COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PETROLEUM SEARCH SUBSIDY ACTS

Publication No. 29

GREY RANGE SEISMIC SURVEY, QUEENSLAND, 1959

BY

L. H. SMART OIL EXPLORATION COMPANY LIMITED

Issued under the Authority of Senator the Hon. W. H. Spooner,
Minister for National Development
1962.

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DEPARTMENT OF NATIONAL DEVELOPMENT

Minister: SENATOR THE HON. W. H. SPOONER, M.M.
Secretary: H. G. RAGGATT, C.B.E.

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FOREWORD

In 1959 the Commonwealth Government enacted the Petroleum Search Subsidy Act 1959. This Act enables companies that drill for new stratigraphic information, or carry out geophysical or bore-hole surveys in search of petroleum, to be subsidized for the cost of the operation, provided the operation is approved by the Minister for National Development.

The Bureau of Mineral Resources, Geology and Geophysics is required, on behalf of the Department of National Development, to examine the applications, maintain surveillance of the operations, and in due course publish the results.

A seismic survey was carried out under the Petroleum Search Subsidy Act 1959 in the Grey Range area of Queensland by L.H. Smart Oil Exploration Co. Ltd. This Publication deals with that survey and contains information furnished on behalf of L.H. Smart Oil Exploration Co. Ltd and edited in the Geophysical Branch of the Bureau of Mineral Resources. The final report was written by R.C. Sprigg, Managing Director, and R.G. Dennison, Geophysicist, both of Geosurveys of Australia Ltd. The methods of carrying out the seismic survey and the results obtained are presented in detail.

CONTENTS

ILLUSTRATIONS

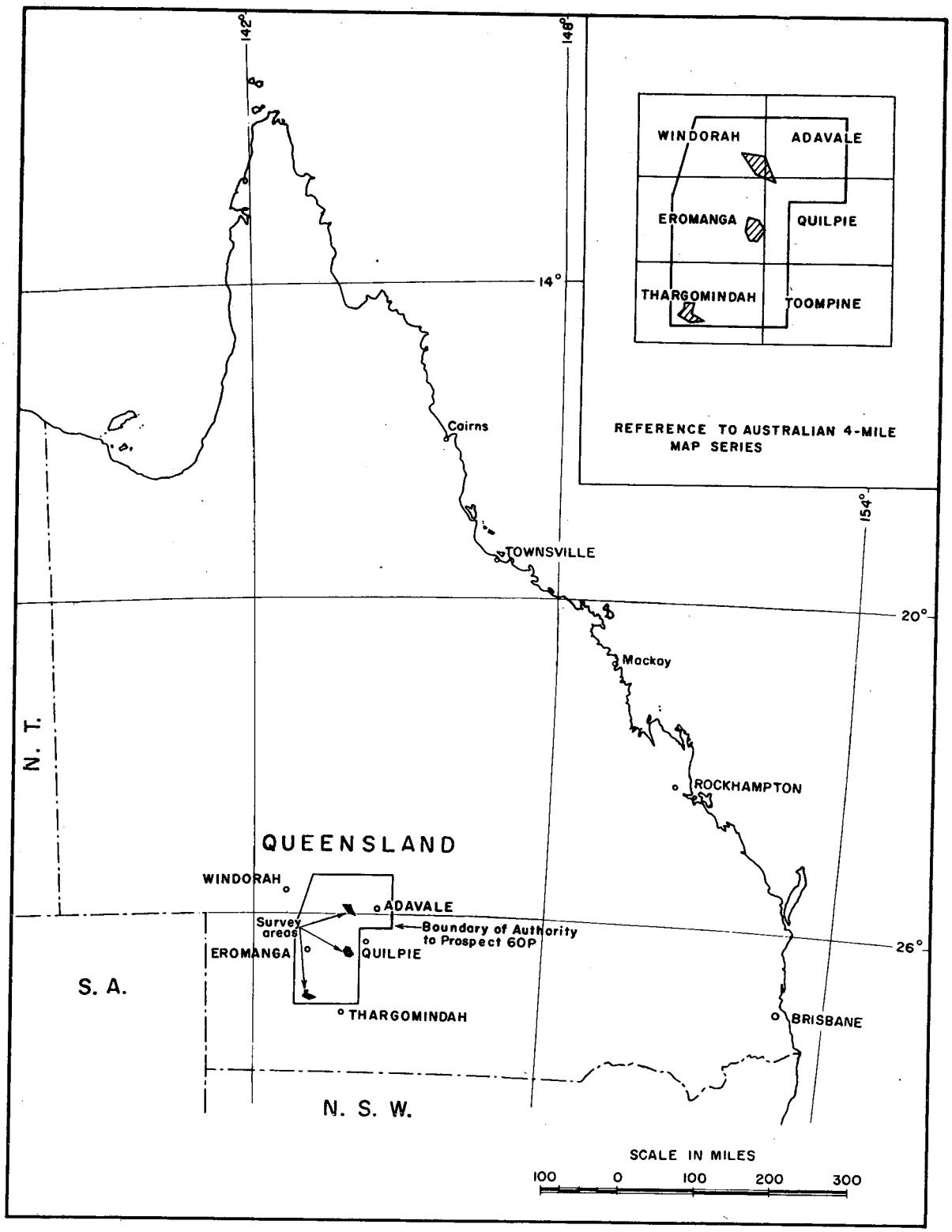

Fig. 1. LOCALITY MAP

ABSTRACT

A seismic reflection survey was conducted on behalf of L.H. Smart Oil Exploration Company Limited by Geosurveys of Australia Ltd during 1959. The survey consisted of a number of shot-points placed at one or two-mile intervals along lines across the Canaway anticline, the Pinkilla anticline, and the Chesson (Orient) anticline of the Grey Range.

The purpose of the survey was to provide detailed information of the subsurface structure of anticlines indicated by surface geology. The survey was interpreted with reference to geology known from the Bulgroo bore on the western limb of the Canaway anticline.

Seismic operations clearly indicated that surface fold structure continues and is enhanced with depth; the anticlines are caused by buried ridges, probably with Precambrian core-rocks. Permian to Cretaceous sediments are draped over these ridges and have a minimum thickness of about 4,000 ft across the Canaway anticlinal crest; in the adjoining trough syncline, they thicken rapidly to 10,000 ft or more.

1. INTRODUCTION

A seismic survey was conducted on behalf of L.H. Smart Oil Exploration Company Limited by Geosurveys of Australia Ltd during 1959. The areas surveyed (see Fig. 1) are on Authority to Prospect 60P which lies in south-western Queensland over the deeper central portions of the Great Australian Artesian Basin. The Authority is approximately 15,600 square miles in area. The town of Quilpie, the largest in the vicinity, is a cattle and sheep station centre situated immediately beyond the eastern boundary. There are air services three times a week and also a railway service. Eromanga and Adavale are much smaller towns within the Authority, and Thargomindah lies beyond the south-eastern corner. The area is reasonably well served by graded dirt roads which, however, are temporarily impassable after heavy rains.

Geological and gravity surveys had previously been made over the Canaway, Pinkilla, and Chesson areas. The purpose of the seismic survey was to provide detailed information about the subsurface structure of anticlines indicated by surface geology.

Local terrain is broadly undulating, with wide Mitchell grass plains and broad river systems separating rough stony tablelands and low broken ranges constituting the Grey Range. Plateau levels seldom exceed 1,200 ft above sea level, and the plains are as low as 500 to 600 ft above sea level.

Climate approaches semi-arid, with local rainfall about eleven inches. Summers are hot with periodic thunderstorms; winters are cold and windy with some rains. Prolonged droughts are not infrequent.

Of the many water bores within the Authority, few are deeper than 1,000 ft, and of the deeper ones, only six have penetrated to artesian water below the marine Cretaceous. Little is known of pre-Mesozoic rocks at depth, although the Eromanga No. 2 and Bulgroo bores may have encountered disconformable Permian rocks at 4,230 and 5,372 ft respectively.

Gas showings, principally of methane and hydrogen, have been reported widely in the area, and a number of water bores emit methane gas continuously in small quantities. Ethane and higher hydrocarbon gases have been reliably identified only in the present Company's Gumbla No. 2 bore, near Mt Margaret. Oil "showings" have been reported in a number of bores, and several of these may be reliable indications (Mott, 1952).

2. PREVIOUS INVESTIGATIONS

Shell (Queensland) Development Pty Ltd and Australian Oil Exploration Company N.L. have previously conducted wide-spread geological and geophysical surveys in the general area. Gravity and geological surveys on the Authority have also been made for L.H. Smart Oil Exploration Co. Ltd.

Reconnaissance gravity surveys by Shell (Queensland) Development Pty Ltd in 1942 established a broad anomaly pattern which, however, was too general to be of much value in the present survey area. Selected gravity traverses by H. Narain in the Tallyabra Plains syncline in 1956-57, and by H. Hancock and D. Walker in the Canaway Downs vicinity in 1957 (all on behalf of the L.H. Smart group) added valuable information.

The general geological review of the oil prospects of the Great Artesian Basin by Mott (1952) was of considerable help; this was followed by a more comprehensive report by Sprigg (1958).

Reconnaissance gravity surveys completed in 1958 and 1959 by Geosurveys of Australia Ltd indicated the Canaway and Pinkilla anticlines as positive gravity anomalies, and thereby indirectly confirmed the geological outcrop picture. These surveys, and others by the Bureau of Mineral Resources in 1958, confirmed the broad structural pattern in the area (see BMR gravity contour map No. G69-47). Anomalies of 20 to 25 milligals were recorded in the area between the Tallyabra Plains syncline and the Grey and McGregor Range anticlinoria.

At the same time as Geosurveys of Australia Ltd conducted the surveys described in this Publication, the Bureau of Mineral Resources made seismic refraction and continuous-profiling reflection surveys along selected traverses. Four of the traverses surveyed by the Bureau were as follows:-

(1) Traverse A, across the Tallyabra gravity "high".

(2) Traverse B, across the Grey Range, along the Quilpie-Eromanga road.

(3) Traverse C, commencing 14 miles west of Eromanga and extending 8 miles westward.

(4) Traverse D, along the road that turns off to Windorah from the Quilpie-Eromanga road, commencing 10 miles from the turnoff.

3. GEOLOGY

Structure

The Great Artesian Basin is the largest sedimentary basin in Australia. Much of it is low-lying and characterized by internal drainage, stony tablelands, and deserts.

Despite more than 5,000 water bores, little is known of the geological structure below the shallow artesian aquifiers. The Mesozoic sediments are thickest near the border of Queensland and South Australia. Thicknesses of probably more than 10,000 ft are now indicated by recent seismic exploration and stratigraphic test drilling. These Mesozoic sediments overlie a complex of Palaeozoic basins in-faulted and in-folded with sediments, metasediments, and igneous intrusives rangeing from Archaean to Upper Proterozoic.

Several bedrock ridges subdivide the basin into sub-basins or synclines. The ridges in the east tend to crop out; e.g. the Nebine Ridge and the Eulo Shelf. Granites [1]

(1) Footnote by Bureau of Mineral Resources:
An age determination by the potassium-argon method has recently been made on a granite sample from Eulo by Dr Curtis at Berkeley University, California; the age is 368 million years or Devonian. A similar determination was made on a granite from Tibooburra by Professor Evernden at the Australian National University, Canberra, and gave Silurian age of 427 million years. Details of these and other granite ages will soon be published by Professor Evernden and Dr J. Richards in the Geological Society of Australia publication entitled "Potassium-agron ages in Eastern Australia".

appear on the surface near Hungerford and Eulo, immediately south-east of Authority to Prospect 60P.

Among the Mesozoic rocks, thick marine sediments have been reported only in the Lower Cretaceous. Below this, thick successions of marine sediments of Cambro-Ordovician age plunge beneath the Great Artesian Basin from the north-west (Georgina Basin), from the west (Amadeus Trough), and from the south-west (Adelaide Geosyncline). Thick, possibly Upper Devonian, deltaic deposits, with marine interfingerings, plunge under the Basin from the direction of Mootwingee (north-western New South Wales). More distinctly marine deposits plunge under the Basin from the direction of Cobar. The possibly Upper Devonian continental beds of the Drummond Range crop out immediately north-east of the survey area and are presumed to extend far into the Basin.

In most places the Palaeozoic rocks are several thousand feet thick. The few bores that have bottomed in pre-Palaeozoic rocks have been drilled in the vicinity of the previously mentioned bedrock ridges. In the broad low-lying areas between these ridges there are likely to be large thicknesses of Palaeozoic sedimentary rocks, including marine deposits.

Structurally, the Great Artesian Basin has been extensively warped in post-Cretaceous times into a series of gentle anticlinal ridges and arches, but the origin of this diastrophism is extremely ancient. Folding, particularly in the extensive lines of en echelon folds that dominate the deeper areas of the Basin, is controlled by bedrock fault movement ancient lineaments. Development of folds has been considerable; some anticlines have limb dips of 20 or more degrees, and domes have vertical structural "closure" of several hundred feet at the surface.

The Grey Range anticlinorium is one such arrangement of en echelon folds in Cretaceous shale; it has been preserved by ancient duricrust (siliceous "laterite") layers. Limb dips only occasionally exceed 5 degrees in outcrop and are more commonly only 1 to 3 degrees. At least ten anticlines are known in the area and three of these were selected for seismic reflection work, namely the Canaway, Pinkilla, and Chesson anticlines.

As the folding process has been active since at least early Palaeozoic times, it is not surprising that in places the buried structure is complicated. Folding in marginal areas is known to have accelerated spasmodically, probably in early Palaeozoic times (Boulia), again in late-Middle Palaeozoic times (Mootwingee and Drummond Range), in post-Permian times (Bowen Basin), and in Mesozoic and Tertiary times. Movement at the present time is principally regional warping and tilting. In the anticlinal ridges, including the Grey Range, the folding is mainly late Cretaceous and early Tertiary in age.

Stratigraphy

In the Authority (ATP 60P) little is known of the rocks below the Mesozoic sequence. There are only two bores drilled deeper than 5,000 ft and these both encountered presumed Permian rocks. The other numerous artesian water bores in the district were not drilled below Mesozoic rocks.

The nature of the pre-Permian rocks can only be inferred. Evidence from the Eulo Shelf suggests that along buried ridges the sub-cropping basement is likely to be Pre-cambrian granite [(2)] and metamorphic rocks. The possibility of there being thick sequences

(2) Footnote by Bureau of Mineral Resources:
See Footnote (1).

of unmetamorphosed Upper Proterozoic shale, sandstone, and limestone in these core regions cannot be disregarded.

Palaeozoic sub-basinal sedimentation between buried ridges in the area is expected to include Cambrian and Ordovician and Devonian to Permian sediments.

Permian: Rocks probably of Permian age are the oldest sediments yet encountered in drilling within the Authority area. Sandstones probably of this age, and presumed to be continental deposits, were recorded below 4,230 ft in the Eromanga bore, and also at 5,372 ft in the Bulgroo bore. The thickness of the deposits in even these bores is not known, but Permian sandstones at some depth below the surface of the Great Artesian Basin are probably widespread and unconformably overlie the Palaeozoic or basement rocks.

Triassic-Jurassic: Sedimentary rocks of this age were encountered in several of the deeper bores within the Authority, and typically reddish or greenish shales (possibly of the Moolayember Shale) were found overlain by a succession of sandstone and interbedded shale with carbonaceous partings and coal seams. The more permeable sandstones provide artesian water of good quality; this could be due either to extensive flushing by artesian waters or to the non-marine origin of the sandstone.

The principal sediments that overlie the Moolayember Shale are the Marburg Sandstone and the Walloon Coal Measures, which are considered to be Triassic (3).

Cretaceous: This is represented by the Rolling Downs Group. The lowest member of this Group is the Roma Formation (Aptian) which is richly fossilferous; five ammonite stages have been recognised by Whitehouse (1954) along with Fissilunula and Maccoyella. The succeeding Tambo Formation (Albian) is also entirely marine, featuring Aucellina and Inoceramus, and the ammonites Beaudanticeras, Hamites etc. and numerous giant swimming reptiles.

The marine rocks are almost entirely shaly, being relieved only by thin (possibly lagoonal) limestone. Clean sandstones are almost entirely absent.

During late Cretaceous times, as the seas receded, interbedded shaly and silty deposition continued, enclosing also brown coal in marshy situations. Araucarites and Protophyllocladus are typical plant forms found in the third member of the Group, the Winton Formation.

Cainozoic: Tertiary and Quaternary deposits are typically only veneers in plains areas of the synclines. Tallyabra Plain is one such example. Fossil soil deposits include laterite and siliceous duricrust, the latter of which has been gently folded in early Tertiary times and later eroded along the major anticlinal crests (e.g. the Grey Range) to expose the soft Cretaceous shale.

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(3) Footnote by Bureau of Mineral Resources:
Recent palaeontological evidence, especially from microfloral studies, shows that the Moolayember Shale as recognised in the subsurface of the Roma area is Jurassic as well as Triassic, but in the type outcrop areas it is Triassic. The Marburg Sandstone and the Walloon Coal Measures are Jurassic. The evidence also shows that the Transition "beds" of the Blythesdale Group are Cretaceous and the remaining units of the Group are Jurassic.

Detailed Structural Geology

The Grey Range, which dominates the local geology, is clearly anticlinal. The ridge extends north and north-east from Tibooburra for almost 350 miles and produces a major drainage boundary. It is, in fact, a broad arch-like anticlinorium complicated at depth by faulting. Flank dips average one to three degrees, except on the western limb of the Canaway anticline, where faulting at depth has produced a tendency to monoclinal folding with limb dips of five to seven degrees.

Of the many local anticlinal folds, the following ones were investigated by the present survey:

Canaway	35 x 15 miles
Pinkilla	15 x 10 miles
Chesson (Orient)	45 x 20 miles

The anticlinal structures are well expressed topographically and can be readily recognised from low-flying aircraft. These and other anticlines have been delineated in broad detail photogeologically, and several have been mapped in detail on the ground.

Surface topographic closures on the duricrust layer (which is not necessarily completely conformable) in each of the foregoing examples is from 100 to 300 or more feet. In most cases the closures on the top of the Blythesdale Group and on the underlying pre-Mesozoic Horizon "P" are more than double this figure, and fold amplitudes (crest to keel) are very much greater. In the case of the Canaway anticline, for example, the fold amplitude exceeds 1,000 ft.

Although principal interest in the seismic surveys centres on the anticlinal ridges, the importance in oil exploration of the great Tallyabra and other synclines should not be overlooked. The Tallyabra syncline is a broad structure 40 miles or more in width (east to west), and probably greater than 70 miles in length. The negative Bouguer gravity anomalies relative to the enclosing Grey Range on the east and McGregor Range on the west, exceed 20 and 25 milligals respectively. On the western margin of the Pinkilla anticline, seismic surveys made by the Bureau of Mineral Resources have shown that the sharp gravity gradients correspond to steepened dips in pre-Mesozoic sedimentary rocks. This confirms the expectation that sedimentary rocks will be thicker in the syncline.

4. METHODS AND RESULTS

Weathering and elevation corrections were computed by the normal up-hole method. Reflections were plotted in time on cross-sections and graded as to their certainty according to criteria defined by Gaby (1947). Information additional to that included in the present Publication has been filed in the Bureau of Mineral Resources and is available for reference. It includes a complete set of record sections and a complete set of plotted cross-sections. The following is a discussion of the records taken in the various areas.

Canaway anticline

The shot-points were placed at one or two-mile intervals and the reflections were correlated by character.

Reasonable to good reflections were obtained generally in the area using 20 to 30 lb of seismic explosive in holes of up to 120 ft in depth. In order to present two contour maps in depth, an average velocity of 9,000 ft/sec was assumed down to the reflecting Horizon "P" and an average velocity of approximately 7,600 ft/sec was used to the "Top of the Blythesdale" horizon based upon a t:Δt velocity analysis. The t:Δt analysis is not considered reliable owing to the lack of interlocking shot-points.

The contour maps show a large asymmetrical anticline trending north-south with approximately 700 ft of closure on Horizon "P", and approximately 350 ft of closure on the "Top of the Blythesdale" reflector. A normal fault, up-thrown to the west, is shown on Horizon "P" map and is probably associated with the structure. This fault probably extends through the Blythesdale Group, but is not shown on the contour map.

Pinkilla anticline

Reflection quality varied widely. One reflection event was correlated by character over most of the prospect. An average velocity of 7,000 ft/sec was assumed down to this reflecting horizon, so that the data could be presented as depths. In previous seismic surveys conducted near Pinkilla an average velocity of 10,000 ft/sec was assumed. However, the rocks penetrated by the Naratha bore are mostly shale and it is therefore believed that an average velocity of 7,000 ft/sec is more appropriate.

One other reflector, approximately 1,000 ft below the mapped horizon, was correlated on some lines. Sufficient depth points were not obtained to permit construction of an accurate map, but the bed appears to be conformable with the mapped horizon. Deeper reflections, which appeared on some records when shooting the flanks of the anticline, showed much steeper dips than those from the shallower horizons.

The contour map shows an anticlinal structure as predicted from the aerial photographs and the gravity survey. Dips near the crest are very gentle, being about 1 degree or less. A steeper dip of up to two degrees occurs in the north-western corner of the survey area. This dip is interpreted as meaning that that corner is on the margin of the Grey Range anticlinorium.

Closure of the Pinkilla anticline has not been verified by the results of the seismic surveys. Divergence of the contours was observed at the southern end of the area surveyed, and further work was suspended until shooting on the other areas controlled by the Company had been completed.

Chesson anticline

The progress of the survey was very slow owing to difficulties in drilling shot-holes. The nearest supply of drilling water was a permanent water-hole in the Wilson River at Conbar Out-Station, approximately 25 miles from the camp site. This long distance and the water losses, running as high as 3,500 gallons in some holes, made drilling very slow. No water-flows were reported by the drillers and it seems that air drilling should be used in this area in future.

The records were generally not good, and only one reflector could be correlated over the area with certainty. Records shot at the southern end of the area failed to show any

reflected events. A study of records shot by the Bureau of Mineral Resources near Eromanga showed that record quality improved with shot-hole depth down to 375 ft. The average shot-hole depth at Chesson anticline was 120 ft, and it is believed that better records could have been obtained with deeper shot-holes; this was not feasible in the time allotted for the survey, and would have increased costs very considerably. Comparison of record quality with the driller's logs showed that good records were obtained only in those holes where the strata changed to blue shale directly beneath the first few feet of brown surface clay. Holes in which there was a section of white or grey shale above the blue shale did not produce good reflection records.

Corrections for weathering and elevation were made by the normal up-hole method using an elevation velocity of 7,000 ft/sec, the velocity computed from an up-hole survey conducted in Shot-point No. 1. This shot-hole, which was drilled to a depth of 265 ft, was located on the crest of the anticline, and as shooting progressed it was found that the depth of the weathered layer increased considerably over the flanks. All refraction first arrivals were therefore plotted and further corrections were applied for shots fired in the weathered layer.

An average velocity of 7,000 ft/sec was assumed down to the prominent reflecting horizon, and this velocity was used to convert reflection times to depth below the surface. Plate 6 is a contour map of the horizon showing depths below sea level. Preliminary evidence suggests that this reflecting horizon may be the top of the Blythesdale Group, but as the nearest deep bore is more than 50 miles away there is no proof of this.

The contour map shows two closed structures or domes. If oil or gas occurs in the Mesozoic sandstones of the Great Artesian Basin, these domes may be looked upon as promising traps.

More detailed shooting was conducted on the larger (southern) dome located under Boundary Tank. There appears to be at least 300 ft of local closure, but the total closure on the Chesson anticline is probably much greater. The movements that caused the folding in the area were apparently not simple, as the axis of the dome is not parallel to that of the main anticline.

For future seismic work in the area, it is recommended that continuous profiling be used, to enable additional horizons to be mapped and to reveal any faulting. Shot-holes should be deeper than those used for this reconnaissance survey, and the use of air drills should be carefully considered because of the short supply of drilling water.

5. DISCUSSION OF RESULTS

Seismic cross-sections, particularly east-west lines across the Canaway anticline, show in general a conspicuous absence of deep reflectors over the crest of the anticlines (see Plate 4). This longitudinal zone of few, or no, deep reflections is interpreted as probably representing pre-Palaeozoic rocks in the nature of "bedrock" or alternatively, as very thick, monotonous sedimentary rocks, such as were intersected in drilling below Horizon "P" at Innamincka and Betoota. East and west of this buried horst-like zone, sediments that are obviously stratified extend to much greater depths and are presumed to be Palaeozoic. Apparently these deeper stratified sediments are not present over the crest of the anticline,

and the deeper structures are "bald-headed". This interpretation is confirmed by the results of a check seismic traverse made by the Bureau of Mineral Resources across the steep gravity gradient along the Windorah Road north of the turnoff from the Quilpie-Eromanga Road.

The results of the gravity surveys correlate well with the general structural configuration revealed by the seismic survey. The gravity "high" relates to the gentle surface anticline, and the "lows" relate to thick sediments in the adjacent synclines. This is in agreement with the hypothesis of the "buried ridge".

A similar "buried ridge" structure is apparent also over the Pinkilla anticline but only in the extreme north-west where shooting extended sufficiently far west. The cross-sections suggest that the "buried ridge" is widening to the south. The western limits of the presumed "buried ridges" on both Canaway and Pinkilla anticlines agree with the boundaries of the gravity "lows" remarkably well. From these results it appears likely that the gravity results generally indicate the configuration of basin-and-buried-ridge structure.

In the Chesson anticline area, no traverse was carried sufficiently far to provide deeper reflections. Consequently there is no guide to the edges of any deeper sedimentary deposits.

In the Eromanga area, traverses by the Bureau of Mineral Resources have disclosed that sediments thicken sharply eastward off the Harkaway structure, only a few miles west of the town. The great Tallyabra Plains to the east are a broad area of extensive gravity "low" between Eromanga and the Pinkilla anticline, except for an area around Tallyabra itself where there is a gravity "high". The broad area of gravity "low" is presumed generally to be one of deep sedimentation between "buried ridges" as in the Grey Range (Canaway, Pinkilla etc.) and the McGregor Range.

6. GEOLOGICAL INTERPRETATION AND CONCLUSIONS

Combined seismic and gravity studies have demonstrated quite clearly that several features in the Grey Range area are anticlinal structures of buried ridge type.

To the east the nearest basement "high" that has been reached by drilling is at Charleville (120 miles east of Quilpie), and there are the outcrops at Eulo 100 miles to the south. These are of granitic and gneissic rocks presumed to be Precambrian (4). To the west, possibly in the region of the McGregor Range, early Palaeozoic rocks and also little-altered Upper Proterozoic rocks must be thinning out. Whether these are present in the great Tallyabra depression and syncline (50 miles wide) between the McGregor and Grey Ranges is debatable. Refraction velocities measured immediately west of Eromanga indicated that the second deepest layer (5,850 ft) has a horizontal velocity of 18,000 ft/sec. This layer could be Proterozoic or Palaeozoic, and in this region is overlain presumably with gentle unconformity by Permian or Mesozoic sediments.

Across the Canaway anticline, where the most extensive traverse into neighbouring synclines was completed (Plate 4), faulting is seen to exercise a major control on "buried

(4) Footnote by Bureau of Mineral Resources:
See Footnote (1).

ridge" configuration, at least on the eastern margin. Faulting and/or monoclinal folding has dislocated the pre-Mesozoic Horizon "P" by more than 1,200 ft on the east, and this is reflected at the surface in monoclinal dips of 5 to 7 degrees. With respect to the culmination of the "buried ridge", the flat-lying sedimentary sequence in the eastern syncline has thickened by 3,000 ft or more in the space of about one mile. To the west, sedimentary thickening is much gentler, so that the thickness increases by about 3,000 to 3,500 ft in 12 miles; i.e. wedging out to the extent of 1 in 20. It is postulated that erosional wedge-out of the Palaeozoic sequence occurs from this direction.

An interesting feature of the wedge-out below Horizon "P" in the Canaway area is that it is in the form of transgressive overlap. This sedimentary sequence is assumed to be disconformably overlain by the Mesozoic-Permian sediments, as is clearly indicated on the seismic cross-section (Plate 4).

Along the Quilpie-Windorah Road, near Pinkilla, the continuous-reflection traverse (Traverse D) made by the Bureau of Mineral Resources has demonstrated angular unconformity at the Horizon "P" break, with the older (presumed Palaeozoic) beds steepening locally to 1,000 ft per mile, compared with the dip of the overlying beds averaging only 100 to 200 ft per mile. The local steepening coincides with a gravity gradient change.

The age of the pre-Horizon "P" sediments of the Tallyabra Plains syncline is still unknown. They extended to a depth of 10,000 to 12,000 ft along the Windorah road from its turnoff from the Quilpie-Eromanga road (BMR Traverse D), and are presumably much deeper at the centre of this 50-mile-wide depression. The most reasonable interpretation is that the beds are Cambro-Ordovician and Devono-Carboniferous and can be expected to include gentle internal unconformities.

Seismic operations have clearly indicated that surface fold structure continues and is enhanced with depth. The Grey Range, and probably also the McGregor Range, is underlain by "buried ridges", probably with Precambrian core-rocks. Permian to Cretaceous sedimentary sequences, within which there is little or no evidence of internal unconformity, are draped over these "buried ridges".

A regional disconformity at Horizon "P" is presumed to be immediately pre-Permian. Although this is primarily a zone of disconformity, it has angular unconformity in some areas, such as the locality of BMR Traverse D.

Block-faulting is an obvious factor in "buried ridge" formation beneath the Canaway anticline (or tilted monocline). However, the ridges are very ancient features, with the consequence that the pre-Horizon "P" sediments wedge out against them in progressive overlap. While sedimentary thickness over the anticlinal ridges may be reduced to 4,000 ft or less, in the synclines the thickness may exceed 12,000 ft.

The Tallyabra Plains syncline is obviously a dominating structural feature in the area. More than 50 miles across at its widest part and broadly open to the north, it has the elements of a deep Palaeozoic sub-basin or broad remnant syncline. If a marine sequence is present in this gently warped zone, its importance in the search for commercial oil is obvious. Many traps for migrating hydrocarbons are likely in wedge-outs against marginal "buried ridges", against buried faults, or against unconformities. In particular, relatively depressed anticlinal structures known to be present more centrally within the areas of deeper sedimentation, will be important drilling targets if the rocks prove to be porous.

The surveys have clearly demonstrated that the Grey Range is an anticlinal flexure and that numerous shallow targets exist along the crests. Geological and gravity surveys can be extensively used to define these structures, and vertical closure within the Permian-Mesozoic sequence is known to exceed several hundred feet in both the Canaway and Chesson anticlines.

Deeper drilling targets are available "off-structure" in the deep synclinal basins, but require detailed seismic investigation before they are drilled. Holes to a depth of 10,000 ft or more may be necessary to explore the sedimentary sequence in those areas.

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APPENDIX 1

CALCULATION AND INTERPRETATION METHODS

	Canaway area	Pinkilla area	Chesson area
Weathering and elevation correction	Normal up-hole and differential weathering	Normal up-hole	Normal up-hole and refraction intercepts
Elevation datum (ft above sea level)	600	500	300
Weathering velocity (ft/sec)	2300	2500	2500
Elevation velocity (ft/sec)	6000	6000	7000
Vertical velocity (ft/sec)	9000 estimated	7000 estimated	7000 estimated
Correlation	Character and interval	Character and interval	Character and interval

APPENDIX 2

FIELD PROCEDURE

	Canaway area	Pinkilla area	Chesson area
Traverse type	One- and two-mile correlation	One- and two-mile correlation	One- and two- mile correlation
Spread length	1320'-0-1320' straddle spread	24-station 1320'-0-1320' 12-station 110'-0-1210'	12 station 110'-0-1210'
No. of stations adjacent to shot-point	2	2	2
Distance offset geophones from shot-point	80 ft	80 ft	80 ft
Type geophone	Electro-Tech.	SIE S16 18c/s	Electro-Tech.
Number per trace	4	4	4
Connexion	Series	Series	Series-parallel
Spacing in group	30 ft	30 ft in line of profile	20 ft
Amplifier	Century 501A	Century 501A	Century 501A
Number of channels	24 plus AVC monitor	24 plus AVC monitor	24 plus AVC monitor
Filter setting	39-66 c/s	36-66 c/s	39-66 c/s
Mixing	No mixing	24-station spreads unmixed. 12-station spreads (1-12 single, 13-24 mixed)	Channels 1-12 single, 13-24 mixed
Difficulties	Delay due to breakdown of equipment. Estimated time lost - 2 days for drill repairs		Short supply of water for drilling. All water hauled from Conbar. Many holes blind, with water losses up to 3500 gallons per hole. Estimated time lost - 5 days.

APPENDIX 3

STATISTICS

	Canaway area	Pinkilla area	Chesson area
Field work commenced	2nd June 1959	11th July 1959	12th Aug. 1959
Field work completed	10th July 1959	7th Aug. 1959	12th Sept. 1959
Miles traversed	93	79	86
Holes shot	94	92	103
Gelignite used	3880 lb	4100 lb	2310 lb
Detonators used	184	242	259
Average shot depth	98 ft	120 ft	110 ft
Average charge size	25 lb	30 lb	10 lb
Number of drills	2	2	2
Type of drill	One Failing-1500 One Mayhew-1000	One Failing-1500 One Mayhew-1000	One Failing-1500 One Mayhew-1000
Total footage drilled	9343	13,392	10,955
Total drilling time	370 hr	310 hr	290 hr
Driving time, drills	54 hr	25 hr	58 hr
Average rate of penetration	29.5 ft/hr	49 ft/hr	47.2 ft/hr
Number of holes drilled	95	93	113
Total recording field hours	290 hr	220 hr	210 hr

APPENDIX 4

LOCATION AND PERSONNEL

	Canaway area	Pinkilla area	Chesson area
Crew Headquarters	Bulgroo via Quilpie	Pinkilla via Quilpie	Boundary Tank via Thargomindah
Party Chief	D.M. Pegum	E.R. Denton & D.M. Pegum	E.R. Denton
Computor	C.N. Strong	F. Stephens	F. Stephens
Observer	L. Read	C.N. Strong	C.N. Strong
Shooter	W. Werren	W. Werren	W. Werren
Surveyors	H. Ridge G. Wright	G. Paterson	G. Paterson
Drillers	W. Duke J. Hannan F. Miller	W. Duke J. Hannan F. Miller	J. Hannan F. Miller

PLATE I

To Windorah

KYABRA ANTICLINE

To Windorah

GRAVITY LOW

-65

-60

RANGE

Mc GREGOR

MT. MARGARET ANTICLINE

BROMANGA ANTICLINE

Eromanga

As per B.M.R. Seismic Survey

TALLYABRA ANTICLINE

POSTULATED AREA

OF DEEP SEDIMENTATION

SEISMIC CONTROL "P" HORIZON

CANAWAY ANTICLINE

-2500

-2000

-1500

-1000

-60

-62

GRAVITY LOW GRADIENT

Adavale

RAY ANTICLINE

PINKILLA ANTICLINE

-2200

-2000

-1800

-1700

SEISMIC CONTROL CRETACEOUS(?)

GREY

GRAVITY LOW GRADIENT

To Quilpie

CHESSON ANTICLINE

SEISMIC CONTROL ON CRETACEOUS?

NO DEEP REFLECTORS PRESENT

-2000

-1800

148°00'

148°30'

149°00'

25°30'

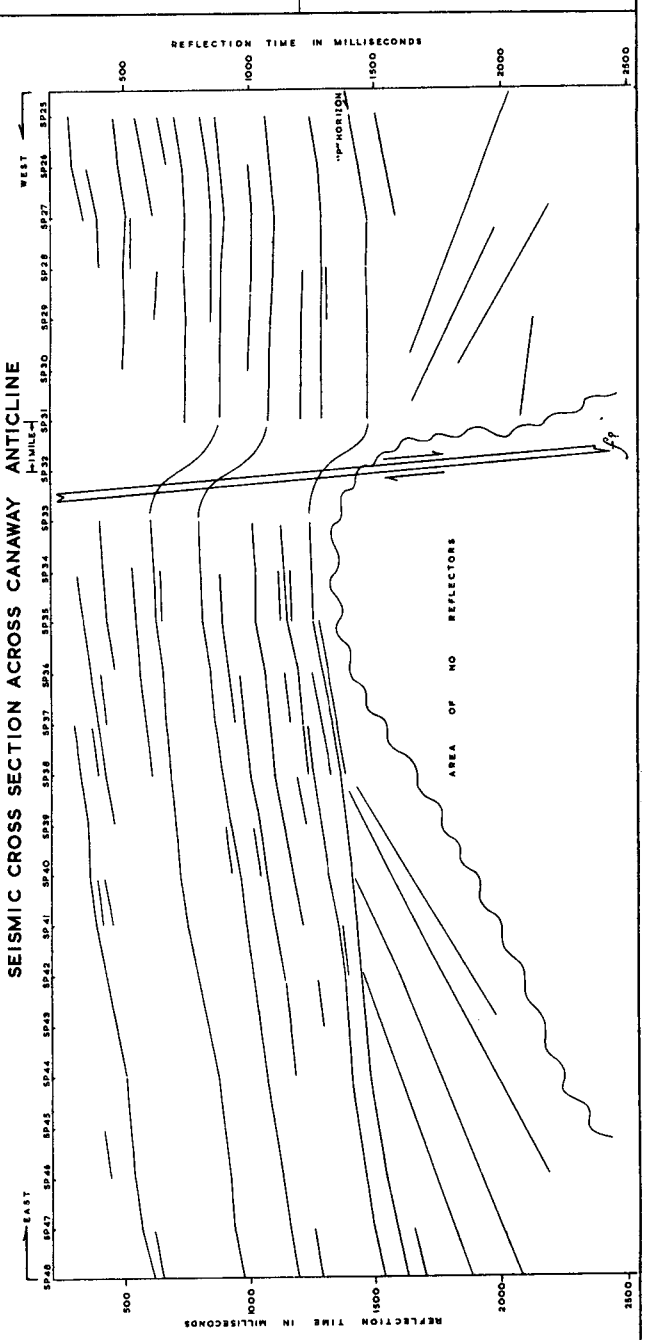
26°00'

26°30'

27°00'

27°30'

SEISMIC CROSS SECTION ACROSS CANAWAY ANTICLINE



SEISMIC REVIEW
GEOLOGICAL – GEOPHYSICAL MAP OF
A.T.P. No. 60P
WINDORAH-EROMANGA-THARGOMINDAH AREA

Surface Anticline

Seismic Traverse Lines

Track

-1800 -1700 Seismic Contours

-60 -62 Gravity Contours

Area of Deep Reflectors. Not present on Crest of Anticline.

-SCALE-

MILES 4 0 4 8 12 MILES

6th May, 1960

Geosurveys (Aust) Ltd.

PLATE 2

L.H SMART OIL EXPLORATION CO. LTD.

CANAWAY DOME

CONTOUR PLAN

OF THE 'TOP' OF THE

BLYTHESDALE GROUP

IN RELATION TO SEA LEVEL

Contour Interval 100 feet

Shot Points ○ 31

Interpreted Reflection Depths in Feet, 3530

SCALE 0 1 2 3 4 MILES

D M. PEGUM B. Sc.
GEOPHYSICIST & PARTY LEADER
GEOSURVEYS (AUST.) LTD.

Plan prepared by GEOSURVEYS (AUST.) LTD. 22 7·59 PALC

PLATE 3

REFLECTION SEISMIC SURVEY

CANAWAY ANTICLINE

CONTOUR PLAN OF "P" HORIZON

FOR

L.H. SMART OIL EXPLORATION CO. LTD.

BY GEOSURVEYS (AUST.) LTD.

DATUM PLANE – SEA LEVEL

ESTIMATED AVERAGE VELOCITY – 9000'/sec.

SCALE

CHAINS 80 0 1 2 3 MILES

R.G. DENNISON GEOPHYSICIST

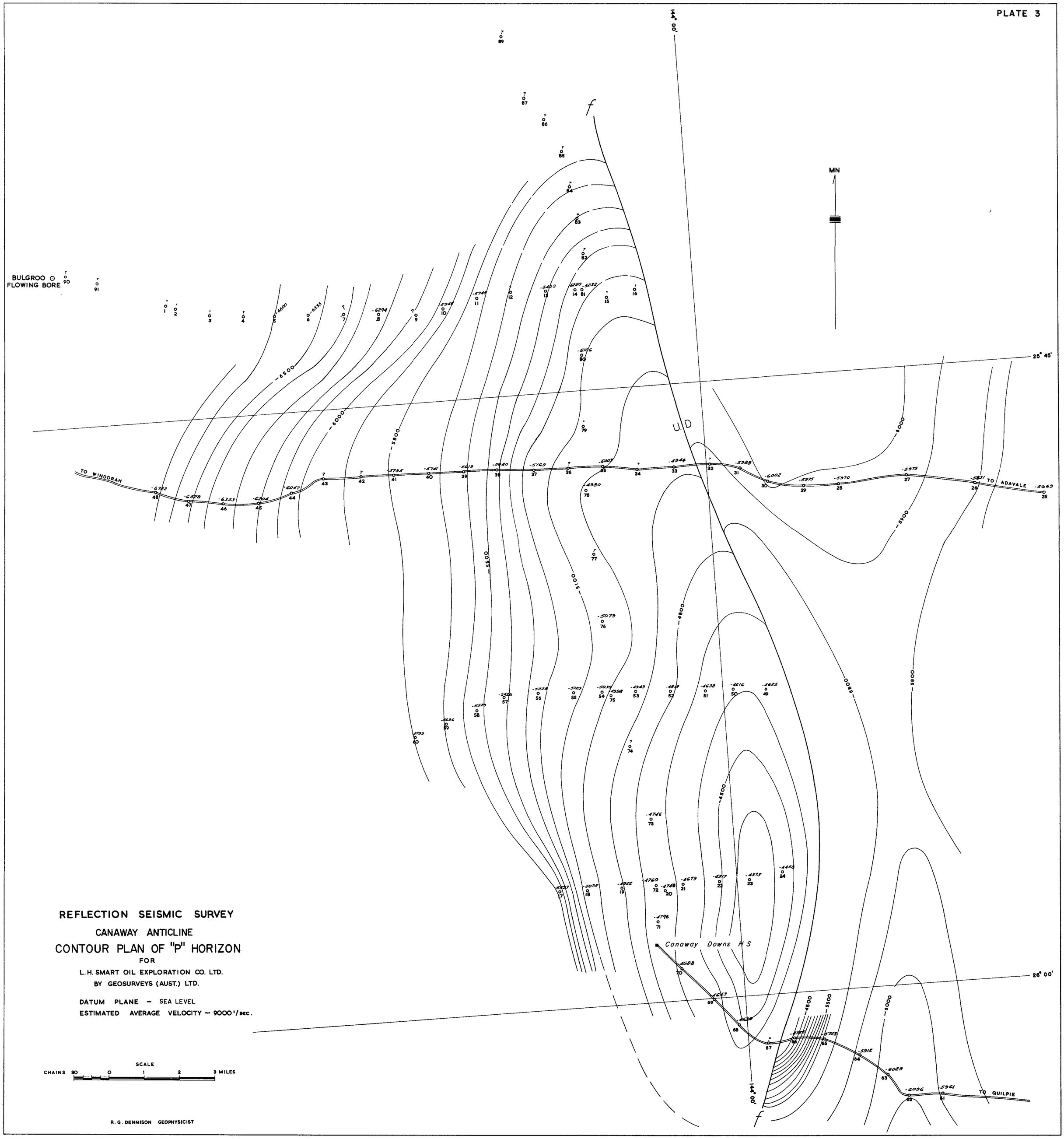
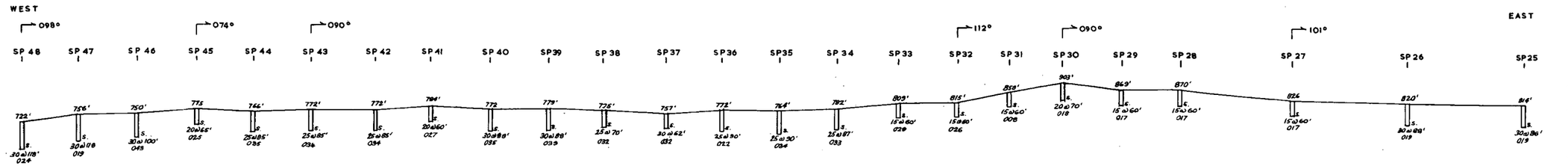
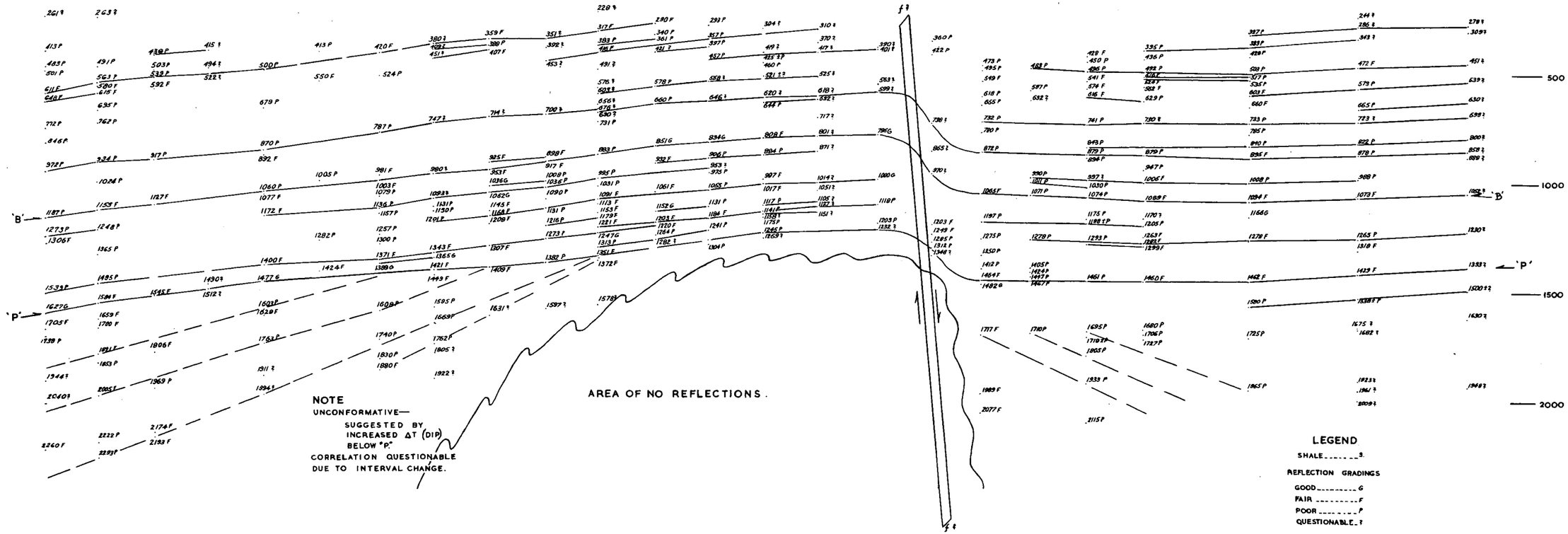


PLATE 4

WEST

EAST





NOTE
UNCONFORMATIVE—
SUGGESTED BY INCREASED ΔT (DIP) BELOW "P."
CORRELATION QUESTIONABLE DUE TO INTERVAL CHANGE.

AREA OF NO REFLECTIONS.

LEGEND

SHALE ..... S.

REFLECTION GRADINGS

GOOD ..... G
FAIR ..... F
POOR ..... P
QUESTIONABLE ..... ?

REFLECTION SEISMIC SURVEY

CANAWAY ANTICLINE

LINE "B"

FOR

L. H. SMART OIL EXPLORATION CO. LTD.

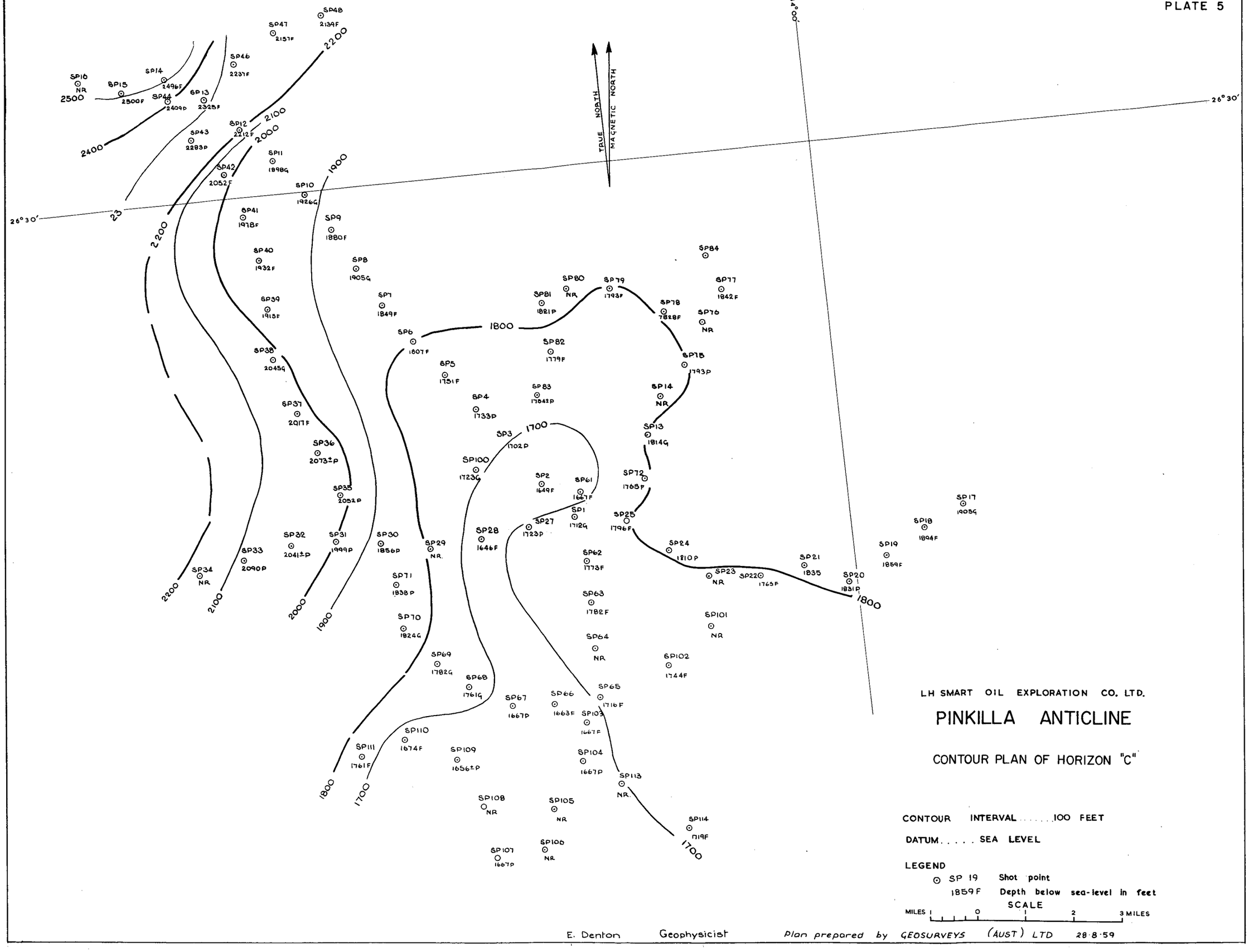
BY

GEOSURVEYS AUST. LTD.

SCALE

MILE 0 1 2 3 4 MILE

PLATE 5



LH SMART OIL EXPLORATION CO. LTD.

PINKILLA ANTICLINE

CONTOUR PLAN OF HORIZON "C"

CONTOUR INTERVAL ..... 100 FEET

DATUM ..... SEA LEVEL

LEGEND

⊙ SP 19 Shot point

1859F Depth below sea-level in feet

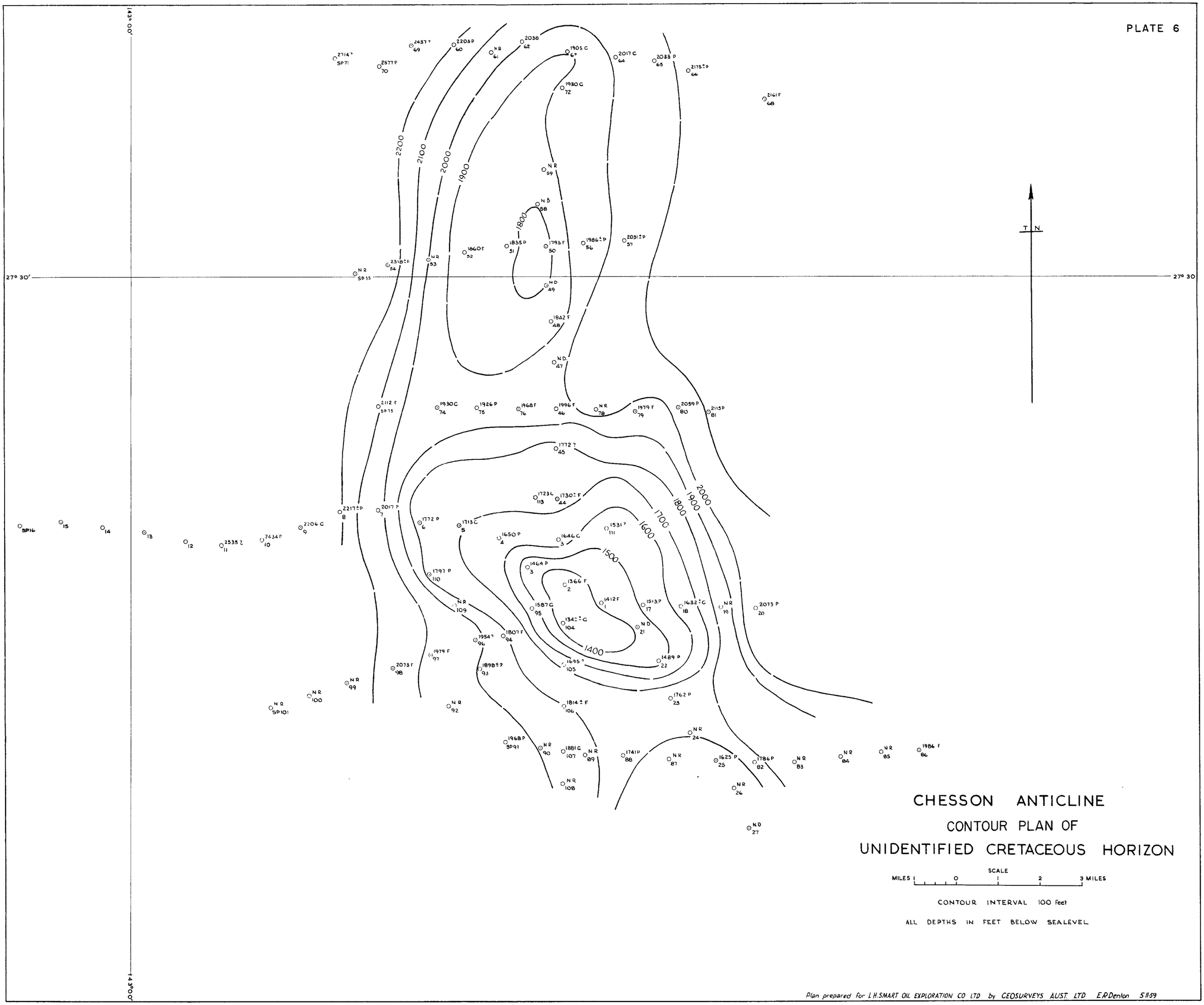
SCALE

MILES 1 0 1 2 3 MILES

E. Denton Geophysicist

Plan prepared by GEOSURVEYS (AUST) LTD 28·8·59

PLATE 6



CHESSON ANTICLINE

CONTOUR PLAN OF UNIDENTIFIED CRETACEOUS HORIZON

SCALE

MILES 1 0 2 3 MILES

CONTOUR INTERVAL 100 Feet

ALL DEPTHS IN FEET BELOW SEALEVEL

Plan prepared for L.H.SMART OIL EXPLORATION CO LTD by GEOSURVEYS AUST. LTD E.P.Denton 5.11.59