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Preliminary Report

GEOPHYSICAL INVESTIGATION BURDEKIN RIVER BRIDGE SITE

by

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DEPARTMENT OF SUPPLY AND SHIPPING

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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PRELIMINARY REPORT

GEOPHYSICAL INVESTIGATION BURDEKIN RIVER BRIDGE SITE

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PRELIMINARY REPORT

GEOPHYSICAL INVESTIGATION BURDEKIN RIVER BRIDGE SITE

I. INTRODUCTION

The Burdekin River enters the Pacific Ocean on the eastern Coast of Queensland about 60 miles ~~S.E.~~ of Townsville, ~~and~~ the coastal railway from Brisbane to Cairns crosses ~~it~~ two miles north of the town of HomeHill and about 10 miles from its mouth. Where the railway crosses the river its bed is a little less than half a mile wide and it is bridged by a low level bridge of wooden trestle construction.

For nearly nine months of the year the river proper is confined to a narrow channel two ~~or~~ three hundred feet wide, the rest of the bed comprising low banks of coarse sand and gravel lyingal 10 to 15 feet above water level. During the remainder of the year however the river is subject to periodical flodings resulting from tropical ~~downpours~~ on its water-shed and for periods of a week or more at a time the low level bridge is covered by flood water. The ~~serious~~ dislocation of rail traffic which results from these periodical floodings ~~have~~ been a matter of serious concern to the Queensland authorities for many years and a decision has now been made to construct a high level rail and road bridge to replace the existing structure. The construction of the new bridge has commenced already. Three large concrete Caissons which will be piers from the new bridge are being cast and sunk near the south bank of the river on the new bridge line which is five chains up stream from the present bridge. It is intended to sink these one hundred feet into the unconsolidated material which overlies bedrock at the bridge site.

Drilling which preceeded the construction of the existing bridge indicated that bedrock is not shallower than 146 feet at a point approximately five chains south of the northern bank. The deepest ~~material logged by~~ the driller ~~(at 146 feet) was~~ "quartz" which was not generally accepted as indicating bedrock. Other holes drilled on the existing bridge line were bottomed at depths of less than 100 feet below river bottom in river material such as sand and ~~cemented~~ wash. It ~~is~~ generally believed that at the new bridge site bedrock would lie at depth considerably in excess of 150 feet and might even be several hundred feet deep.

Before the construction of the bridge had proceeded far, however, it was considered desirable that the depth to bedrock should be established without doubt. Further drilling was the obvious means of doing this but in view of the uncertainty of the depth to be drilled and the very considerable difficulty in drilling through alternating layers of drift sand and boulder wash a request was made by the Co-ordinator General of Public works for Queensland for a geophysical investigation of the site. A geophysical survey was carried out by the geophysical section of the Commonwealth Bureau of Mineral Resources, Geology and Geophysics, during August and September 1947. The investigation of the results is far from complete but the seismic method gave such concise results that this preliminary statement is justified.

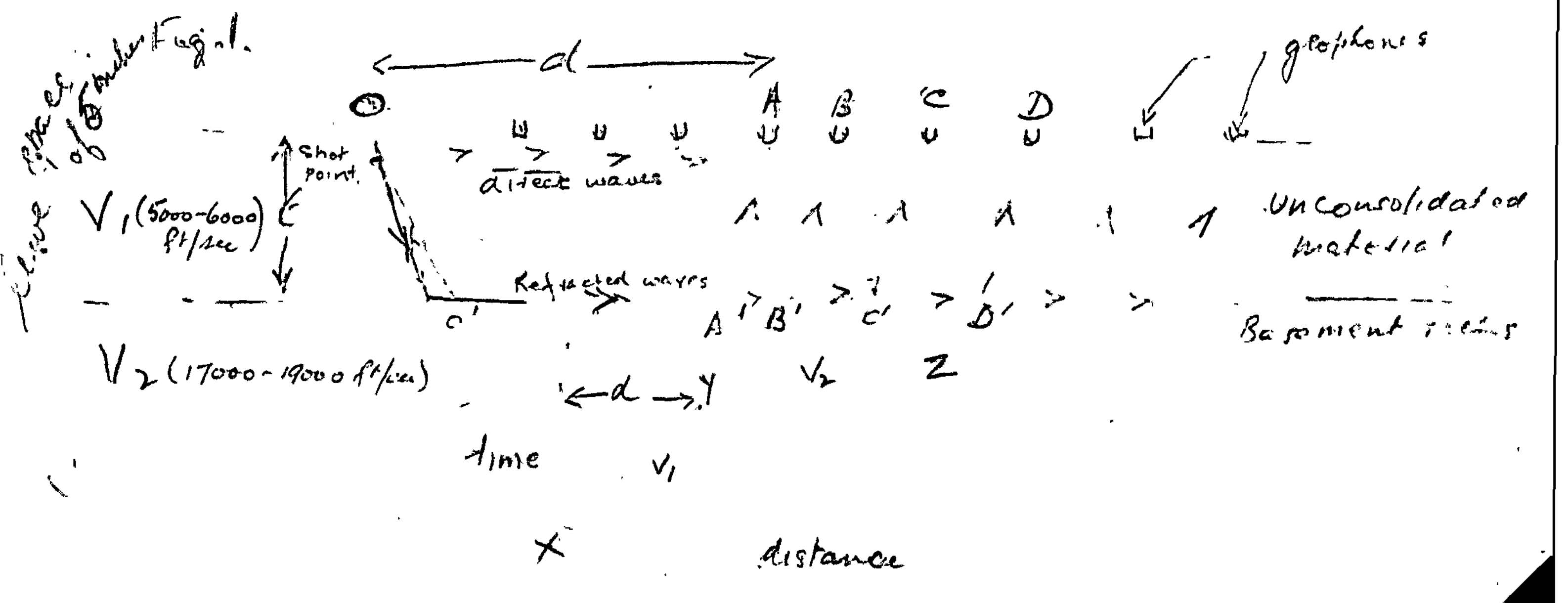
II GEOLOGY

The geology of the Burdekin River Bridge Site is simple. It is in fact an area in which an unknown thickness of alluvial material comprising sand, clay, and wash overlies a basement which is believed to be substantially gneissic granite freely intruded by dykes of fine grained porphyrites and diorites as well as porphyries. The area covered by alluvium is extensive and forms a coastal plane some ten to thirty miles wide. Both upstream and downstream from the bridge site and for many miles on either side of the river sugar cane is cultivated and it is irrigated by wells sunk in individual farms. These wells are for the most part shallow and rarely exceed fifty feet deep but in every one excellent water is obtained in layers of drift sand similar to that encountered in the bores which were put down to test the foundation of the existing bridge. In addition to the river which intersects this plane there are numerous bullabongs and marshes which by virtue of these alignments are evidently older courses of the river. In the course of time the river may have flowed anywhere across the coastal plane. In the first place it would have carved its channel in the basement rocks and later as the stream deposited sand and wash brought from its higher reaches the stream bed was elevated to its present position. Neither the present topography nor the position of the river give any clue as to where the channels in the basement rocks might lie.

III THE GEOPHYSICAL METHODS AND THEIR APPLICATION TO THE PROBLEM

The problem to be solved by geophysical means was that of determining within reasonable limits of accuracy the thickness of alluvial material overlying the granite basement rocks. Three methods were used namely refraction seismic, gravity and electrical resistivity. Of these the seismic method appears to have been the most reliable but the results of the others has been valuable in interpreting the seismic results.

The refraction seismic method is one in which an elastic wave is generated in the ground by exploding a charge and the time of travel for this wave is recorded at different points on the surface. The velocity of the elastic wave is relatively slow in the unconsolidated material (5000 - 6000 feet per second) and relatively fast in the solid basement rocks (17000 - 19000 feet per second). For recording points near the explosion point the waves that arrives first travels directly through the unconsolidated material at the slower velocity. At more distant points however the wave to arrive first is that which travels down to the basement rocks, is reflacted along the top of the basement rocks through which it travels with the higher velocity and finally upwards through the unconsolidated material. The different paths taken by the direct and refracted waves are shown in figure (1)



The times of travel between the explosion point and the recorder station are plotted against the distance. At a point A at a distance "d" from the explosion point the wave that travels at the slower velocity direct from O to A arrives at the same time as the wave that travels down to O' at the slower velocity, from O' to A' at the fast basement velocity and finally from A' to A at the slower velocity. Recorders at distances greater than 'd' will record first the refracted waves ray and those at distances less than 'd' will record first the direct waves.

It will be seen that the slope of the graph XY represents the velocity (V_1) in the unconsolidated material while the portion YZ represents the velocity (V_2) of the basement rocks.

From a knowledge of V_1, V_2 and d it is possible to calculate the thickness (t) of the unconsolidated material.

The foregoing is a very abreviated and simplified explanation of the refraction seismic technique but it is substantially correct. A more detailed description of the technique actually employed on the present survey will be given in a later report or if the reader so wishes he can refer to a standard text book (1) on geophysical prospecting.

b Gravity. - In the gravity method a sensitive spring belance is used to weigh a small gold mass at different points in the area being investigated. Variations in the gravitational attraction produce corresponding variations in the weight of the mass so that the instrument measures variation in the gravitational attraction "g". Naturally the instrument used to record these variations is extremely sensitive and the one used on the present survey was capable of measuring changes of "g" of the order of one part in 50 million. Changes in "g" are recorded and corrected for changes due to elevation and latitude and the corrected readings can then, in simple problems, be related to the geological section underlying the recording station. The unconsolidated sand, gravel wash and clay which overlie bedrock at the bridge site were collectively less dense than the basement rocks. It was expected therefore that the gravitational attraction would ~~therefore~~ be reduced from that

(1) eg. C.A. Heiland - Geophysical Exploration Prentice Hill 1940

measured directly on the basement rocks by an amount that can be directly related to the thickness of the unconsolidated material providing of course that the basement rocks themselves were uniform in density.

The electrical resistivity method measures the way in which electrical resistivity varies with depth. Four electrodes are placed in the ground in line at equal intervals (a). A measured current is passed through the ground between the outer pair and the potential drop between the inner pair is measured. In effect the measurement is one of the electrical resistance in the ground for a given electrode separation (a). While (a) is small most of the current flows in the near surface layers but as (a) is increased a bigger percentage of the current flows in the deeper layers which consequently have more influence of the resistance to current flow. Figure 2 is a sketch of the electrode arrangement for small and a large separations with a diagrammatic representation of the lines of current flow.

The apparent resistivity of the ground is related to the resistance (R) measured and the electrode separation (a) by

$$r = 2 \pi a . R.$$

values of r are plotted against their corresponding values of a and from the curve so drawn it is possible in simple problems to determine the thickness and resistivity of the layers.

The geological section at the bridge site seemed to be a suitable one for this technique. It was believed that the water saturated sands and gravels would have a relatively low and uniform resistivity whilst that of the basement rocks would be high by contrast. The interpretation of so called resistivity curves is however, rarely simple and seldom ~~concise~~ precise.

IV RESULTS AND INTERPRETATION.

(a) Seismic

The results of the seismic investigation are shown in the form of a tabulation (Table 1) and a contour plan. The contour plan also shows the location of the points at which the tests were made. Prior to tests being made in the river bottom some time was spent at a site approximately 12 miles up stream from the bridge site near where the basement rocks were outcropping. The rocks here comprised gneissic granite with dykes of porphyrite - the dyke rocks being more abundant than the granite. These tests were particularly valuable in that velocities known to ~~definitely~~ correspond to the basement rocks were obtained. These ~~varied from~~ averaged approximately 18000 ~~to 19000~~ feet per second which is ~~high even~~ what one would expect for rocks of this kind. In later tests in the river bottom at the bridge site and elsewhere velocities of this order were obtained for the refracted waves, and consequently it has been assumed that the material in which these refracted rays travelled is bedrock of a kind similar to that for which the above mentioned velocities were obtained. The whole interpretation of the seismic results hinges on this assumption so that before proceeding to a discussion of the results in general it is proposed to examine the assumption more critically and to consider the alternatives, if any.

Seismic velocities of all classes of rocks have been measured during the course of investigation of oil structures, bridge and dam foundations, deep leads and in many other problems in vaste numbers during the past decade and summaries of the measurements have appeared in text book on geophysics. Heiland (1) for example lists hundreds of rock types ranging from sedimentary rocks to igneous. Of

(1) C.A. Heiland op. cit.

the sedimentary rocks, limestones, especially those which are compact and strongly cemented have velocities which range between 12000 and 17400 feet per second. Other types of sedimentary rocks have velocities considerably less than this for example sandstones range from 6000 to 14000 feet per second whilst shales have velocities generally somewhat less than sandstone of comparable age. Deeply buried sandstones and shales (e.g. under more than 20,000 feet of cover) have velocities which may be as high 18000 to 19000 feet per second.

Unconsolidated materials like clay, sand and gravel have relatively low velocities not in excess of 7000 feet per second.

If the material in which the refracted waves travel is not the igneous basement rock then it is necessary to assume the presence of a layer of rock of sedimentary origin with a velocity of 18000 to 19000 feet per second. The lists of wave velocities discussed above give no clue as to what such a layer could be. Cemented wash has been encountered in some of the bore holes at the present bridge site but no list was found in which the velocity of cemented wash was given. It could conceivably have a velocity as high as 18000 feet per second.

Even if it were conceded that cemented wash could have a velocity as high as 18000 feet per second, however, there are several reasons why it is considered unlikely that energy is being refracted in such a layer. These reasons may be stated briefly.

(1) Those layers of cemented wash which have been encountered have been only a few inches thick and it is unlikely that layers of this thickness would refract sufficient energy to produce the effects recorded.

(2) If a cemented layer of thickness (say 10 to 15 feet) sufficient to produce the measured effects existed one would expect, from purely geological reasons, that the layer would be more or less horizontal. The tests showed, however, that the depth of the refracting layer varied between 110 feet and 150 feet in a relatively short distance.

(3) If there was a layer of cemented wash say 10 to 15 feet thick in an otherwise unconsolidated section it should be possible by means of the electrical resistivity method to estimate its thickness. The electrical results, however, indicated that the material in which the refracted waves travelled has a thickness which is probably in excess of several hundreds of feet although its resistivity is less than would have been expected for a granitic basement rock.

The main uncertainty in the nature of the refracting material arises from the gravity results which show a negative anomaly (reduction in "g") more or less circular in shape, some 4 to 5 miles in diameter and centered approximately 1½ miles due south of the bridge. In appearance this anomaly is similar to those obtained over deep sedimentary basins (e.g. Leigh Creek, S.A. and Collie, W.A.) and to account for the anomaly (about 10 milligals) it would be necessary to assume a thickness of perhaps 2000 to 3000 feet of relatively light sediments in the centre of the supposed basin. Alternatively the gravity anomaly could be due to a more or less circular plug some 3 to 4 miles in diameter of intrusive rock less dense than the known basement rocks and of very considerably vertical dimensions. It is suggested that the anomaly body may be a rhyolite plug, rhyolites being generally less dense than granitic rocks.

From the geological view point the latter alternative seems the most probable. Rhyolite plugs are known to occur at Reid River within 40 miles of Home Hill and at Mount Leyshon, Mount MaWe and 70-Mile Mountain south of Charters Towers. The existence of such a plug could be consistent with -

(a) The high basement velocity at the bridge site.

(b) The occurence of the gravity minimum anomaly.

(c) Relatively low electrical resistivity of the "basement" rock.

The seismic results are presented in the form of a tabulation (table I) and a contour plan. The basement elevations have been reduced to State Datum (mean sea level) and the contours are related to the same datum.

Values, in addition to that shown on table I, of depths to basement were obtained at "shot-holes" up stream and down stream from the various seismic stations and these additional values have been used in plotting the contours. The seismic evidence points to the surface of the basement rocks being very uneven and for this reason basement elevations shown in table I are only given to the nearest 5 feet.

The approximate position of the deepest bore hole (146 feet) on the present bridge line is shown on the contour plan. ~~The deepest material logged in~~ This bore bottomed in "quartz" at an elevation of approximately - 132 feet (State Datum). It would appear from the seismic results that this bore reached basement or at least got close to it. The "quartz" logged may have been derived from a quartz vein in the basement rocks or may have been derived from a coarse basal conglomerate composed chiefly of quartz.

Seismic stations No. 1 and 2 are not shown on the accompanying plan. They were located in the bed of the river near the road crossing approximately one mile down stream from the present bridge. Depths to basement at these two stations and their associated shot-points were generally greater than at stations near the bridge site, but in view of the irregular basement surface indicated by the seismic results these greater depths are believed to have no special significance.

Electrical tests were made at seismic station No. 4 and near stations 2, 7 and 11. The results have not been investigated fully but in a general way they confirm the seismic interpretation. The significant feature in all four resistivity curve is the indication of an interface between relatively conductive material and resistive material beneath it, at depths corresponding approximately to the seismic basement depths. The change in resistivity can be attributed to a change from water saturated unconsolidated materials to a compact basement rock of low porosity.

The electrical results indicate that the bottom resistive material has a very considerable thickness, at least in excess of several hundred feet.

The gravity results have been described briefly above where reference was made to the large circular gravity minimum centered about 1½ miles south of the bridge. This anomaly has, superimposed on the broader pattern, various local disturbances which appear to represent variations in thickness of the unconsolidated material. The detailed gravity work which was carried in the vicinity of the bridge site has not been investigated to date owing partly to the fundamental difficulty in separating these local effects from the broader anomaly. However, it is believed that further investigations of the results may lead to a more detailed pattern of bedrock contours at the bridge site.

V. TESTING.

The results of the seismic investigation were conveyed verbally to the Engineer in charge of the bridge construction

(Mr. Lowe) and arrangements are in hand to commence confirmatory drilling. It is understood that the first hole to be drilled will be from the base of a test cylinder which is sunk 50 feet into the bed of the river near seismic station No.5.

VI CONCLUSIONS

The geophysical survey of the Burdekin River Bridge Site has indicated the presence, at depths ranging from approximately 110 ft to 150 feet below ~~the surface~~ State Datum, of a compact rock in which seismic velocities of the order of 18000 feet per sec. were recorded. From geological and geophysical evidence it is ~~claimed~~ ~~considered~~ concluded that this rock is the igneous basement ~~for~~ in which the original channels of the Burdekin River were carved. Although the results of electrical and gravity survey have not been investigated fully to date it is believed that they support this ~~claim~~ conclusion.

Drilling to test the results is recommended and is being arranged by the authorities in charge of Bridge Construction.

VII ACKNOWLEDGEMENT

The ready co-operation in carrying out the field survey, the keen interest in and appreciation of the geophysical work shown by the officers of the Co-ordinates General of Public Works, the Main Roads Commission and other authorities associated with the bridge construction is gratefully acknowledged. In particular, the co-operation of the resident engineer, Mr. H. C. Lowe, and his staff is acknowledged.

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T A B L E   I

BURDEKIN RIVER BRIDGE SITE

RESULTS OF SEISMIC TESTS

Station Number	Reduced Level of Basement (State Datum)	Mean basement Velocity (feet per sec.)
1	- 135 feet	18,450
2	- 150 "	18,800
3	- 115 "	18,250
4	- 110 "	17,700
5	- 105 "	18,100
6	- 110 "	18,200
7	- 110 "	17,900
8	- 120 "	18,200
9	- 110 "	18,700
10	Results not yet investigated completely	
11	- 110 feet	17,000
12	- 110 "	19,600

Elevations represent the means of several determinations at each station and are expressed to the nearest five (5) feet.

BURDEKIN RIVER BRIDGE SITE – AYR N.Q.

SEISMIC INVESTIGATION

OF

DEPTH TO BASEMENT

SEISMIC STATIONS SHOWN THUS --------- ◎ 10
BASEMENT CONTOURS ARE ON STATE DATUM

SCALE 1 INCH EQUALS 200 FT