COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORDS 1955, No. 89

SEISMIC VELOCITY SURVEY IN ROUGH RANGE No. 1 WELL, WESTERN AUSTRALIA

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ABSTRACT

At the request of West Australian Petroleum Pty. Ltd. and the Department of Mines, Western Australia, the Bureau carried out a seismic velocity survey in Rough Range No.1 Well, with the object of obtaining velocity distribution data for use in the interpretation of results of seismic refraction surveys in the area.

Twenty-two shots were fired from a shot point about 1,000 feet from the well. Geophone depths in the well ranged from 2,000 feet to 14,000 feet, usually at intervals of 500 feet, but the intervals were varied at points where there was a significant change in the stratigraphy. Recordings from 16 of the shots were used in the calculations.

Results indicated that, as would be expected, the hard crystalline limestone which comprises the top 700 feet of section has a much higher velocity than the clastic limestones which underlie it. An abrupt velocity change from 7,100 ft/sec. to 12,600 ft/sec. at 3,250 feet corresponds approximately with the change from Windalia Radiolarite to Muderong shale, and also with a density change from 2.1 to 2.4. A second major velocity change from 12,600 ft/sec. to 16,500 ft/sec. at 6,800 feet also corresponds approximately with a density change from 2.5 to 2.7. An abnormal increase in velocity recorded at about 9,000 feet must be considered as very doubtful and velocities at this depth have been averaged.

1. INTRODUCTION

Rough Range is a small topographical feature in the North-West Division of Western Australia (latitude 22°25'S, longitude 114°04'E), and extends southward for about 10 miles from exmouth Gulf Homestead (see Plate 1). The maximum elevation of the range is about 400 feet above sea level. The physiography is a reflection of a surface geological structure - an anticline in Tertiary limestones. The West Australian Petroleum Pty. Ltd. commenced drilling its first exploratory oil well on Rough Range in September, 1953 and completed it at a depth of 14,607 feet in January, 1955. It was this well, Rough Range No.1 which produced oil at a depth of 3,603 feet in November, 1953.

At the company's request, the Bureau of Mineral Resources, Geology and Geophysics conducted a seismic velocity survey of the hole on the 21st and 22nd February, 1955. The purpose of the survey was to obtain a velocity distribution curve for use in the interpretation of results of seismic reflection surveys in the area. The survey was made by E.R. Smith (Bureau geophysicist), M.J. Garrett (company geophysicist) and two assistants provided by the company. The equipment used was supplied by the Bureau.

The well seismometer used was a three-element vertical component type manufactured by Technical Instrument Company, U.S.A. The seismometer was fitted with a Schlumberger Universal Head, which enabled it to be lowered into the well by the cable and winch attached to the Schlumberger well-logging unit under contract to the company. The recording equipment used was a Heiland 12-channel reflection seismograph.

2. PROCEDURE.

(a) Shooting.

Normally, shooting is done from at least two shot holes, at different distances from the well. This enables a more accurate correction to be made to the observed slant times to convert them to equivalent vertical times, and also enables a check to be made on whether the seismic energy has travelled through the geological section or whether it has travelled down the geophone cable, giving rise to "cable breaks" (Dix, 1952, pp.118-124), For this survey, two shot holes were drilled - S.P.1, 1,500 feet east of Rough Range No.1 and cased to a depth of 275 feet, and S.P.2, 1,010 feet from Rough Range No.1 on a bearing of 88° and cased to 200 feet. Unfortunately, S.P.1 was lost to a depth of 170 feet, which was above the water level, and it was impossible to raise this level so that a charge at 170 feet would be tamped with water. Consequently, all the shooting was done from S.P.2. However, for reasons that will be stated later, it is believed that the energy recorded at the geophone was seismic energy which had travelled through the geological section. The quantity of explosive needed to produce sufficient seismic energy to be recorded satisfactorily at the well geophone ranged from 20 lb. when the geophone was at 2,000 feet to 100 lb. when the geophone was below 11,000 feet.

(b) Recording.

The depths to the well geophone were at 500 feet intervals throughout most of the hole, but these were varied at points where there was a significant change in the stratigraphic section. At depths of 3,350 feet, 3,475 feet, 3,600 feet, 6,225 feet and 9,200 feet, the interval was varied to suit the section. The last two intervals were increased to 1,500 feet and 1,300 feet respectively, as there is little variation in the section near the bottom of the hole.

The output from the well geophone was recorded through two different channels in the recording equipment. One channel was held at high gain to enable a good "first break" to be obtained, while the other was at low gain so that any secondary events recorded at the well geophone could be studied. A "reference" geophone was placed near the top of the well and was recorded on another channel of the instrument. This geophone acted as a check on the time break, and also enabled corrections to be made for any time delays or advances related to the shot; these often exist when several shots are fired in the same hole. Five other geophones were placed at intervals of 110 feet on a line running south from the well, to record any reflections that might occur at this location.

3. <u>RESULTS</u>.

Twenty-two shots were fired in S.P.2 with the well geophone placed at depths ranging from 2,000 feet to 14,000 feet. Of these shots, twelve gave good first breaks which could be picked to within 1 millisecond and were graded "A", four gave fair first breaks which could be estimated to within 2 milliseconds and were graded "B", another four were so poor that there was no certainty as to where the first break came and were graded "C", and a further two were not readable. Only those recordings graded as "A" or "B" have been used in the calculations.

The times observed for the paths from the shot to well geophone were first corrected to a common datum level, which was chosen as sea-level. The elevation velocity used to calculate these corrections was 9,000 ft/sec., this being obtained by uphole shooting in S.P.2. These corrected "slant" times, plotted against the depths of the well geophone below sea-level are shown on Plate 2, Fig.1. The grade of the recording from which these times have been taken is shown.

The slant times are corrected to equivalent vertical times by multiplying them by the cosine of the angle between the vertical and the direction from the geophone to the shot reduced to the datum. These vertical times are also plotted on Plate 2, Fig.1. Features of this vertical time-depth curve are:-

(i) If the curve is produced to cut the time axis, it does not pass through the origin but actually cuts it on the negative side of the origin. This would be the case if there was a high velocity section near the surface; in fact, the top 700 feet of section penetrated by Rough Range No.1 Well is hard crystalline limestone which would be expected to have a much higher velocity than the clastic limestones which underlie it. The reference geophone gave further evidence of this high velocity near the surface, as the time for the energy to travel the 1,010 feet from the shot to the reference geophone was only 0.093 milliseconds, indicating a horizontal velocity of 10,800 ft/sec.

(ii) At a depth of 3,250 feet below sea-level, there is an abrupt change in the slope of the curve, indicating a change in velocity from 7,100 ft/sec. to 12,600 ft/sec. This depth corresponds closely to a change of geological formation, namely from Windalia Radiolarite to the Muderong Shale, which occurs at 3,285 feet below sea-level (D. Scott, personal communication). The density log (Plate 2, Fig.3), which has been plotted from data provided by West Australian Petroleum Pty.Ltd., shows that there is also a density change at this depth from an average of 2.1 to 2.4.

(iii) A second major change in the slope of the curve occurs at 6,800 feet below sea-level, where the velocity changes from 12,600 ft/sec. to 16,500 ft/sec., and once again there is a corresponding density change from 2.5 to 2.7 at 6,500 feet.

(iv) The velocity below 9,000 feet is 18,200 ft/sec., which is extraordinarily high.

The time-depth curve described above and shown in Plate 2, Fig.1 shows that the energy received at the geophone travelled through the geological section and not through the cable, for the following reasons:-

(a) The cable velocity expected would be about 9,000-10,000 ft/sec. but the actual velocities measured were 7,100 ft/sec., 12,600 ft/sec., 16,500 ft/sec. and 18,200 ft/sec.

(b) The change from 7,100 ft/sec. to 12,600 ft/sec. occurs almost exactly at a stratigraphic and density break in the section, and consequently the energy must have been travelling in the geological section at this point to be affected by the change.

From each individual time and its corresponding depth, an average velocity for the section down to that depth can be calculated. These average velocities are plotted against depth on Plate 2, Fig.2. This shows that the average velocity is 8,170 ft/sec. to a depth of 1,764 feet, but then decreases to 7,640 ft/sec. at 3,239 feet. This effect is caused by the high velocity limestone at the surface. Below 3,239 feet the average velocity increases fairly uniformly, reaching a value of 12,540 ft/sec. at a depth of 13,764 feet below sea-level.

The interval velocities at the various depths are also plotted on Plate 2, Fig.2. These interval velocities are actually the average velocities of the section between adjacent depths at which readings were taken. These show clearly the two increases in velocity at 3,250 feet and 6,800 feet which have previously been noted from the study of the time-depth curve.

The large increase from the low interval velocity of 12,720 ft/sec. between 8,264 feet and 8,964 feet to the high interval velocity of 22,360 ft/sec. between 8,964 and 10,464 feet is caused by an abnormal time recorded at 8,964 feet. This time lies about 12 milliseconds off the straight line drawn through the other points near this depth. The first break recorded at this depth is quite good, being graded as an "A", and it seems unlikely that the time is in error by more than one millisecond. It is also considered unlikely that the depth is in error, as it would require a mistake of approximately 250 feet on the part of the Schlumberger operator. It was considered at first that this time might have some definite relation to the geological section, but detailed density data recently received from the company and plotted on Plate 2, Fig.3 does not show any such relation. On the other hand, the velocity of 12,720 ft/sec. seems too low for this depth when compared with velocities measured above it, and the value of 22,360 ft/sec. is almost beyond the limits of velocities recorded for sedimentary rocks throughout the world. Thus, in spite of what has been said above concerning the time measured at 8,964 feet, it must be regarded with suspicion. For this reason an alternative value of 18,030 ft/sec. has been calculated for the interval velocity between 8,264 feet and 10,464 feet, neglecting the time recorded at 8,964 feet. This is shown on Plate 2, Fig.2 by a dotted line.

No reflections were recorded from the section on the five geophones which were set out south of Rough Range No.1.

4. REFERENCE.

Dix, C.H., 1952 - SEISMIC PROSPECTING FOR OIL, Harper and Bros., New York.

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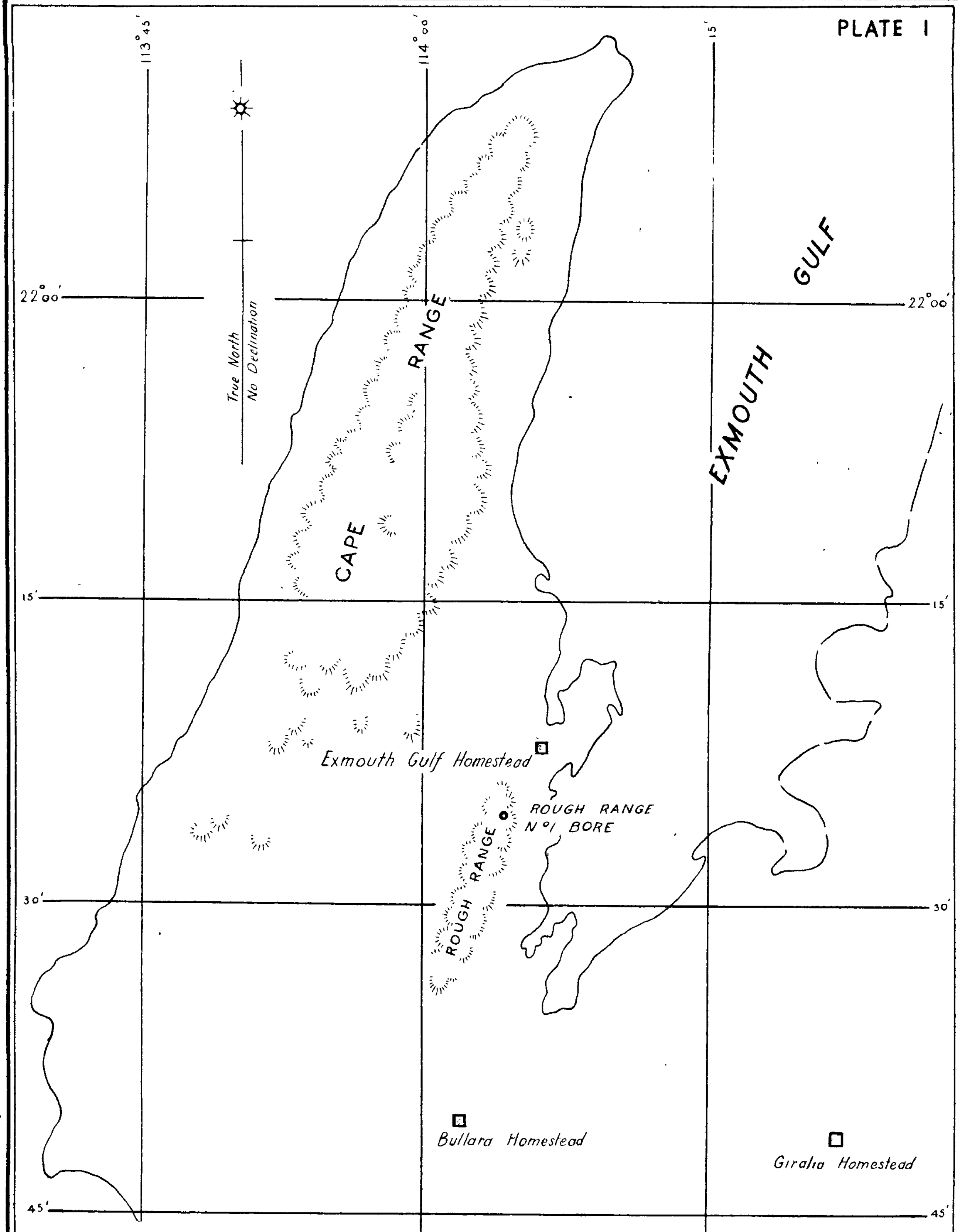
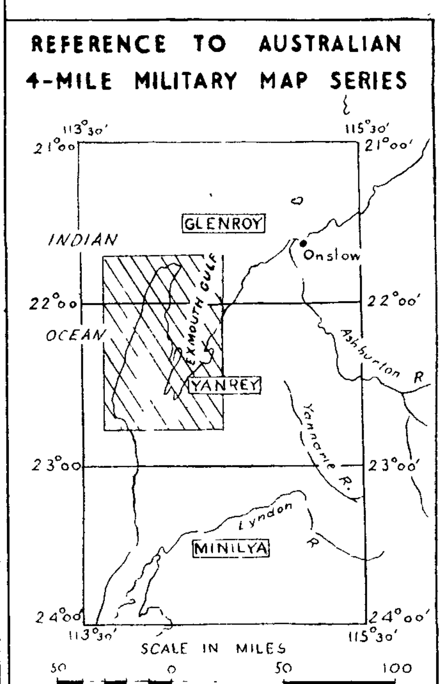
PLATE I





SEISMIC VELOCITY SURVEY IN ROUGH RANGE N°1 WELL, W.A.

LOCALITY MAP

Geophysical Section,
Bureau of Mineral Resources Geology and Geophysics

G 98-30

PLATE 2
TIME 1" = 0·1 sec.
VELOCITY 1" = 2000 ft/sec.
DENSITY
SEA LEVEL
DEPTH of GEOPHONE (below S.L.) 1" = 1000'
V = 7100 ft/sec.
V = 12600 ft/sec.
V = 16600 ft/sec.
V = 18200 ft/sec.
AVERAGE VELOCITY
INTERVAL VELOCITIES
TIME – DEPTH CURVE
CORRECTED SLANT TIMES ⊙
" VERTICAL " ×
FIGURE 1
AVERAGE VELOCITY AND INTERVAL VELOCITY
VERSUS DEPTH
FIGURE 2
DENSITY – DEPTH
FROM CORES ×
FROM DITCH SAMPLES •
FIGURE 3
ROUGH RANGE NO. 1 WELL
SEISMIC VELOCITY SURVEY
SIGNED:
GEOPHYSICAL SECTION, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.
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