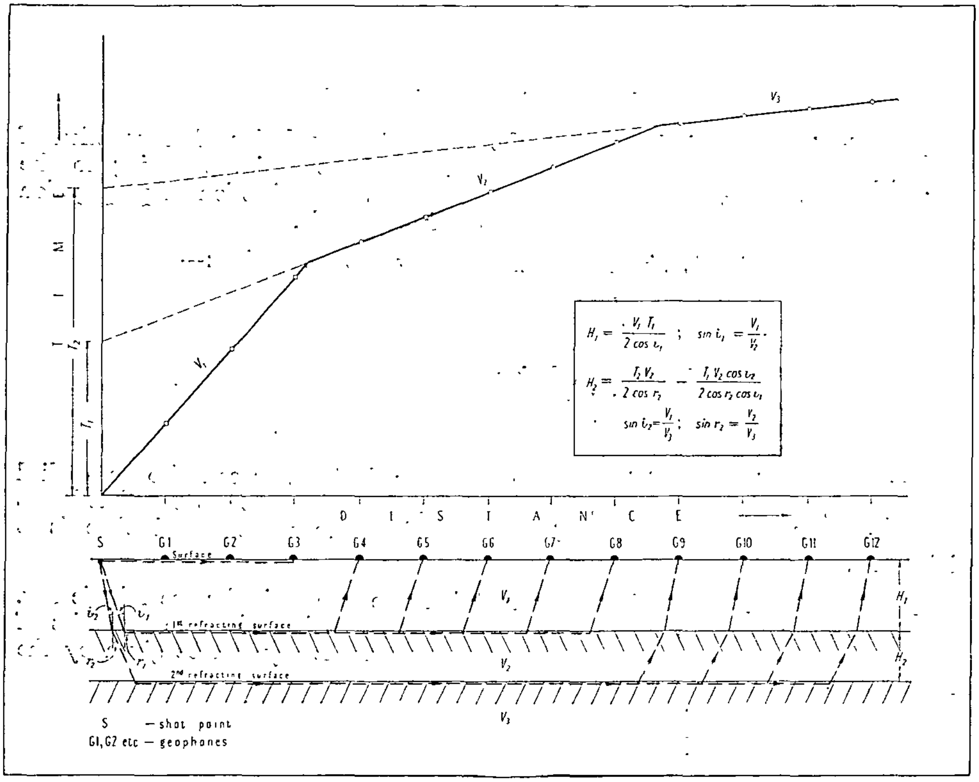

Fig. 1.—Ray paths and time-distance curve for three-layer case.

The thicknesses (H_1 and H_2) of the two top layers may be calculated from equations derived by Ewing, Crary and Rutherford (1937).

For the top layer :—

$$H_1 = \frac{V_1 T_1}{2 \cos i_1} \quad \ldots \ldots \ldots \quad \text{(i)}$$

where T_1 = the intercept made on the time axis of the time-distance graph by that part of the curve representing the velocity V_2 (Fig. 1)

$\sin i_1 = V_1/V_2$

For the second layer :—

$$H_2 = \frac{T_2 V_2}{2 \cos r_2} - \frac{T_1 V_2 \cos i_2}{2 \cos r_2 \cos i_1} \quad \ldots \ldots \ldots \quad \text{(ii)}$$

where T_2 = the intercept made on the time axis by that part of the curve corresponding to V_3

Sin $i_2 = V_1/V_3$

Sin $r_2 = V_2/V_3$.

In practice it is often impossible to obtain all the required points on the time-distance curve by means of a single shot (as shown, for simplicity, in Fig. 1). For example, with the equipment used in the surveys to be described here, four geophones only could be used in the central spread and it was necessary to fire a series of shots at increasing distances from the geophone spread in order to obtain refractions from each of the surfaces which were relevant to the particular problem. It is also necessary to increase the size of the charge as the shot point is moved farther away from the geophones.

The equations (i) and (ii) above are true only for ideal conditions in which all refracting surfaces are parallel to the surface and the velocities are uniform in each layer. However, it is possible to derive more general equations for the case where the refracting surfaces are of uniform slope but not parallel to the surface. The derivation of these equations can be found in any standard textbook on geophysics, e.g., Heiland (1946). From these equations it is possible to determine the depth and dip of two or more refracting surfaces provided shots are fired from both sides of the geophone spread. This is necessary because the slope of the time-distance graph will be influenced by the slope of the refracting surfaces as well as by the velocity in the lower layer. This can be seen in the simple two-layer case illustrated in Fig. 2.

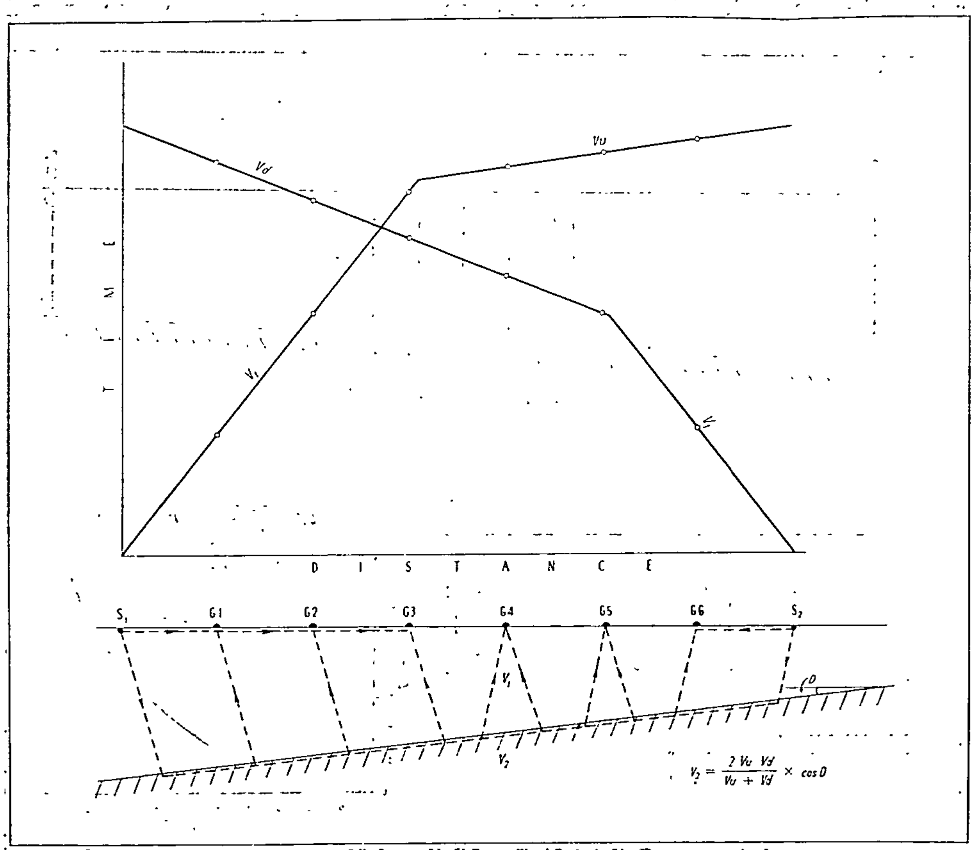

Fig. 2.—Ray paths and time-distance curve for two-layer case, with interface dipping at an angle D.

Here, the slope of the time-distance graph gives an apparent, second-layer velocity of V_u for the shot point at S_1 (shooting "up-dip") and a lower, apparent velocity V_d for the shot point at S_2 (shooting "down-dip"). The true, second-layer velocity, V_2, can however, be found from the equation :—

$$V_2 = \frac{2V_uV_d}{V_u + V_d} \cdot \cos D \ ,$$

where $D =$ the angle of dip..

In the application of the seismic method to the investigation of deep leads, the problem is generally one of determining the depth to bedrock under a covering of alluvium. The surface of the bedrock is often quite irregular, with steep and variable slopes. In such cases a slight modification in the layout of geophones and shot points enables the refraction profiles to be obtained more simply and with greater detail than by the normal method already described. This modification, which is known as the reciprocal method or method of differences, is accurate only when there is a great contrast between the different layer velocities.

The method can be described by reference to Fig. 3 (a), which shows the layout of shot points and geophones for a simple two-layer case. A shot point (S) and reciprocal geophone (G_r) are located on each side of a normal geophone spread (G_1 to G_5). Both the shot and reciprocal geophone are placed

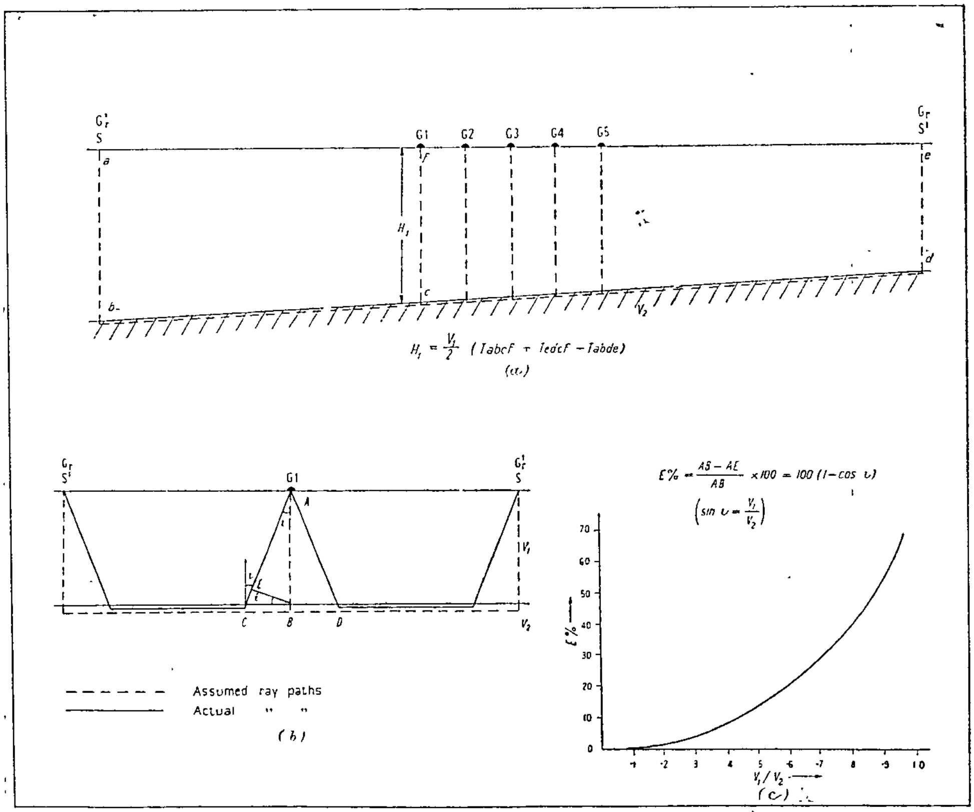

Fig. 3.—Reciprocal method for two-layer case, and error involved.

beyond the critical distance so that the travel times recorded are all for refracted rays. A second shot is fired at the point previously occupied by the reciprocal geophone (G_r).

If the velocity V_2 is much greater than V_1, the ray paths through the upper layer will be almost vertical. If this assumption is made it can be seen by reference to the figure that :—

$$T_{abcf} + T_{edcf} - T_{abde} = 2T_{cf} .$$

where T_{abcf} = the recorded travel time for the path $abcf$, and similarly for the other terms.

Hence the travel time for the path cf is known and if the velocity V_1 is also known, the depth to bedrock under the geophone G_1 can be found. In the same way the depth to bedrock under the other geophones can be calculated.

The error introduced by the assumption of vertical ray paths depends on the ratio V_1/V_2 and can be easily calculated by reference to Fig. 3 (b). It can be seen from this figure that the time actually obtained by the method of differences is for the path AE rather than for the required distance AB. Hence the percentage error (E) (due to the assumption of vertical ray path) in the depth calculations is given by the equation :—

$$E = 100 \cdot \frac{AB - AE}{AB} = 100 \, (1 - \cos i)$$

where $\sin i = V_1/V_2$.

This equation is plotted in Fig. 3 (c) for different values of V_1/V_2. It can be seen that if the ratio V_1/V_2 is less than 0·45, the error introduced into the depth calculations will be less than 10 per cent., the calculated depth being less than the true depth by this amount. This curve can be used to make a correction to the depth calculations when the ratio V_1/V_2 is known.

The reciprocal method can be applied in cases where there are more than two layers. After finding the thickness of the top layer, the shot points and reciprocal geophone are moved out beyond the second critical distances. Vertical travel times through the two layers are then obtained. The vertical travel time previously obtained for the top layer is then subtracted, giving the time through the second layer and hence the thickness of that layer. The reciprocal method is particularly suitable for continuous profiling, because a separate value for the depth beneath each geophone is obtained, and once the layer velocities have been obtained fewer shots are required for each spread than for the time-distance graph method.

The main source of error in seismic refraction methods is in the determination of the layer velocities. If there is no control provided by drilling in the survey area it is necessary to obtain the layer velocities from the time-distance graph. However, the velocities so obtained are for horizontal ray paths along the surface of each layer, whereas the velocities required for the depth calculations are for vertical ray paths through each layer.

If there are drill holes available in the area of the survey it may be possible to measure the vertical velocity directly, either by placing a charge at the bottom of the drill hole and measuring the "up-hole time" to a geophone at the surface, or, if the drill hole is to be preserved, it may be possible to lower a geophone to the bottom of the hole and fire a charge at the surface.

Again, if the depth to bedrock is accurately known at certain points in the survey area, a velocity may be assumed such that the vertical travel times obtained by reciprocal shooting are consistent with the known depth to bedrock at those points. However, even when such control is available, errors may be introduced by non-uniformity of the layer velocities over the region of the survey.

In shallow refraction shooting it is often possible to determine the trend of refracting surfaces beneath the shot points as well as the depth beneath the geophone spread. The way in which this can be done can be seen by reference to the simple case illustrated in Fig. 4.

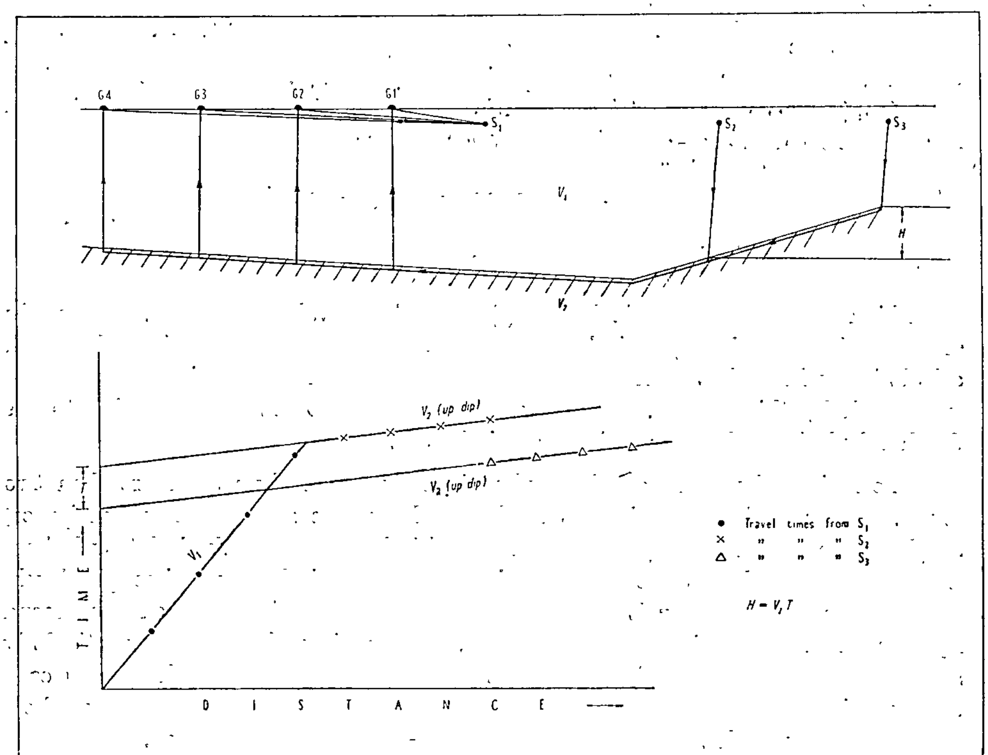

Fig. 4.—Change in bedrock level with irregular interface (two-layer case).

Here, the last part of the time-distance graph is displaced downwards as a result of the shallowing of the overburden between shot points S_2 and S_3. The change in the level of bedrock, H (relative to the surface), between S_2 and S_3 is approximately equal to V_1T, where T is the displacement of the time-distance graph along the "time" axis, and V_1 is the velocity in the overburden. Conversely, a deepening of the overburden between S_2 and S_3 would have caused an upward displacement in the graph.

Similar effects on the time–distance graphs may also be produced by lateral changes in the bedrock velocity, but if due regard is paid to this possibility, useful information about the trend of refracting surfaces well beyond the geophone spread may be obtained in this way.

Recording Equipment.

The portable seismic equipment mainly used in the surveys to be described was a six-channel instrument produced in the United States of America by the Heiland Research Corporation. Although this equipment is now obsolescent it operates in essentially the same way as more modern portable instruments, which may have up to 24 recording channels.

The arrival of a wave train at the base of a geophone planted firmly in the ground produces a vertical mechanical vibration in the geophone which is converted electromagnetically into a current pulse which is fed through a suitable cable to the recording unit. There, the pulse is amplified and then applied to the coil of a small galvanometer. A source of light is supplied which, after reflection from the galvanometer mirror, produces a spot of light on a fast-moving strip of photographic paper. An impulse picked up by the geophone appears on the developed record as a sudden break in the straight line traced by the spot of light on the moving paper.

The Heiland instrument records six traces simultaneously and reference "time lines" are produced on the record at intervals of 10 milliseconds. Times can be read from the records to within 1 millisecond. The time of detonation of the shot is also recorded by feeding an electric pulse from the dynamo exploder (used to detonate the charge) to one of the galvanometers.

For shallow refraction shooting the size of the charge varies considerably in different areas, but in general the largest charge required is 20 lb. to 30 lb. of gelignite. The most suitable depth for the shot hole must generally be found by experiment in each new area but it is generally desirable to bury the charge sufficiently deeply to prevent the surface from being broken by the explosion. However, this may not always be possible in hard ground when the shot holes are bored by hand. The geophones are contained in metal cylinders about 6 inches high and 3½ inches in diameter and consist essentially of a permanent magnet rigidly attached to the case and a spring-mounted coil suspended between the poles of the magnet. When the geophone receives a seismic impulse the magnet is displaced relative to the coil, thereby inducing an e.m.f. in the coil.

When a recording is to be made, the gain of the amplifier for each galvanometer trace is increased until the background vibrations, due to the effect of wind and the swaying of trees, &c., on the geophones, are just visible. This can be done by viewing the light spot, reflected from each galvanometer mirror, through a small window in the front of the recording camera. When the amplifier gains are adjusted, the motor which drives the recording paper is switched on and a signal is given to the firer to explode the charge. The paper-drive motor is then switched off again as soon as the galvanometer connected to the most distant geophone is seen to receive the impulse

GEOPHYSICAL SURVEYS FOR DEEP LEADS IN AUSTRALIA.

A considerable amount of experimental geophysical work was done in Australia during 1929-1930 by the Imperial Geophysical Experimental Survey, and is fully described by Broughton Edge and Laby (1931). During this work four methods were tried over some of the deep leads of the Gulgong gold field, New South Wales. Magnetic and earth resistivity methods were used over portions of the leads which were covered by basalt, and seismic and gravity methods were used in part of the area where the covering of the leads was entirely alluvial. The most promising results were obtained by the magnetic method, which gave a good indication of the boundaries and deepest parts of the basalt flows. The seismic method did not show much detail in the surface of the bedrock immediately below the alluvium, but this was probably due to the "averaging out" effect of the time-distance graphical method which was used in the depth calculations. The reciprocal method would probably have shown more detail.

A further, more extensive magnetometer survey of the Gulgong deep leads was made in 1930 by Rayner (1940). As a result of this survey it was possible to recommend several unworked areas as being favourable for further test drilling.

Geophysical surveys have also been made over the stanniferous deep leads at Tingha, N.S.W. (Rayner, 1933), Emmaville, N.S.W. (Rayner, 1937a), Stannum, N.S.W. (Rayner, 1937b), and at Herberton in north Queensland (Thyer, Rayner and Nye, 1938).

More recently, three geophysical surveys for deep leads were carried out by the Bureau of Mineral Resources. These surveys, which are fully described in the ensuing sections of this report, were at Kalgoorlie, Western Australia, in 1948, and at Wellington and Ardlethan in New South Wales, in 1949. In all three surveys the seismic refraction method was used, although a limited amount of gravity work was also done in the Kalgoorlie survey.

The shallow, alluvial, auriferous deposit which was investigated in the Wellington survey was not, strictly speaking, a deep lead, but from the geophysical aspect the problem was identical to that involved in the investigation of deep leads.

KALGOORLIE, WESTERN AUSTRALIA.

INTRODUCTION.

A preliminary seismic and gravity survey was made by the Bureau over an area near Kalgoorlie, Western Australia, in which a deep lead system was believed to occur.

Kalgoorlie, the western terminus of the Trans-Australian Railway, is approximately 320 miles east-north-east from Perth, Western Australia.

Gold was discovered at Kalgoorlie in 1893, and the area is now the greatest gold-producing centre in Australia. At present, practically all mining activity is confined to the celebrated "Golden Mile" and, although this small area maintains ten different mining companies, a large proportion of the known ore bodies has already been worked out. There is, therefore, an urgent need for exploration for further major gold deposits in the area, the development of which could ensure the future prosperity of Kalgoorlie.

The Western Mining Corporation, in particular, undertook a major exploratory programme and the Corporation's geologists obtained much useful geological data. One aspect of this work involved the tracing of detrital gold which has been shed from the Kalgoorlie reefs. This report deals with the preliminary geophysical survey which was made during the latter half of 1948 in an effort to locate any deep lead which may emanate from the primary ore bodies.

The writer wishes to acknowledge the valuable assistance given during the course of the survey by Mr. D. Campbell, Chief Geologist of Western Mining Corporation, and the members of his geological staff.

The writer is also indebted to members of the survey and workshop staff of Gold Mines of Kalgoorlie Ltd. for assistance given in surveying and in maintenance of the geophysical equipment. Also to the Western Mining Garage for maintenance of the vehicle used throughout the survey.

Geology.

In a report by Clarke (1934), special reference is made to the possibility that deep leads of considerable value may be found on the Western Australian goldfields. He points out the importance of the chains of salt lakes running through the goldfields as a guide to an earlier drainage system, down which eroded material containing gold may have been carried. There is considerable controversy as to the true origin of these salt lakes, but Clarke suggests that the most likely theory is that they are the survival of early Cainozoic rivers. The following extracts from his report are of interest.

" Epeirogenic uplift, very early in the Cainozoic, raised at least all that part of the State which lies south of the Canning region. To visualize the amount of movement, one might take as datum a horizontal plane passing through a definite point in the pre-Cambrian complex, e.g.. the 100-ft. level in a mine at Kalgoorlie. During the Cretaceous submergence that plane would have been at least 1,300 feet lower than at present; at the climax of the Eocene emergence it was certainly at its present level and probably higher. This elevation was greatest in the north and the period of emergence was long enough for the development of several consequent rivers, draining some to the south and some to the west."

At the maximum of the following Miocene submergence " our imaginary datum plane would, in the north-west, be but little below sea level, while at Norseman it would be more than 1,000 feet below it ".

" The gradual advances of the sea up the shallow valleys, excavated during the Eocene emergence, caused a re-arrangement of the gravels, &c., in those valleys and more detritus was added, so that the valleys became partly filled. It is this material which forms the filling of the deep leads of the Goldfields."

During the late Cainozoic emergence, " the relative movement was greater in the south than in the north and was of the order of 2,000 feet."

" The effect of the gradual uplift on the Central Goldfields was to cause a slow retreat of the Miocene sea, accompanied by further working over of the fragmental deposits. At the same time, the depressions of the sea floor—direct descendants of the early Cainozoic river system—became lakes."

In a further reference to these salt lakes, Clarke writes "the remains of the Eocene drainage channels which had been only partially filled in the Miocene submergence are seen to a great degree in the salt lakes system, although lateral migration of some of these lakes has taken, and is taking, place".

The question of the possible migration of these lakes is of some importance in deciding upon a favourable area for initial prospecting for a buried channel. The direction of the movement is known to be from east to west—under the influence of the prevailing westerly winds—and although the degree of the displacement is not known exactly, it may be of the order of several miles.

The geology of the Golden Mile indicates that the ore body which is now being worked once extended far above the present erosion surface, and if such is the case, considerable quantities of gold must have been removed from the area in earlier times. If the chain of small salt lakes, shown in Plate 1, to the south of Kalgoorlie provides a reliable guide to the old drainage system, it seems that the main channel probably ran in a south-easterly direction from Kalgoorlie and may now lie beneath the salt-bush flats to the east of the salt lakes.

Immediately to the west of these lakes is a ridge of low hills running south-south-east through Mt. Hunt and Feysville. Outcrops of pre-Cambrian greenstone and sediments occur along this ridge. To the east of the lakes is a stretch of flat, sandy, salt-bush country terminated on the east by another ridge consisting of greenstone running through Boorara and Golden Ridge. The area investigated consists of a shallow valley about 7 miles wide, lying between the two ridges.

As a result of extreme folding, rocks in the area generally dip very steeply. The regional strike is approximately north-south.

Geophysical Problem and Methods Used.

From the geophysicist's point of view the problem reduces to the location of a buried channel or channels which may be anywhere beneath a belt of flat alluvial country about 7 miles wide, and of unknown depth below the present surface. The investigation of an area as large as this would clearly be very slow and expensive by drilling alone. By locating the deep ground by geophysical methods the drilling can be localized to places where concentrations of gold could be expected.

The ultimate aim of a geophysical survey such as this would be to produce a bedrock contour plan of the area. The preliminary work which was done was limited to two traverses (A and B), about 9 miles apart, running approximately north-east across the shallow valley between the two greenstone ridges. The position of these two traverses and a shorter one (A') is shown on Plate 1.

A Heiland 6-channel portable seismograph was used in the seismic survey. The shot holes (up to 6 feet deep) were put down with a post-hole digger. Charges up to 30 lb. of 50 per cent. or 60 per cent. S. N. gelignite were used and the shots were fired by means of a standard dynamo exploder. Portion of the firing pulse was fed to one of the recording galvanometers in order to register the zero time or shot instant. Heiland oil-damped geophones were used through the survey.

The field party consisted of one operator, and two field assistants who were supplied by Gold Mines of Kalgoorlie Ltd.

The reciprocal or difference method was used to determine the depth to bedrock, and geophone spreads (each covering 300 feet) were set up at intervals of approximately 1,000 feet along the two main traverses (A and B). In those parts of the traverses where the presence of a channel was indicated, intermediate spreads were added to obtain a continuous refraction profile in those particular sections.

It was also necessary to use short spreads (geophones 10 to 20 feet apart) to determine the velocity of the shallow surface layer which varied from 5 to 50 feet in thickness.

In addition to traverses A and B, a refraction profile was obtained along a short traverse (A′), about three-quarters of a mile north of traverse A (Plate 1).

Before commencing the seismic work a gravity survey was made along traverse A. Readings were taken at intervals of 100 feet, using a Heiland gravimeter with which changes in gravity of less than 1 milligal can be measured with an accuracy of $\pm 0 \cdot 05$ milligals. The gal (10^3 milligals) is the C.G.S. unit of acceleration (1cm/sec.^{2}). Changes of less than one part in a million of the earth's gravitational field can, therefore, be measured in this way.

After completing the gravity traverse, seismic profiles were obtained along traverses A, A′ and B, in that order.

For the surveying of the traverses the water level in the lakes was taken as the datum level and given the arbitrary value of R.L. 1,000 feet. At the time of the survey there was a continuous stretch of water over the lake country at the western end of traverses A and B which provided a convenient means of tying the levels of the two traverses.

Results and Interpretation.

The results of the gravity and seismic surveys are shown in the form of profiles on Plate 2.

The gravity profile.

The relative gravity values observed at each station on traverse A were corrected for drift, elevation and latitude effects, and after an arbitrary datum value had been chosen, the reduced gravity values were plotted, producing the observed gravity profile on Plate 2. The outstanding feature of this profile is the pronounced gravity "low" extending from the western end of the traverse to a point about 20,000 feet east. It is almost certain that a gravity anomaly of this magnitude would be produced by a mass of relatively light rock beneath this section, rather than a channel in the surface of bedrock. Two secondary "lows" occurring at 11,500E and 29,000E may, on the other hand, represent depressions in the surface of bedrock. Although it would have been difficult to make any definite predictions on the basis of these results alone, an attempt has been made to carry the analysis of the gravity profile a little further in the light of the results of the seismic work. This will be described later in this report.

The seismic profiles.

The results of the seismic survey were, on the whole, satisfactory and channels in bedrock were detected at several points along traverses A and B.

From the results obtained at each geophone spread, "refraction profiles" were constructed (Plate 2), showing the boundary surfaces from which refractions were obtained and the zones of different velocities of propagation.

The construction of the refraction profiles was based on calculations of layer depths (by the reciprocal method) beneath each of the four central geophones in each spread. Although these stations were in many places 1,000 feet or more apart, the trend of the refracting surfaces in the region between spreads could often be determined from a consideration of certain effects produced in the time-distance graphs by the outer shots of adjacent spreads.

Over the greater part of the traverses three distinct layers were observed.

The top layer was found to be quite shallow over most of the area, ranging in thickness from 1 or 2 feet to 50 feet, with an average value of about 20 feet. The velocities observed for this layer were between 1,200 feet per sec. and 2,510 feet per sec. with a mean value of 1,830 feet per sec. on traverse A and 2,010 feet per sec. on traverse B. It can be seen that on traverse A and the western half of traverse B the top of the second layer maintains a nearly horizontal horizon at the level of the water in the lakes at the western end of the traverses. Due to heavy rain which fell early in 1948 there was a continuous stretch of water from Hannan's Lake to Feysville at the time the survey was made.

The average velocity of the second layer was 6,100 feet per sec. on traverse A and 5,400 feet per sec. on traverse B. However, towards the eastern end of traverse B the velocity of this layer was lower, namely 4,000 feet per sec.

The depth of the second layer ranged from a few feet to 300 feet on traverse A and from 0 to 250 feet on traverse B.

The velocity of the third layer ranged between 11,000 and 20,000 feet per sec. over both traverse A and traverse B and, as the slope of the surface of this zone was found to be very irregular, the velocities obtained are liable to considerable error.

At a few parts of traverse A an intermediate layer was detected. Velocities observed in this zone were in the range 8,000 feet per sec. to 11,000 feet per sec.

Interpretation.

The interpretation of the refraction profiles was made by substituting for the different velocities, geological formations having elastic properties consistent with the observed velocities and with the known local geology.

During the comparatively short history of geophysical exploration a considerable amount of data has been collected (particularly in North America) concerning the velocity characteristics of different sub-surface materials. An analysis of this information shows that when attempting to differentiate between detrital material and "country" rock an interpretation of very low and very high velocities can generally be made without serious error. For example, velocities from 600 to 2,500 feet per sec. are generally produced by unconsolidated moist or dry sands, loams, clays and loose gravels, while velocities in the range 9,000 to 20,000 feet per sec. may be taken to represent formations such as shale, sandstone, granite, basalt, limestone, &c. Velocities in the intermediate range (2,500 to 9,000 feet per sec.) are, on the other hand, very difficult to interpret unless some local correlating data in the form of drill logs, &c., is available. For example, badly fractured or decomposed sandstones, granites or shales may have velocities as low as 2,500 feet per sec. whereas some saturated or compacted sands, clays and gravels have velocities as high as 8,500 feet per sec. When sands and gravels become highly saturated they often have a velocity of propagation close to that of water (about 5,000 feet per sec.). In such cases, velocities are often found to be remarkably constant over considerable areas.

From the observed velocities and the examination of shot holes it seems likely that the top layer consists mainly of sand and clay.

The second layer is in the range of velocities which is most difficult to interpret, however, as the velocity was found, fairly consistently, to be in the region of 5,000 or 6,000 feet per sec., and as the surface of the zone maintains a nearly horizontal horizon it was thought early in the survey that the boundary between the first and second layers represented a water table. In order to verify this, a test shaft was sunk at 18300E on traverse A to a depth of 40 feet. Water started seeping into the shaft at about 27 feet from the surface and when work was abandoned on the shaft the water finally rose to within 25 feet of the surface.

The shaft revealed successive layers of sand, dry clay, laterite, a heavy, white water-logged clay and, finally, a very heavy, purple clay. Water-worn pebbles found at the bottom of the shaft established the alluvial nature of the material. The layer of laterite was about 4 feet thick and occurred at a depth of about 20 feet. This evidence indicates that the second layer consists of water-logged alluvium.

Because all the recorded velocities in the third layer are higher than would be expected from any type of detritus, this zone represents "country rock"—probably pre-Cambrian greenstones and sediments.

At two or three spreads on traverse A the presence of an intermediate layer, in which the velocity ranged from 8,500 to 11,000 feet per sec., was detected. Velocities as high as this cannot be attributed to alluvium and it is possible that this zone consists of weathered "rock". Considerable depths of weathering are quite common on the Western Australian goldfields and it is possible that a weathered layer extends along a considerable part of traverses A, A′ and B.

If the bedrock has become decomposed to any great extent it will have lost all its original elastic properties and could have a "velocity" the same as that of the heavy, wet clay above. If such is the case, the depth to bedrock along traverses A, A′ and B may not be as great as shown in the refraction profiles. Furthermore, if the depth of weathering is extremely irregular the deep channels shown in the profiles may be nothing more than deeply weathered sections of the bedrock. It seems unlikely, however, that such is the case and although the general level of the surface of bedrock may be higher than shown in the refraction profile, the channels shown in the profiles are probably reflected in the surface of the decomposed bedrock at a higher level.

This uncertainty in the interpretation of the results can only be removed by deep test drilling.

Two channels stand out very clearly in the profile on traverse A. These are between 17000E and 20000E and between 27500E and 30500E. Both these channels are over 300 feet deep (unless there is a considerable depth of decomposed rock present). The deepest parts of both channels are at R.L. 700 feet.

Three channels can also be seen in the profile for traverse B. These are between 4000E and 7000E, between 16000E and 18500E, and between 20000E and 22000E. The R.L. of the deepest points of these channels is approximately 770 feet. If the channels located along traverses A and B are connected, the fall from traverse B to traverse A would, therefore, be about 8 feet per mile.

The refraction profile also indicates that there may be deep ground beneath the lake near the western end of traverse A. There is also the possibility that deep ground may exist beyond the western end of traverse B, beneath Hannan's Lake; a greenstone outcrop rises steeply from the western shores of this lake.

The channel between 17000E and 20000E on traverse A was observed again on traverse A′, but displaced about 1,000 feet to the west. The channel, therefore, appears to run in a south-easterly direction.

Having determined the trend of the bedrock surface along traverse A from the seismic survey, it is now possible to proceed further with the interpretation of the gravity profile.

Although the large "density anomaly" which appears in the "observed gravity profile" does not directly concern the investigation for deep leads in the area, it partly obscures the small anomaly between 17000E and 20000E which, it will be seen, is associated with the channel in bedrock which appears in the seismic profile. It is of interest however to determine the order of the changes in density of bedrock and the size of the rock masses required to produce a gravity anomaly of this kind.

By dividing the sub-alluvial bedrock into sections with different densities, several gravity profiles were calculated and compared with the observed profile. The theoretical profile which gave the best "fit" was calculated on the assumption that the bedrock beneath traverse A consisted of four different rock types in which the main densities were D_1, D_2, D_3 and D_4, where $D_1 - D_2 = 0 \cdot 2$, $D_2 - D_3 = 0 \cdot 1$ and $D_4 - D_3 = 0 \cdot 2$. It was assumed that the planes of contact between these different rock types are vertical and extend to a depth of 3,000 feet.

The position of the planes of contact is shown on Plate 2.

It has been suggested by Western Mining Corporation that the low density rocks might be the Black Flag sediments and that the denser rocks could be greenstones.

Density determinations were made on a number of drill core samples, taken from the Kalgoorlie mines, of both these rock types. The density of the Black Flag samples ranged from 2·71 to 2·75; and that of the greenstone samples (including calc schist and amphibolite) ranged from 2·86 to 3·23.

It therefore seems possible that even a complex structure of greenstone and Black Flag sediments could exist beneath traverse A and produce a "density pattern" similar to the one which was assumed in the calculations of the theoretical gravity profile. The densities D_2 and D_3 may therefore be due to a predominance of the Black Flag sediments down to a depth of 3,000 feet and the densities D_1 and D_4 may be produced by a predominance of greenstones down to the same depth.

When the theoretical "density" anomaly is eliminated from the observed gravity profile the "resultant" profile (see Plate 2) can be seen to correspond in many respects to the refraction profile. In particular, the small anomalies (about 1 milligal) between 17000E and 20000E and between 27500E and 30500E correspond closely in position and width to the deep channels indicated in the refraction profile.

Another small gravity ancmaly occurs between 11000E and 12500E and this also appears to be related to the small channel indicated at the same place in the refraction profile. Although this channel is not as deep as the two main channels on Traverse A, it may be worthy of further investigation.

The gravity work which has been done establishes the fact that the channels which have been located by the seismic method can also be detected by the gravity method. The latter method may therefore prove very useful if it is decided to carry out a comprehensive geophysical survey of the area between traverses A and B. This large area could be covered quickly and cheaply by a gravity party and with some control provided by a limited amount of seismic work or by drilling it should be possible to map the course of the channels shown on the two seismic profiles.

Conclusions.

As a result of the preliminary geophysical survey of the Kalgoorlie alluvial area, several deep channels in the sub-alluvial bedrock have been located at points along traverses A and B. Before undertaking any further geophysical work it was recommended that these channels be drilled in order to check the geophysical results and to determine whether or not significant gold values are present.

It was recommended that the large channel between 17000E and 20000E on traverse A be tested first (drill holes (1) and (2)). If these test bores confirm the interpretation of the geophysical results further drilling could then be done at the sites shown in Plates 1 and 2 in order to determine whether or not gold deposits of economic importance are present.

If, as a result of the test drilling, it is decided to continue with the geophysical survey it is considered that a detailed gravity survey would provide most of the information necessary to map the course of these channels and thus provide a guide for further drilling.

The geophysical survey indicates that the alluvial ground is too deep for dredging, and other more costly methods of exploitation of the deep leads, if present, would have to be employed.

ARDLETHAN, NEW SOUTH WALES.

Introduction.

The town of Ardlethan, on the Temora-Griffith railway, is approximately 330 miles west-south-west of Sydney. Tin was discovered near Ardlethan in 1912, and the total production of the field has been considerable. However, all mining activity ceased many years before the geophysical investigations were begun in 1949.

The bulk of the payable ore has come from the Carpathia, White Crystal, and New Venture Mines located at Yithan, about 3 miles north-west of Ardlethan (Plate 3). Two other important mines are Big Bygoo and Little Bygoo, 3 and 4 miles respectively north of the Yithan group. Several smaller companies and syndicates operated in these two areas with varying degrees of success.

Geologists of North Broken Hill Ltd. were interested in the possibility of finding payable deposits of alluvial tin shed from the Yithan, Bygoo and other deposits on the Ardlethan Tin Field.

At the time of the geophysical survey (1949) in the Bygoo area, shallow alluvial ground had been proved to the south of the Yithan mines. Drilling which was carried out subsequent to the geophysical survey showed that the lead which had been worked in the Yithan area was lying on a false bottom and a deeper lead was discovered at 160 feet, lying on bedrock. This lead has since been developed and has yielded satisfactory values in recent months.

Nothing was known, however, of the possibilities of the Bygoo area and the boundaries of the alluvial ground are not clearly defined. The company therefore asked the Bureau of Mineral Resources to carry out a geophysical survey in this area in order to define the zones in which accumulations of alluvial tin could occur.

Geology.

The geology of the Ardlethan tin field has been described in published reports by Harper (1919), Raggatt (1939, 1950a, and 1950b) and Garretty (1953).

Harper believed the sedimentary rocks in the Ardlethan area to be of Devonian age, but Raggatt considers that some at least are Silurian or Ordovician. Harper describes the sediments as mainly quartzites, fine-grained micaceous sandstones, and slates.

The Bygoo mines are located on the eastern slopes of a range of low hills running approximately north and south. These hills are composed of granite, which has intruded the sedimentary rocks subsequent to their folding, and cover a belt of country 5 to 8 miles wide, running south through the Yithan mines and beyond.

The Yithan mines are situated close to the eastern boundary of this granite belt, and Harper considers that this boundary between the granite and sedimentary rocks continues north and passes a little to the east of the Bygoo mines. The actual boundary, however, is completely obscured in the Bygoo area.

Flat country immediately to the east of the mines consists of material shed from the eastern slopes of the hills in which the Bygoo deposits were mined. It seems likely therefore that alluvial tin may be found in this area.

Application of the Seismic Refraction Method.

The object of the preliminary geophysical survey, which was carried out in October, 1949, was to determine bedrock profiles along three traverses across the alluvial area immediately to the east of the Bygoo mines. It was hoped to find one or more "gutters" in the sub-alluvial bedrock in which concentrations of alluvial tin could be expected.

The seismic equipment used in the survey consisted of a Heiland 12-channel mobile recorder, Heiland shooting truck and water tender, and a Failing shot-hole drill. The field crew consisted of an operator and assistant, driller and assistant, and one shooter. A surveyor and staff man were supplied by North Broken Hill Ltd. and a company geologist remained with the party during the survey.

Three north-south traverses, each about three-quarters of a mile long, were surveyed. The position of these traverses (A, B, and C) is shown on Plates 3 and 5.

Results and Interpretation.

The refraction profiles obtained along traverses A, B, and C are shown on Plate 4. Beneath a shallow surface layer of soil and hard clay in which the velocity was found to be 2,200 feet per sec., there is a band of hard, rocky material in which the velocity is of the order of 5,000 feet per sec. The actual thickness of this hard zone is not known, but from shot holes which have been drilled through it, it appears to be generally about 20 feet. A rock bit had to be used for most of the drilling through this rocky layer, but in some places the rock was not quite so hard and an ordinary drilling bit could be used.

Below this hard zone there is a considerable depth of "3,000 feet per sec." material consisting of a heavy white and brown clay in which a mass of small quartz particles is imbedded. This material was thought to be decomposed granite. The next refraction occurs at depths ranging from 30 to 260 feet, where the velocity of propagation rises sharply to approximately 19,000 feet per sec. It is now considered that this refracting surface corresponds to the surface of unweathered granite and that the overlying layers consist mainly of alluvium. A zone of decomposed granite may be included in the 3,000 feet per sec. layer, although the zone of decomposition is unlikely to extend more than 40 feet above the surface of the unweathered granite and is unlikely to obscure any deep gutters in the bedrock.

During the early part of the survey it was thought that the shallow refracting layer represented the old land surface, and short geophone spreads and close shot points were used in order to trace the surface of this layer. Consequently, it was not always possible, from the records so obtained, to calculate directly the depth of the deeper refracting surface. However, when a deep drill hole, put down at 2,400 feet N. on traverse C, passed 30 feet of sand at a depth of approximately 200 feet it seemed certain that all material down to this depth consisted of alluvium and that the deep refracting surface was the significant one. This bore hole was stopped in very hard material (presumably bedrock) at R.L. 195 feet.

A wider distribution of geophones and shot points was subsequently used on traverse C and a complete profile of the deep refracting surface was obtained. This profile is in good agreement with the bore hole at 2,400 feet N.

It was not convenient at the time to repeat the work on traverses A and B but it has been possible to make use of the records obtained on those traverses to determine approximately the profile of the deeper refracting surface. This approximation involves the assumption of a value for the velocity of bedrock based on values obtained in the other parts of the area. Points on the profiles on Plate 4 which were obtained by this approximation are shown by small circles and points known with greater certainty are shown by large dots.

With two exceptions, values obtained for the velocity in bedrock ranged between 17,000 and 20,000 feet per sec., with a mean value of 19,000 feet per sec. On two geophone spreads, however, a value of 14,500 feet per sec. was obtained. These spreads were between 1,200 N. and 2,400 N. on traverses A and B. It is possible that this lower velocity indicates the presence of sedimentary rocks in this area.

CONCLUSIONS.

An interpretation of the refraction profiles is shown in the form of a bedrock contour plan on Plate 5. It would be possible, however, to make other slightly different interpretations of the profiles and a complete picture of the configuration of bedrock in the area cannot be obtained until further refraction work or drilling has been done. Nevertheless, it is considered that the presence of a gutter running in a north-easterly direction, and crossing the southern end of traverses A, B, and C, is fairly well established. It is also clear from the contour plan that very deep ground exists at the northern end of the area covered by the seismograph survey, but the course of the channels here cannot be determined until further work has been done.

An important conclusion to be drawn from the survey is that the alluvial ground to the east of the Bygoo mines is much deeper than had been anticipated and that the working of alluvial leads may prove very costly.

On the basis of the seismic results, Mr. L. W. Parkin, geologist of North Broken Hill Ltd., made a recommendation to his company that a test drill hole be put down at the point 1,400 feet north on traverse C. This recommendation was supported by members of the Exploration Section of the company, but because of a change in the exploration policy of the company, the hole was never drilled. It might be well to point out that the shot-hole drill used in the seismograph survey was not suitable for sampling for tin values. The company proposed to use a churn drill for this purpose.

Since the geophysical survey was carried out, payable quantities of tin have been found at a depth of 160 feet in the Yithan area. This discovery has shown that the previously known shallow leads were lying on a false bottom and that the newly found deeper lead is lying on bedrock. This discovery should revive interest in the Bygoo area, as the geophysical work has shown that similar conditions exist there.

At Yithan it has been possible to make the initial investigations of the deep lead by drilling, as the course of the upper part of the channel is quite well defined by outcrops of bedrock on either side. At Bygoo, however, there are no surface indications, and if further investigation of this area is to be made it is considered that additional seismic work would be very useful. A clearer picture of the bedrock topography would be obtained by extending traverses A, B, and C, and by the addition of two traverses to the west of traverse A.

WELLINGTON, NEW SOUTH WALES.

INTRODUCTION.

For several years alluvial gold dredging operations have been carried out by Wellington Alluvials Ltd. along the banks of the Macquarie River, near Wellington, New South Wales (Plate 6).

The gold is found in a course wash, distributed along the river valley. The alluvial area, along which the company holds extensive dredging leases, is generally not more than one-quarter of a mile wide and is well defined by high rocky outcrops along both sides of the river. The wash is in most parts covered by 20 to 50 feet of overburden, consisting of a sandy black soil, and the surface of the wash corresponds approximately to ground water level.

Extensive boring along the dredging leases has revealed the presence of a narrow channel in the bedrock beneath the gold bearing wash along which the Macquarie River flowed at an earlier time. However, sampling of the borings has shown that the horizontal and vertical distribution of the gold in the wash does not bear any clear relation to the position of the old river channel.

From the boring which has been done, bedrock contour plans have been constructed by officers of Wellington Alluvials Ltd. A knowledge of the configuration of bedrock is of value in planning future dredging operations. It is necessary, for example, to avoid areas of very shallow ground which may not be dredgable. These contour plans are, however, incomplete or unreliable in those parts of the area where little boring has been done. For this reason, the company requested the Geophysical Section of the Bureau of Mineral Resources to undertake a geophysical survey of the dredging leases in order to make possible the construction of a complete bedrock contour plan.

Geology.

The depth to bedrock over most of the area is generally not more than 100 feet and the rocks which crop out on each side of the river are mainly andesite and slates with small areas of limestone.

The bore logs show that the same rocks occur under the alluvium.

Application of the Seismic Refraction Method.

Along the leases held by Wellington Alluvials Ltd., boring has revealed three different layers which would be expected to possess distinct seismic propagation properties.

The overburden, consisting of fairly light sandy soil, should have a velocity of less than 2,000 feet per sec. The wash, consisting of a water-saturated gravel, would be expected to have a velocity close to that of water—4,000 to 5,000 feet per sec. The velocity of bedrock would be relatively high and, as drilling has shown that very little decomposition has taken place, could range from 10,000 to 20,000 feet per sec., depending on whether the bedrock is slate, andesite or limestone.

Before undertaking a large scale survey of all the dredging leases, it was decided to test the suitability of the method by obtaining one or two bedrock profiles along bore lines in order to check the accuracy of the results. Bore lines E E F and F (Plate 7, Fig. 2) were selected, as they provided fairly complete profiles. These lines were pegged and levelled at intervals of 50 feet by a company surveyor. Bore line G was also pegged and levelled in case an additional test line was required.

The survey was commenced in July, 1949, on bore line E E F, using a portable, six-channel Heiland recording camera and Apache geophones. Fifty per cent. ammonium-nitrate gelignite was used for initiating the seismic waves, the charges being detonated electrically, using a standard dynamo exploder and instantaneous detonators designed specifically for seismic work. The shot holes were put down with a manually operated post-hole digger. The field party consisted of a geophysicist of the Bureau and two field assistants supplied by the company. The company also supplied the gelignite used in the preliminary tests.

The reciprocal method was tried initially on bore line E E F but it was impossible to obtain satisfactory records without using abnormally large charges. Because of the thickness and poor transmission qualities of the overburden, it was necessary to use shots of 50 lb. at a depth of 15 feet in order to obtain a good response on the reciprocal geophone. It had been anticipated that charges of 20 lb. at a depth of 6 feet would have been sufficient. It was immediately clear, therefore, that the survey would prove more costly and much slower than had been expected. The traverse along bore line E E F was completed using the time-intercept method because, although this method is generally applied in surveys where the surface of bedrock has a fairly uniform slope, it is not necessary to shoot over such long distances as in the reciprocal method. In this way the consumption of explosives was reduced but the results obtained were very erratic and were in error by as much as 50 per cent. It was apparent, therefore, that owing to the irregularity of the surface of the bedrock the time-intercept method was not applicable and the reciprocal method was subsequently used on bore line F.

RESULTS AND INTERPRETATION.

The initial interpretation of the results obtained on bore line F was very disappointing, the calculated depth to bedrock being 10 to 50 feet greater than that shown by the bore logs. However, it was noticed that the difference between the calculated and actual values of the depth to bedrock was greatest in those parts of the profile where a particularly high value was obtained from the time-distance curves for the velocity in the wash. The values obtained were generally higher than anticipated, ranging from 5,000 to 8,000 feet per sec. It was thought, therefore, that the velocity in a horizontal direction near the surface of the wash, as obtained from the slope of the time-distance graph, might be higher than the mean velocity in a vertical direction through the total thickness of the wash, as used in the depth calculations. In order to make a direct measurement of this value, a geophone was lowered to the bottom of a recently completed bore hole (No. 15 on bore line E E F) before the casing had been removed from the hole. Another bore hole (No. 17) 2 chains away had been taken to a depth of 28 feet, i.e., nearly to ground-water level. A small charge was fired at the bottom of this hole and the time taken for the wave to travel to the geophone resting on the top of bedrock at the bottom of bore 15 was recorded. Although an exact figure could not be obtained for the velocity of the wash from this experiment, it was shown that the value was not greater than 5,000 feet per sec. No opportunity arose for further experiments of this kind.

It was also found that by using a value of 5,000 feet per sec. for the velocity in wash, the refraction profile on bore line F could be made to fit the known profile quite closely, the error being less than 10 per cent. over most of the traverse, although at one point the error was about 25 per cent. As there was no reason to expect large errors in the depth calculations from any other source, it was considered that the value of 5,000 feet per sec. for the velocity in the wash below ground-water level could be used in future refraction work in the area, and that the accuracy of the results could be expected to be of the same order as obtained on bore line F. These results were, however, not sufficiently accurate to meet the company's needs, particularly in view of the high cost of the survey, and upon completing the traverse on bore line F the survey was temporarily discontinued.

Although it appeared undesirable to continue with a detailed seismograph survey of the dredging leases, it was considered that some useful work could be done in the region of the sharp bend in the river between bore lines F and K where insufficient boring had been done to indicate the course followed by the old river channel.

Profiles along the five traverses in this area were obtained in November, 1949, using a large mobile plant consisting of a shot-hole drill, water tender, shooting truck, and a twelve-channel recording truck. By using the shot-hole drill it was possible to place the shots at the top of the wash and so reduce the absorption of energy by the overburden. A further economy in the use of explosives was made by virtue of the fact that twelve geophones could be used instead of six, thus reducing the number of shots necessary to survey a given length of traverse. By the use of this larger equipment the consumption of gelignite was reduced from approximately 250 lb. per 1,000 feet of traverse to less than 40 lb. per 1,000 feet. The speed of working was increased from approximately 250 feet of traverse per day to more than 1,000 feet per day. The size of the field party required to operate this plant was, of course, greater than with the six-channel recorder. The crew consisted of one operator and assistant, a driller and two assistants and one shooter who loaded the holes and fired the shots.

In both surveys, the velocity in the overburden, obtained from the time-distance graphs, was 1,200 feet per sec., but in the later survey a value of 1,500 feet per sec. was obtained from the "up-hole" times recorded by placing a geophone at the top of each shot-hole. The value of 1,500 feet per sec. was used in the calculation of the overburden correction, because it was obtained by direct measurement. When this value was applied to the results obtained on the test line along bore line F it was found that the first refraction was coming from a surface at R.L. 105 feet. As this surface is probably associated with ground-water level rather than with the top of the wash, it was assumed that the first refraction obtained in the area covered by the later survey also occurred at R.L. 105 feet and this was used in the calculation of the overburden correction on all profiles. It seems unlikely that any serious error will be introduced by this assumption.

As in the earlier survey, values greater than 5,000 feet per sec. were obtained for the velocity in the wash from the time-distance curves, but the value of 5,000 feet per sec. was used in the calculations as before.

The profiles obtained on the test line along bore line F and all the profiles obtained in the later survey are shown on Plate 7, Fig. 1.

The velocities obtained in the bedrock fell into three distinct groups, the mean value in each group being 10,000, 17,000, and 20,000 feet per sec. It is probable that these velocities represent slate, andesite and limestone respectively.

The bedrock contour plan (Plate 7, Fig. 2) has been constructed from bore-log data supplied by Mr. Canavon, of Broken Hill Pty. Co., and from the results of the seismograph survey.

Later boring on a new line F F B indicated the possibility of a tributary channel coming in from the west on the main channel between bore lines F and F B, as indicated on the contour plan. The presence of such a channel can only be confirmed, however, by further boring or by additional refraction work.

An unexpected result of the later refraction survey was the indication of a channel crossing the profile D D′, well to the east of the main channel. This has been interpreted in the bedrock contour diagram as indicating the presence of an anabranch leaving the main channel near bore line I and rejoining it near bore line F A as is suggested by the twin channels shown in profile A A′ between 1,200 feet and 1,900 feet east. It could also be possible, however, that deep ground in the region of profile D D′ is due to a tributary channel coming in to the north of the rock outcrop near bore line K.

DRILLING RECOMMENDATIONS.

On the assumption that a gold-bearing channel in this region could be economically dredged, it was recommended to the company that one or two bores be put down along profile D D′ to test the results of the seismic survey and to determine gold values. It is understood that these recommendations were not followed up by the company, as it was considered that dredging of such a channel would not be an economical proposition.

ACKNOWLEDGMENTS.

It is desired to acknowledge the co-operation of the Manager, Mr. Marshman, and staff of Wellington Alluvials Ltd., who rendered every possible assistance in the carrying out of the field work. The writer also wishes to thank Mr. Canavon, who supplied much information in the form of plans, profiles, and bore log data. Thanks are also due to Mr. Costello, Broken Hill Pty. Co., who undertook the preliminary survey work and later rendered valuable assistance in the geophysical work.

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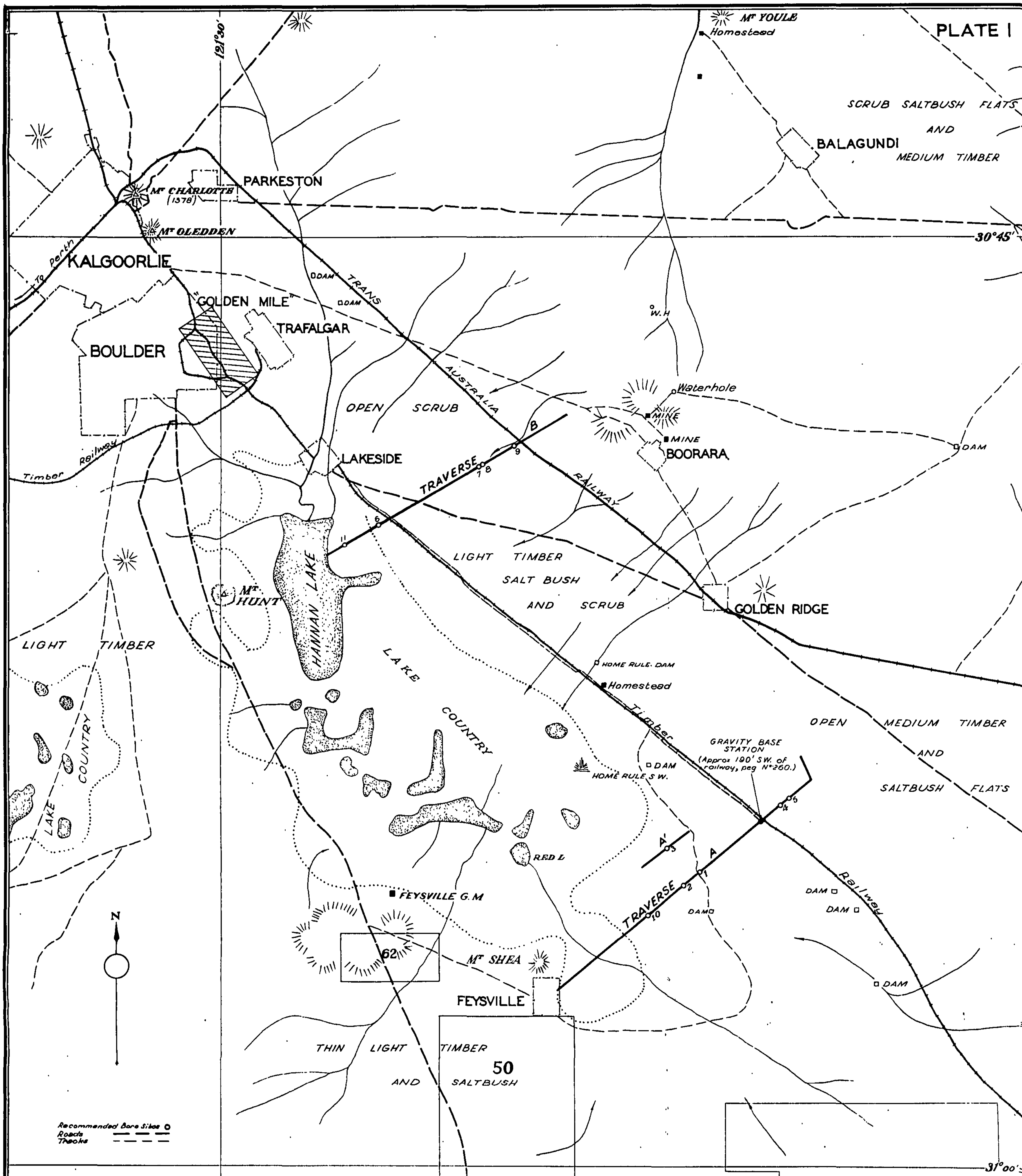


PRELIMINARY GEOPHYSICAL SURVEY FOR DEEP ALLUVIAL GOLD LEADS

KALGOORLIE W.A.

PLAN SHOWING
PORTION OF ALLUVIAL AREA AND APPROXIMATE LOCATION OF
GRAVITY AND SEISMIC TRAVERSES.

D. Urquhart.
Geophysicist
31.5.49

SCALE
1 0 1 2 3 Miles

G61-1

Geophysical Section, Bureau of Mineral Resources Geology and Geophysics.

8523/55

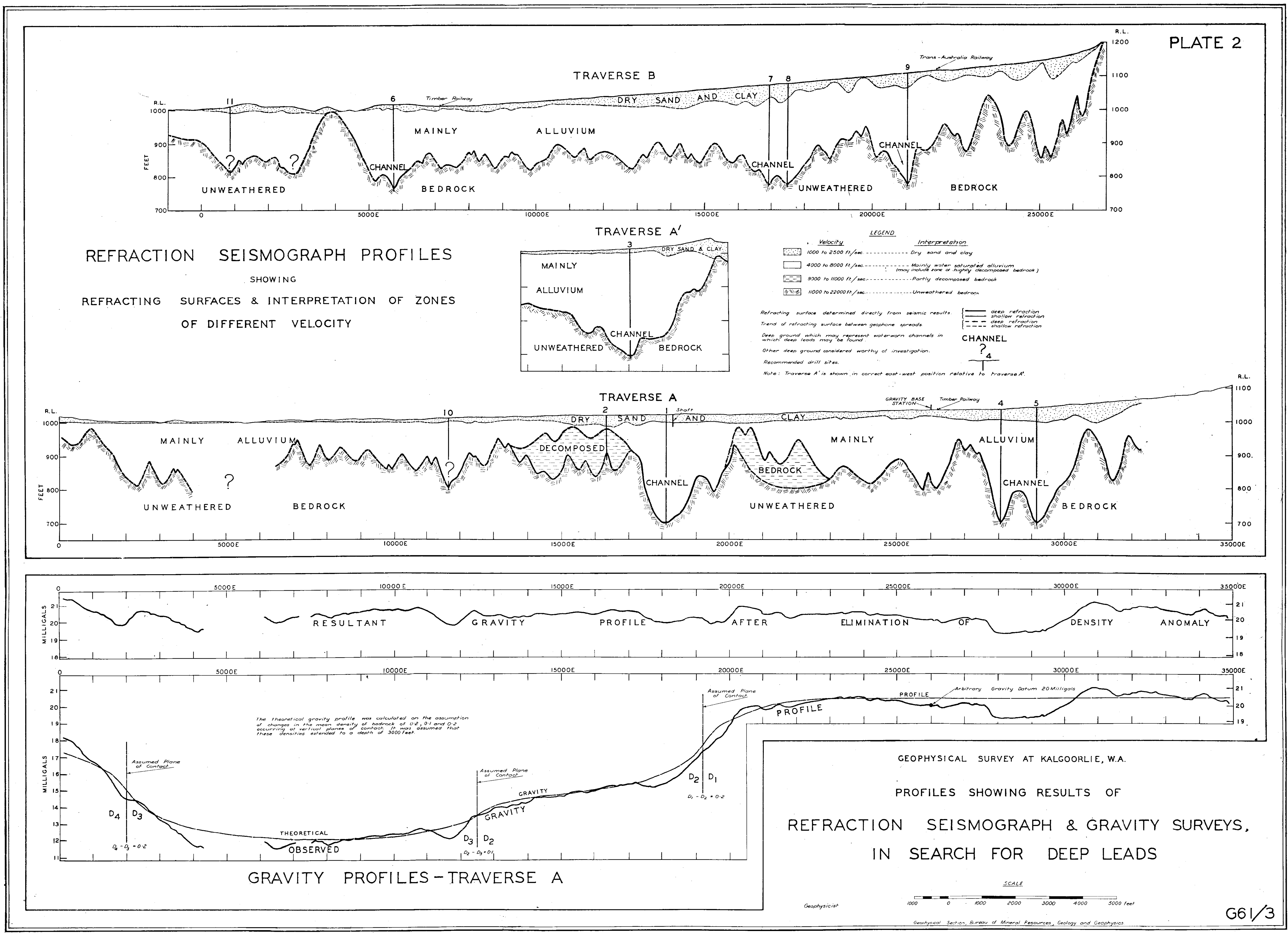
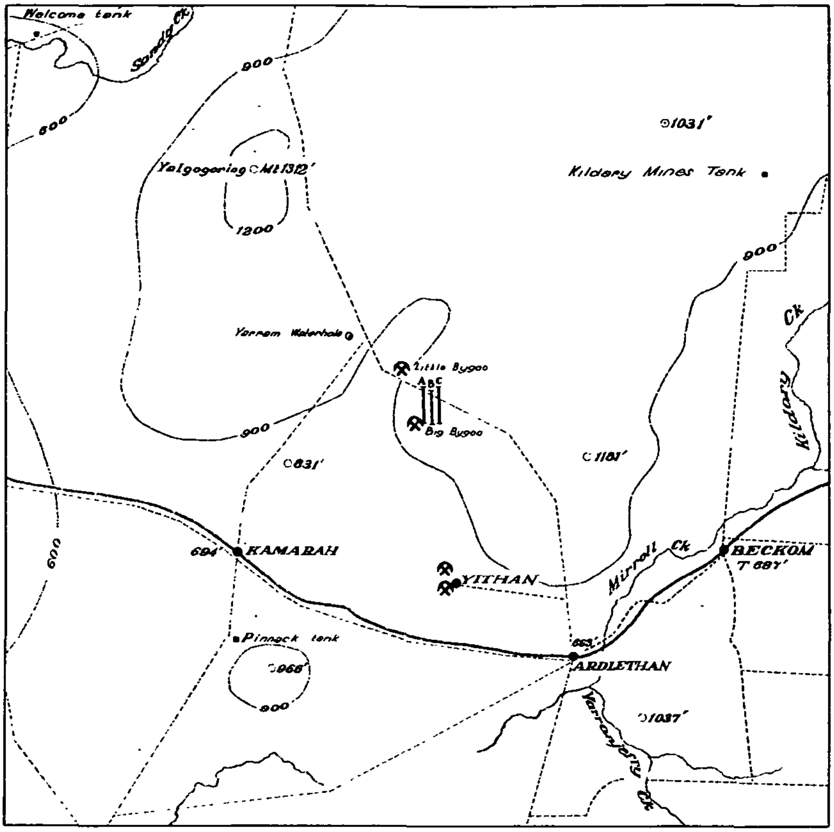


PLATE 2
TRAVERSE B
Trans-Australia Railway
Timber Railway
DRY SAND AND CLAY
MAINLY ALLUVIUM
CHANNEL
UNWEATHERED BEDROCK
R.L.
FEET
TRAVERSE A'
DRY SAND & CLAY
MAINLY ALLUVIUM
CHANNEL
UNWEATHERED BEDROCK
REFRACTION SEISMOGRAPH PROFILES
SHOWING
REFRACTING SURFACES & INTERPRETATION OF ZONES
OF DIFFERENT VELOCITY
LEGEND
Velocity / Interpretation
1000 to 2500 ft./sec. — Dry sand and clay
4000 to 8000 ft./sec. — Mainly water saturated alluvium (may include zone of highly decomposed bedrock)
9000 to 11000 ft./sec. — Partly decomposed bedrock
11000 to 22000 ft./sec. — Unweathered bedrock
Refracting surface determined directly from seismic results. deep refraction / shallow refraction
Trend of refracting surface between geophone spreads. deep refraction / shallow refraction
Deep ground which may represent waterworn channels in which deep leads may be found. CHANNEL
Other deep ground considered worthy of investigation.
Recommended drill sites.
Note: Traverse A' is shown in correct east-west position relative to traverse A'.
TRAVERSE A
GRAVITY BASE STATION
Timber Railway
Shaft
DRY SAND AND CLAY
MAINLY ALLUVIUM
DECOMPOSED BEDROCK
CHANNEL
UNWEATHERED BEDROCK
MILLIGALS
RESULTANT GRAVITY PROFILE AFTER ELIMINATION OF DENSITY ANOMALY
The theoretical gravity profile was calculated on the assumption of changes in the mean density of bedrock of 0·2, 0·1 and 0·2 occurring at vertical planes of contact. It was assumed that these densities extended to a depth of 3000 feet.
Assumed Plane of Contact
Arbitrary Gravity Datum 20 Milligals
THEORETICAL
OBSERVED
GRAVITY PROFILE
$D_4 - D_3 = 0{\cdot}2$
$D_2 - D_3 = 0{\cdot}1$
$D_1 - D_2 = 0{\cdot}2$
GRAVITY PROFILES – TRAVERSE A
GEOPHYSICAL SURVEY AT KALGOORLIE, W.A.
PROFILES SHOWING RESULTS OF
REFRACTION SEISMOGRAPH & GRAVITY SURVEYS,
IN SEARCH FOR DEEP LEADS
SCALE
1000 0 1000 2000 3000 4000 5000 feet
Geophysicist
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics
G61/3



LEGEND

- Tin Mines
- Seismograph traverses
- Roads
- Railways

SCALE

2 0 2 4 MILES

Note. Plan enlarged from 4 mile = 1 inch Military map. Reliability sketchy

D.F. Urquhart.

GEOPHYSICAL SURVEY

AT

ARDLETHAN, N.S.W.

SHOWING

LOCATION OF TIN MINES

&

SEISMOGRAPH TRAVERSES

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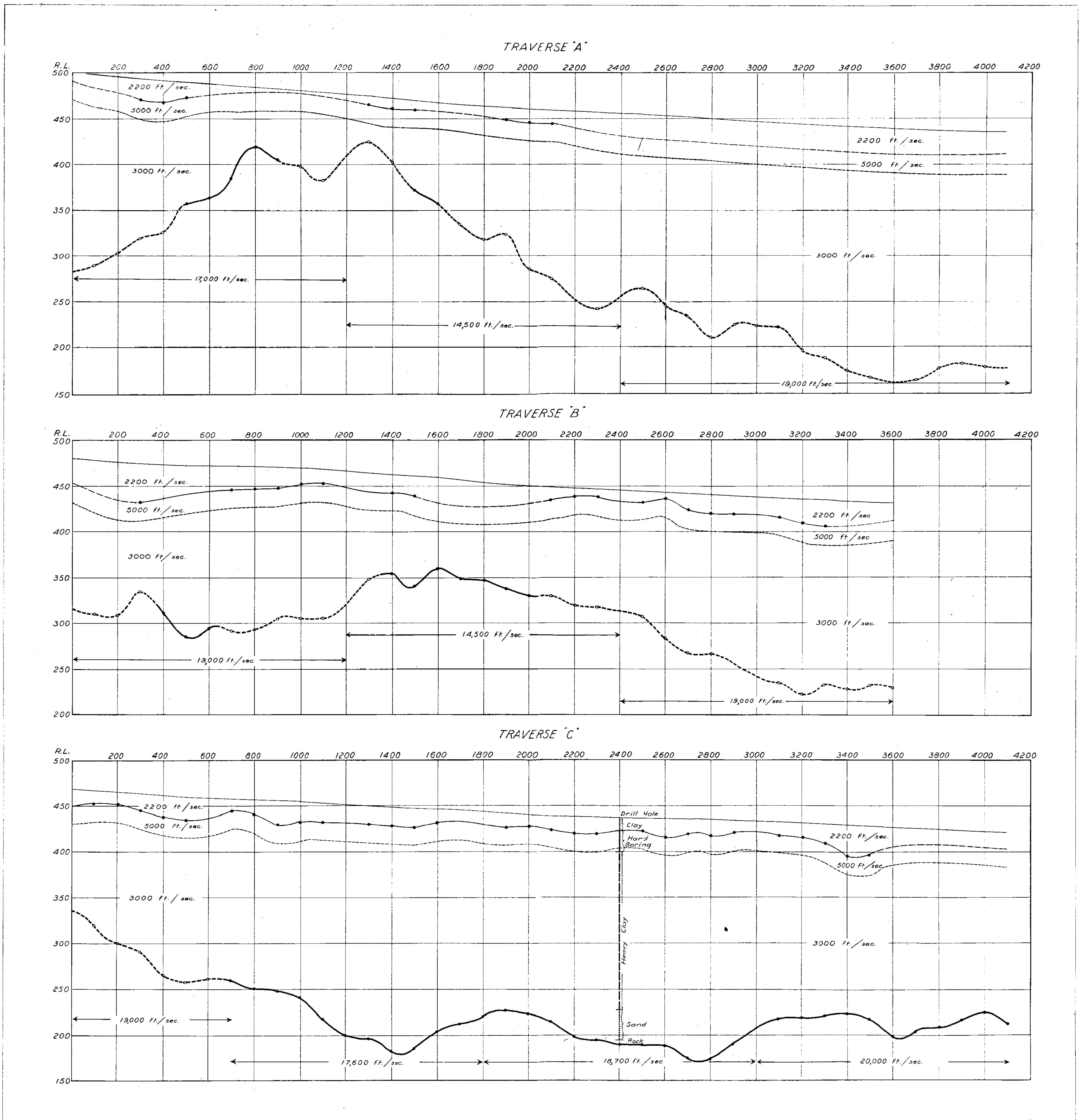
8523

PLATE 4



GEOPHYSICAL SURVEY AT ARDLETHAN, N.S.W.

BYGOO MINES AREA.

SHOWING

REFRACTION SEISMOGRAPH PROFILES

WITH

REFRACTING SURFACES AND

LAYERS OF DIFFERENT VELOCITIES

LEGEND

—•— Surface of bedrock determined by seismic survey

- - - - - Approximate surface of bedrock determined by seismic survey

Note: The thickness of the 5000 ft./sec. layer could not be determined from the seismic survey. Drilling indicates that it is about 20 feet thick.

SCALE

Vert. 50 0 50 100 Ft

Horiz. 200 0 200 400 Ft

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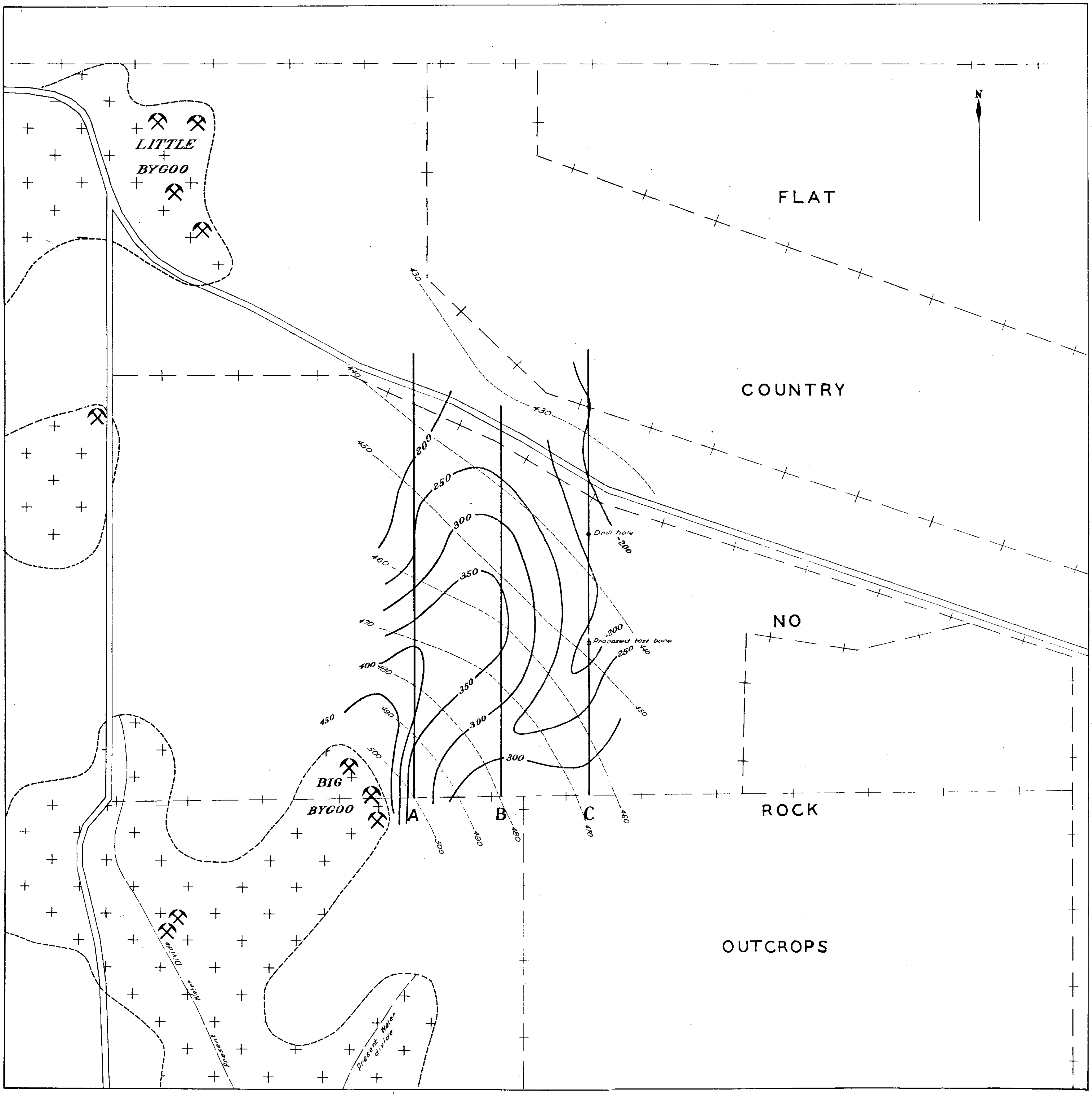
G75-2



LEGEND

- ⚒ Tin Mines
- Granite outcrops
- —300— Bedrock contours
- --450-- Present surface contours
- +— Fences

Note:- Contour numbers are reduced levels referred to an arbitrary datum of 500 feet.

SCALE

500 0 500 1000 1500 FEET

Plan enlarged from 40 chains = 1" Parish map (Reliability - Sketchy)

Geology supplied by North Broken Hill Ltd.

Geophysicist.

GEOPHYSICAL SURVEY AT ARDLETHAN, N.S.W.

BYGOO MINES AREA

SHOWING

SEISMOGRAPH TRAVERSES

AND

PROBABLE BEDROCK CONTOURS

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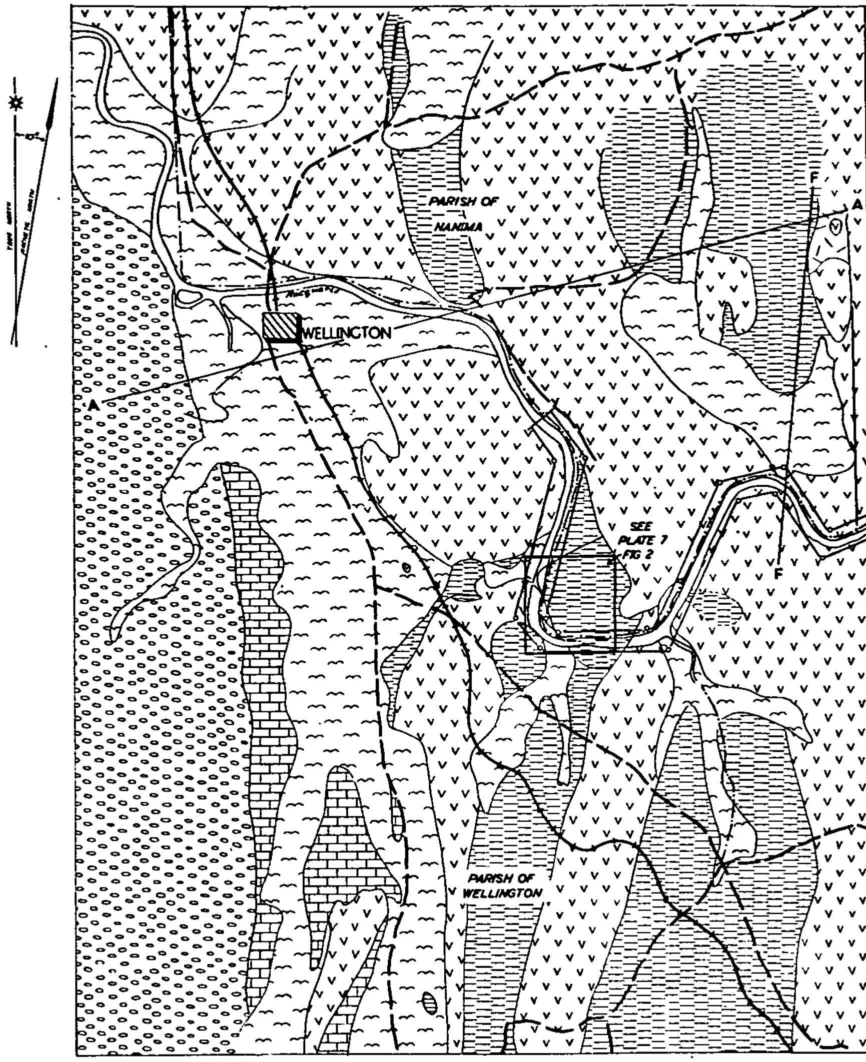
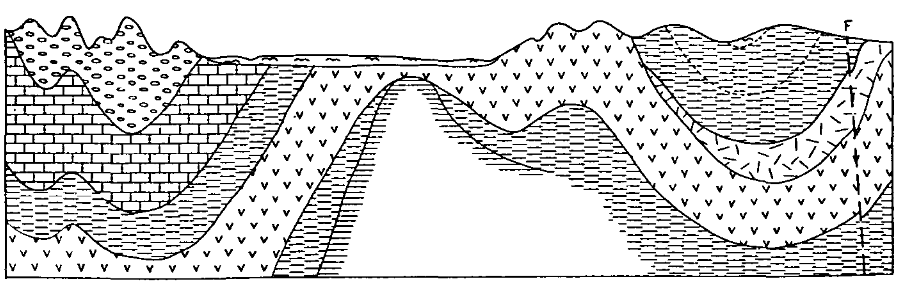
PLATE 6



SKETCH SECTION AA



LEGEND

ALLUVIUM	RECENT	
CONGLOMERATE ETC.	DEVONIAN	
LIMESTONE		
SHALE LIMESTONE ETC.	SILURIAN	
LAVA		
SLATE	ORDOVICIAN	
LAMPROPHYRE		

ROADS & TRACKS — RAILWAY

PARISH BOUNDARIES

APPROXIMATE BOUNDARY OF AREA LEASED BY WELLINGTON ALLUVIALS LTD. FOR DREDGING

SCALE IN MILES

1 0 1 2 3

GEOPHYSICAL SURVEY AT WELLINGTON, N.S.W.

SEISMIC REFRACTION SURVEY
ON
ALLUVIAL GOLD DREDGING LEASES

LOCALITY PLAN SHOWING GEOLOGY, PORTION OF AREA LEASED BY WELLINGTON ALLUVIALS LTD. & AREA IN WHICH SEISMIC SURVEY WAS MADE

NOTE - GEOLOGY COPIED FROM PLAN SUPPLIED BY WELLINGTON ALLUVIALS LTD.

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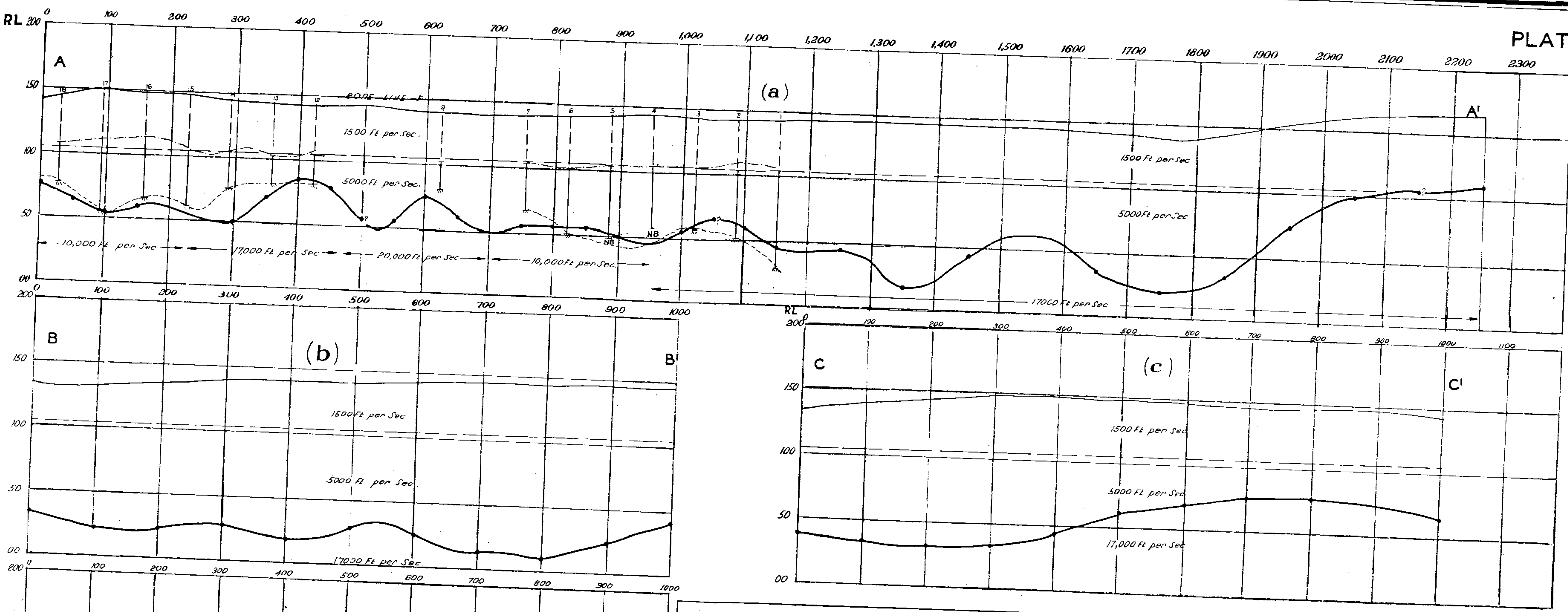
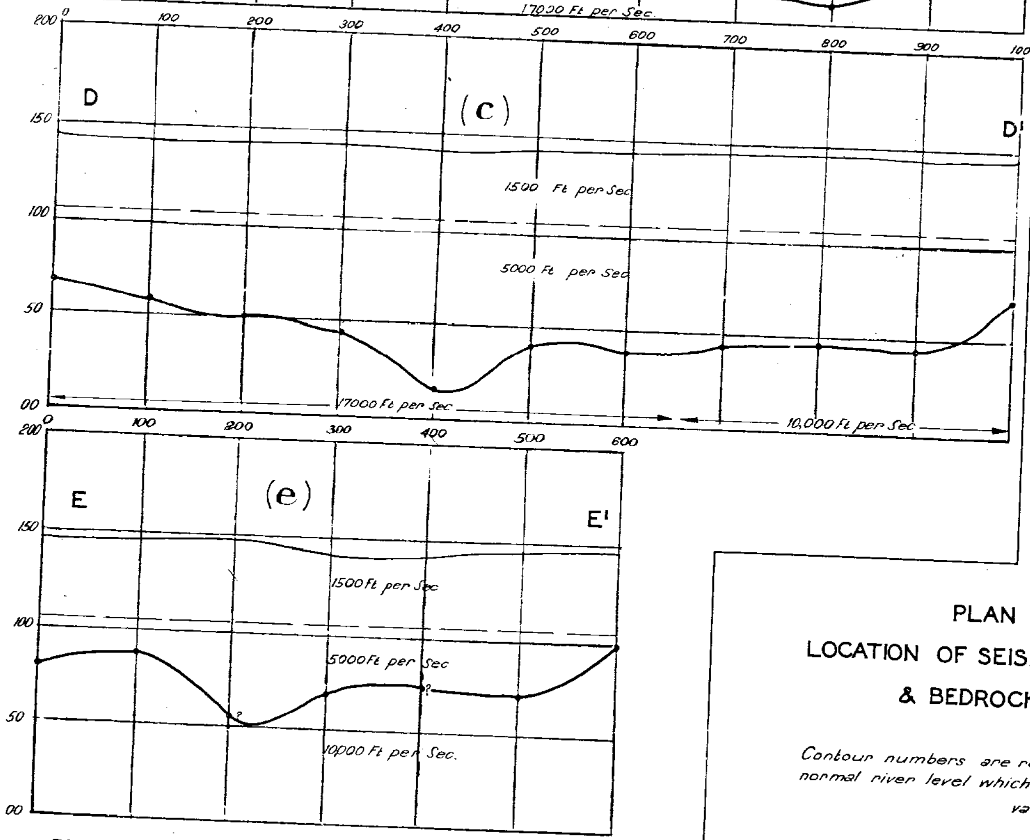
G64-2

PLATE 7





PROFILES SHOWING REFRACTING SURFACES AND ZONES OF DIFFERENT VELOCITIES.

FIG. I.

LEGEND

Overburden
Wash
Bedrock

Bore holes shown thus

Bore bottomed on andesite

Bore bottomed on slate

Bore not bottomed

Surface of bedrock deduced from seismograph survey

Ground water level

Surface of bedrock deduced from bore logs

Surface of wash

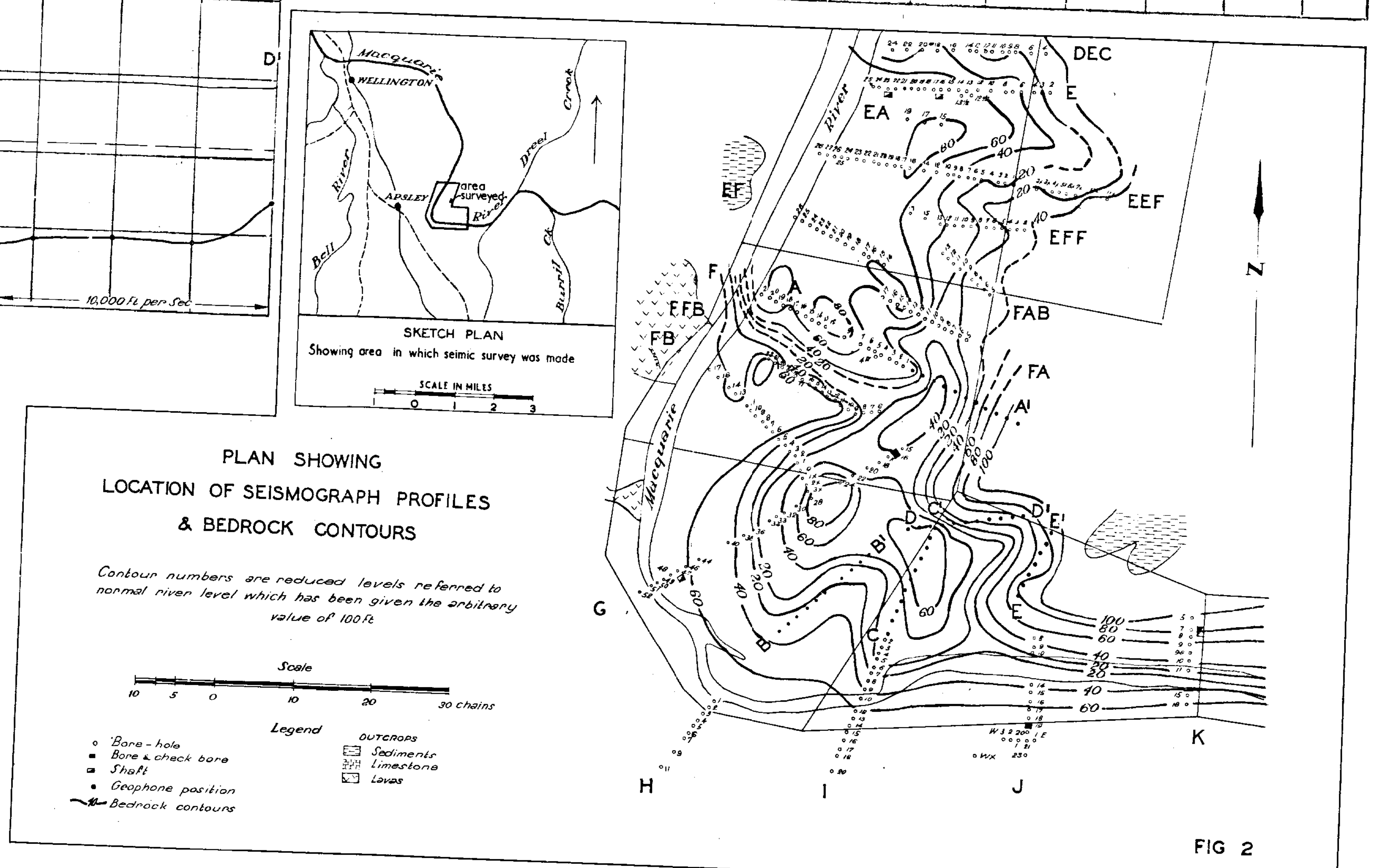


FIG 2

SCALE

Vertical 50 0 50 100 150 Feet

Horizontal 100 0 100 200 300 Feet

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GEOPHYSICAL SURVEY AT WELLINGTON N.S.W.

SEISMIC REFRACTION SURVEY

ON

ALLUVIAL GOLD DREDGING LEASES.

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