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FINAL REPORT

TASMAN-BASS STRAIT MARINE SEISMIC PROFILER AND MAGNETIC SURVEY

for

BUREAU OF MINERAL RESOURCES

by

MAGELLAN PETROLEUM AUSTRALIA LIMITED

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ABSTRACT

Reconnaissance profiles covering 1,835 miles and detail shooting covering 143 miles (all with towed magnetometer recording) were obtained from August 16 to September 18, 1969 in offshore permits NSW EPP/1, VIC/P3, VIC/P4, T/1P, T/9P, T/2P and T/10P in the Tasman Sea and Bass Strait.

The objectives of the reconnaissance work (sparker) was to obtain information on the configuration of the basins, local structures, and the thickness of the sedimentary sequences. The purpose of the multi-coverage work (air-gun) and computer processing was to detail existing structural anomalies.

The detailed work was concentrated on what is considered to be a drillable elongate anticline in T/1P covering 11 square miles in 350 to 400 feet of water and having about 270 feet of vertical closure. About 1,500 to 2,000 feet of highly prospective Latrobe Coal Measures are thought to exist on the structure.

A domal anticline at basement level was found in the southern part of NSW EPP/1 where a maximum of about 3,500 feet of reflecting section is recognizable. The feature has approximately 900 feet of relief encompassing 20 to 25 square miles, but apparently its crest is covered only by less than 1,000 feet of Tertiary (?) section.

At least one large basement anticline with interesting sedimentary cover was found in each of T/9P and T/2P, the former in 3,000 to 5,000 feet of water and the latter on the steep west Tasmania shelf between 500 and 6,000 foot water depths. Other anticlinal features were indicated in deep water in T/2P.

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SECTION I

SUMMARY AND CONCLUSIONS

A. South Sydney Basin Area

A total of 697 miles of single-fold sparker profiling and 58 miles of air-gun multi-coverage data (with marine magnetics) were obtained and interpreted to establish sedimentary thickness, probable stratigraphy and structural leads. Definition of the Permian section in the northern part of the permit was unsuccessful; only the wedge-like Tertiary section was defined with maximum thickness of about 3,500 feet at the continental slope and thinning east and west.

A domal anticline was delineated near the Victorian-N.S.W. border which appears to be a basement high covering 20 to 25 square miles with 900 feet of relief. The feature is covered by less than 1,000 feet of Tertiary (?) sediments on the crest and flanked by about 2,500 feet of such deposits which indicate little growth during sedimentation.

B. East Gippsland Basin and East Tasmania Areas

Reprocessing of digital data from a 1969 survey and the shooting of 228 miles of sparker reconnaissance and 82 miles of CDP data were carried out to detail Feature VII in T/1P, extend basin configuration of the Gippsland Basin and establish section thickness and structural leads in the East Tasmania Area. Feature VII was subsequently interpreted as an elongate anticline having about 11 square miles of closure and 270 feet of relief. This structure is probably associated with a large basement high, which extends into the west-adjoining permit. Apparently several individual culminations occur on the basement feature, and it is flanked

by large faults. Basement is overlain by 1,500 to 2,000 feet or more of Latrobe Complex sediments and 2,000 to 3,000 feet of marine post-Eocene deposits. Both the coals of the Latrobe Complex and the overlying marine marls and mudstones could serve as source rocks for hydrocarbons, and sandstones in the Latrobe sequence are known to have excellent reservoir characteristics. The impermeable post-Latrobe deposits should provide capping, thereby completing the interpreted hydrocarbon trap in 350 to 400 feet of water.

An anticline previously indicated has been confirmed (Feature VIII) near the intersection of Lines M23T and M60T. At Top Latrobe level about 400 feet of vertical closure is mapped covering an area of 7 square miles. More than 2,000 feet of the highly prospective Latrobe Complex is thought to exist on this feature in water depths over 1,300 feet.

A large anticlinal closure was mapped in the northern part of T/9P from sparker control in 3,000 to 5,000 feet of water. More than 50 square miles of closure with more than .5 seconds (two-way reflection time) or about 2,000 feet of structural relief was found. About 1,500 feet of Tertiary rocks are interpreted on the crest.

Sparker work indicates that the bald headed basement ridge previously found along the border of Victoria and Tasmania extends in an east-southeast direction into a deep-water area. The middle and southern parts of T/9P have a thin, disturbed, reflecting section in very deep water and therefore are of little potential as prospective hydrocarbon areas.

C. Northwest Tasmania Area

Sparker traverses covering 851 statute miles were shot and interpreted in offshore Northwest Tasmania to

evaluate prospective section, basin configuration and structural-stratigraphic leads. Results show several large elongate anticlinal features. At least one anomaly extends into the shallow water area (less than 600 feet) which covers 175 square miles of the permits (T/2P and T/10P). This feature with a crest line at SP05, Line M280 trends south-southeast and appears to be a basement erosional high with Tertiary (?) rocks resting unconformably above.

A structural ridge on trend with King Island seems to divide the area between the eastern flank of the Otway Basin on the west and a sub-basin of the Bass Basin to the east.

Stratigraphic trap possibilities are present in a pre-Tertiary sedimentary sequence, which unconformably underlies the Tertiary section to west of the forementioned ridge. The overlap of Tertiary beds onto basement and onto pre-Tertiary structures also affords stratigraphic possibilities.

Tertiary sediments range from 1,000 to 5,000 feet in thickness and thin southerly and westerly. Pre-Tertiary rocks decrease from a maximum thickness of 10,000 feet in the north to 6,000 feet in the south in deep water.

SECTION II

RECOMMENDATIONS

A. South Sydney Basin Area

The present survey did not define the extent and thickness of Permian sedimentation in the northern part of NSW EPP/1. Since onshore geologic information suggest such sediments probably underlie this area, further reconnaissance seismic and magnetic surveying should be undertaken.

B. East Gippsland Basin Area

At least one drilling prospect, Feature VII, is delineated in this work. Because of the difficulty of picking the Top Latrobe Complex erosional surface, more than one test of this structure is justified. On the basis of what is learned in the first test, the west-adjoining noses south of Fault W and west of Feature VII would be enhanced or lessened as drilling prospects. Study of seismic data in the west-adjoining prospect, as it becomes available in subsidy reports or from trades, should have a high priority.

The deep water prospects in T/1P and T/9P should be evaluated by multi-coverage digital seismic methods. This can be deferred, however, until well completion techniques have advanced sufficiently to permit operations in such water depth.

C. Northwest Tasmania Area

Subsidy data from Prawn No. 1 and Clam No. 1 wells should be studied and compared to extrapolate possible source and reservoir potential of Magellan's permits.

Esso Line EO-26 which extends into Magellan's permit should be compared in detail with the present survey tie lines to relate current sparker-magnetic results to previous digital processed multi-coverage data. Thereafter a detailed multi-coverage seismic program can be planned if these studies so warrant. The next geophysical program should be designed to delineate drilling locations.

SECTION III

INTRODUCTION

A. REPORT COMPOSITION

The subsidized part of the Tasman-Bass Strait Sparker Profiler and Magnetic Survey, reported herein, consists of 1,835 miles of single coverage reconnaissance sparker profiling and 143 miles of digital, multi-coverage air-gun shooting; towed magnetic data were concurrently recorded. Data collection commenced on August 16 and the survey was completed on September 18, 1969.

This report consists of the combined contributions of several authors involved in the work. For the data collection effort, Teledyne Exploration Company was the prime contractor with Offshore Navigation Incorporated subcontracting the radio positioning. Their part of the work is presented in Section VI, Field Operations. The digital processing of selected portions of the data was shared by Western Geophysical Company, Geophysical Service International and Teledyne Exploration Company. The results of this phase of the work are contained in Section VII, Data Processing. J.E. Milner, Consulting Geophysicist interpreted the data from Northwest Tasmania (Permits T/2P and T/10P) and A. Sabitay, Magellan's Geophysicist, interpreted the New South Wales (NSW EPP/1), East Gippsland Basin Area (VIC/P3, VIC/P4 and T/1P) and East Tasmania (T/9P) data. These results are presented in Section's IV and V, Interpretation. The remaining Sections (I, II, III) and compilation and editing of the report in total is the work of A. Sabitay.

Previous work in adjoining permits has been incorporated where feasible. A small amount of digital reprocessing of previous Magellan work in T/1P was

included in the present work program. CDP work has been processed separately from sparker reconnaissance data in the East Gippsland Basin Area.

B. LOCATION

Tasman-Bass Strait Survey work ranged over offshore permit areas adjacent to southeastern Australia from south of Sydney to northeastern Tasmania continuing to west of King Island in the Bass Strait. Four small scale maps (Figures 1, 2, 3 and 4) show the program location.

Those lines or parts of lines which are located within the non-subsidy regions determined by 50-mile radii from the Kingfish and Halibut oil wells are not reported herein.

C. REGIONAL GEOLOGY

1. South Sydney Basin Area (NSW EPP/1)

The permit area lies offshore of two major structural features in New South Wales. Northward from the Victorian-N.S.W. border to about 36° of latitude the Southern Highland Fold Belt is found onshore. The bulk of rock exposures adjacent to the permit consists of Cambrian to Upper Devonian clastics, volcanics and associated igneous intrusions, extensively eroded and folded into a series of northerly aligned belts. As in the Gippsland Basin to the south, they are considered to form the basement complex of the bordering continental slope and shelf.

In the northern onshore area basement is overlain, with marked angular unconformity, by sub-horizontal Permian sediments of the Sydney Basin. Minor carbonaceous beds are developed at the base of the section. These delineate the southern extent of the "Southern Coalfield". The main mass of sediments, however, consists of shales, siltstones and

sandstones representing marginal marine facies developed on an irregular platform. The gentle northeast regional dip of the beds apparently is parallel to the paleo-depositional slope. From the fold-belt margin eastward the shale-sand ratio in the Permian beds gradually increases. This may be due to deepening of the basin or increasing distance from the source.

The Permian and older sediments and the basement complex have been intruded at several places along the present coast by igneous plugs of probable Tertiary age.

Cenozoic conglomerates, sandstones, siltstones and lignitic shales are intermittantly exposed overlying the Paleozoic basement along the coast, adjacent to the southern part of the Area of Investigation. No marine fossils have been recorded and the sediments appear to represent back-swamp, paralic to fresh-water deposits. It is possible that these deposits have thicker marine equivalents offshore on the continental slope.

2. East Gippsland Area

The Gippsland Basin is fairly well defined in southeastern Victoria and the adjacent offshore area. However, the eastern and southern boundaries are unknown.

During Paleozoic time the area was part of the Tasman Geosyncline, and great thicknesses of sediments were deposited along with intrusive and extrusive igneous rocks. The Lower Paleozoic strata are not prospective for hydrocarbons because of their intensely folded and metamorphosed nature. However, the Upper Devonian, Carboniferous and Permian rocks have been reported as having possible source and reservoir potential.

The Paleozoic formations are overlain by a thick Mesozoic sequence. The rock types are largely of terrestrial origin and include sandstone, mudstone, shale and coal.

Orogenic movement occurred near the close of Early Cretaceous time which folded, faulted and eroded the lower Cretaceous and older rocks. This was followed by deposition in Late Cretaceous and throughout most of Tertiary time. Deltaic deposits, which may interfinger with more marine beds eastward, were laid down in the western and central portions of the Gippsland Basin from Late Cretaceous through Paleocene and most of Eocene time. Epeirogenetic movement occurred from Late Cretaceous through Pliocene time. This resulted in the deposition of predominant sands and coals until the Oligocene when marine marls, mudstones and limestones were laid down. The sea regressed to its approximate present position near the middle of the Pliocene.

Structural movement, which was oriented generally northwesterly in the Paleozoic, was predominantly directed along east-northeast axes from the Mesozoic on. The Gippsland Basin which began to take form about Jurassic time had attained its present configuration by the early Tertiary.

The area herein referred to as East Tasmania involves Permits T/1P and T/9P. Little is known about the geology of this area, however, the possibility exists that the Gippsland Basin extends southward into the area, perhaps merging with a sedimentary trough more or less paralleling the east coast of Tasmania.

3. Northwestern Tasmania Area

Permits T/2P and T/10P lie west of King Island and the northwest coast of Tasmania at the margin of the

continental slope and shelf. The prospect is thought to be near the southern margin of the Otway Basin and probably crosses the eastern basin margin delineated by a basement ridge trending south from King Island. East of this ridge Bass Basin sediments may exist or another sedimentary trough may be found paralleling the Tasmanian coast.

The western continental shelf of Tasmania is located in the southern part of the Paleozoic Tasman Geosyncline. Deposits in this ancient feature may exceed 25,000 feet in thickness and are composed of a complex of folded and faulted metamorphosed and unmetamorphosed sediments with associated intrusive and extrusive igneous rocks. This Paleozoic sequence is considered economic basement in the area and is not prospective for hydrocarbons.

Sedimentation started in the Otway Basin in Late Jurassic or Early Cretaceous time and continued throughout the remainder of the Mesozoic and much of the Tertiary. The depositional trends were transverse to the earlier northerly aligned depositional trends in the Paleozoic Tasman Geosyncline.

The northern margin of the Otway Basin is known onshore in southwestern Victoria and southeastern South Australia and has been established by outcrop and well control. The eastern margin is formed by the Selwyn Fault - King Island structural trend which is also the western margin of the Bass Basin. The southern margin is not defined. A BMR record (1966/170,"A Preliminary Review of the Otway Basin", page 9) states that available seismic data indicate a continuous section - mostly Cretaceous - extends well south of the 100 fathom line on the continental shelf. Further, the morphology of the slope development suggests pinch-out of offshore sedimentation rather than structural basinal limits.

Post-Jurassic sediments are made up of sandstones, shales and siltstones and have both source and reservoir potential. Convergence of basement and Tertiary (?) strata across the King Island Ridge in the permit area suggest a long growth history for this feature. Faulting and folding in the eastern part of the Otway Basin have dominent northeastern trends.

A sub-basin is suggested southeast of King Island which was open to the sea to the southwest. Prograding Paleocene and Eocene clastic sedimentation overlying a thick Cretaceous section is envisaged followed by the Tertiary deposition of marine marls and shales.

D. PREVIOUS GEOPHYSICAL WORK

1. South Sydney Basin

No previous geophysical work has been done in the permit area. North of the permit aeromagnetic and seismic work have demonstrated the extention of the Sydney Basin offshore on the continental slope. In Victorian waters south of the permit a reconnaissance seismic survey by Shell demonstrated the existance of up to 3,000 feet of Tertiary (?) section approaching the N.S.W. border in approximately 600 feet of water.

2. East Gippsland Basin Area

Magellan submitted a subsidy report on the East Gippsland Marine Seismic and Magnetic Survey in June 1969. This was a semi-detailed survey of Permits VIC/P3, VIC/P4 and T/1P.

Previous to this work a detailed aeromagnetic survey of these permits (not subsidized) was accomplished indicating interesting section thickness and possible structural anomalies in the area. The aeromagnetic results

were used as the basis for planning the subsequent seismic survey.

Numerous aeromagnetic and reconnaissance seismic surveys have been conducted by Esso/BHP in the west-adjoining permits and by Shell in the northern part of the Gippsland offshore area. These are listed and results described in the East Gippsland subsidy report. Where feasible, previous geophysical results have been utilized in planning, executing and interpreting the present survey.

3. Northwest Tasmania Area

The Magellan aeromagnetic survey mentioned previously contained sparse data in the Northwest Tasmania Area. Other pertinent work has been done in the east-adjoining Esso/BHP permits. These are listed below:

1. The Offshore Otway Basin Marine Seismic and Magnetic Survey, EP-67; Esso; May 1968.

2. Offshore Otway ER-68 Seismic and Magnetic Survey; Esso; March 1969.

3. Tasmania EE-68 Marine Seismic and Magnetic Survey; Esso; April 1969.

Other older and/or more distant work has been carried on in the general area. These are described in "A Preliminary Review of the Otway Basin", Record 1966/170 by the BMR.

E. OBJECTIVES

The present survey was planned primarily as reconnaissance of four of the included permit areas which were essentially unexplored previously (NSW EPP/1, T/9P,

T/2P and T/10P). The method used (sparker profiling and marine magnetics) involved a departure from the usual aeromagnetic survey at this stage of exploration. Using the sparker profiler for section depth and structural leads backed up by marine magnetics for spot determinations of magnetic basement depth was thought to have higher delineation potential than the aeromagnetic method. In particular, information on section thickness, basin configuration and possible structural trap leads was sought.

For the East Gippsland Area, where exploration has progressed past the detailed seismic survey stage, further information concerning the eastern and southern Gippsland Basin margins was desired. The availability of digital instrumentation, an air-gun source and a 24-group streamer on the survey ship permitted detailed surveying of a structural anomaly in T/1P. Five lines were surveyed using this approach in defining this feature. In addition a single multi-coverage seismic line (M60T) was programmed for the south central part of T/1P where previous work was too widely spaced for detecting structural leads.

The objective of the reprocessing work was to clarify the mapped structure (Feature VII) in T/1P by subjecting the field data to the most detailed processing sequence available. A contractor, other than the one who processed the data previously, was used to have a second evaluation of the anomalous area.

F. HYDROCARBON POTENTIAL

1. South Sydney Basin

Very little is known of the hydrocarbon potential of the southern part of the Sydney Basin which seems to extend into the northern part of Magellan's N.S.W. permit. In general, exploration onshore has resulted in small gas

flows from Permian formations where poor reservoir characteristics are the rule. In the southern part of NSW EPP/1, interesting structural indications were found; however, the thin sedimentary section occurring there is a major detracting factor.

It is worth noting that the South Sydney Basin Area is situated in proximity to the New South Wales industrial market, which is the largest potential gas market in Australia and is still without a gas supply.

2. East Gippsland Basin Area

The oil and gas fields in the offshore Gippsland Basin are by far the largest in Australia having more than 1.5 billion barrels of oil and 6 trillion cubic feet of gas. Similar source and reservoir rocks are thought to exist in the East Gippsland Basin Area and structural-stratigraphic traps are indicated. Eastward from the Barracouta discovery well to the nearest reported commercial hydrocarbon occurrence at the Kingfish field (about 16 miles west of Magellan's permit VIC/P4) the proportion of oil to gas increases rapidly. No drilling has been done in the vicinity of the Tasmanian blocks (T/1P and T/9P) to indicate their hydrocarbon potential.

A sufficiently thick section has been established a few miles south of the Victorian border in T/1P and in the northern part of T/9P and structural closures have been delineated. Drillable water depths where oil field completions can currently be made are present in much of the interesting part of T/1P but the deeper water in T/9P would require advancement in completion techniques before indicated structures would become prospective.

3. Northwest Tasmania Area

Hydrocarbon shows in the Otway Basin have been limited to the Cretaceous section to date. The Tertiary

section has been fresh-water flushed in wells drilled, but has hydrocarbon potential in the seaward direction where massive sands may interfinger with silts and shales inhibiting flushing.

The potential of Jurassic rocks is unknown and the Paleozoic section is considered economic basement.

A sufficiently thick prospective section is indicated in Magellan's permits (T/2P and T/10P), and structural and stratigraphic trap leads have been established. At the moment the greatest deterent to drilling progress in the area is the excessive water depths.

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SECTION IV

INTERPRETATION

A. SOUTH SYDNEY BASIN AREA

1. Method

Approximately 630 miles of reconnaissance sparker profiles and towed magnetic data were studied. Fifty miles of multi-coverage digital air-gun data were taken on one line (M32S) to clarify preliminary results from the sparker survey. Thirty miles of the common-depth-point (CDP) data of M32S were digitally processed and these results interpreted.

Spot determinations of depth to magnetic basement were made using the rough approximation that the horizontal distance covered during the recording of the maximum linear gradient on a positive magnetic anomaly is equal to the depth of the anomalies' source. These depth estimates are shown on the Basement map outlined in a box with point of location indicated by an arrow (See Plate 1).

A water depth map was constructed from fathometer records for shallow depths (less than 600 feet) and from the water bottom reflection on sparker profiles for deeper water. This is presented as Plate 2.

Water replacement statics were applied to Basement reflection times on the basis of .007 seconds per hundred feet. This correction essentially replaces water travel time at 5,000 feet per second by an estimated sub-water travel time at 6,000 feet per second.

Most surveyed lines were under Shoran radio positioning control. Shotpoint locations for these lines

are shown on the maps by open circles. Where Shoran was not available the surveyed lines are shown with local time indicated on the maps with "filled-in" circles every fifteen minutes.

A half-scale reduction of a portion of Line T-7 is shown in Plate 3 to illustrate a typical sparker profile with structural turnover. The magnetic anomaly associated with the feature is located at 23:25 as shown in Plate 4 (full scale equals 100 gammas).

No geologic depth maps were prepared because of the shallow section found and the lack of velocity information for time-to-depth conversion.

2. Stratigraphy

Sparker control indicates essentially a wedge shaped (east-west) cross section of probably Tertiary sediments resting on the continental shelf and slope, as illustrated by Plate 5, Sparker Profile of Line M4S.

On Plate 5 the red horizons are the water bottom and multiples thereof. The green horizon is a continuous Tertiary (?) reflector and the purple horizon is thought to be economic basement. It is readily seen that the section is thickest at the continental slope (about 2,200 feet) and thins to less than 1,000 feet in each direction.

Onshore stratigraphic studies (New South Wales Geological Survey Bulletin No. 17, 1962) suggest that a fairly thick Permian section would be expected in the northern part of Magellan's permit. West of Ulladulla up to 2,500 feet of a predominantly marine arenaceous section was found and at the coast more than 1,000 feet of Permian overlain by Tertiary clastics and Quaternary alluvium is evident. General easterly to northeast dips of 1° to 2°

were measured in the Permian rocks of the Sydney Basin onshore (op. cit. page 20, 26) and the sequence is thought to have a planar surface but an irregular base. Evidence of a thick Permian section was not found in the present survey.

The geologic history of the southeast part of the Sydney Basin contains numerous periods of intrusions and extrusions. Hypothetically, it may be surmised that basaltic flows which occurred in Permian and Miocene - Pliocene time may have overlain considerable thickness of Permian deposits. This would have adversely affected the interpreted data in two respects. Firstly, reflections from beneath the basalt may be masked, and secondly, falsely shallow indications of economic basement could result from magnetic data.

The areas of maximum interpreted sedimentary thickness are from reflections found from the northern permit boundary to about 35°45'S and from 36°30'S to the southern boundary of the permit. Within these zones sedimentation thickness approaches 3,500 feet along the present hinge line. In the middle part of the permit between 35°45' and 36°30'S the same wedge-like basinal form was noted but having a maximum thickness of about 1,500 feet.

2. Structure

Plate I, a structure contour map of Basement, could also be (in the northern part) a mid-Tertiary or Top of Permian map depending on possible basaltic flows in Miocene-Pliocene and Permian times. In the latter case the rolling aspect of Line T-1 is of particular interest. Structural leads are seen at 0300, 0430, 0520 and 0615. The first may be related to a possible turnover on Line M1S, SP 80 and the second to an anomalous high area in the vicinity of SP 60, Line M41S. Possible turnover is also seen at SP 115,

Line M4S which may be related to that at 0615 on Line T-1.

Other highly speculative anticlinal anomalies are shown at the intersection of Lines M3S and M41S, on M4S at SP 60 on M41S at SP 115 and on T-5 at SP 24.

A fault is postulated across the entrance to Jervis Bay down-thrown to the west. Major faulting and slumping are seen opposite Batemans' Bay near the permit's east boundary.

The most interesting feature in the southern part of the permit is a closed domal anticline found on Lines T-6, T-7, M22S and M32S. Plate 3 shows this feature, which is supported by positive magnetic anomalies on each of the lines (see Plate 4). Water depth at the crest is 390 feet. The dome is roughly five miles in diameter and appears to be a basement high surrounded and thinly covered by Tertiary to Recent sediments. Relief on the "high" is roughly 900 feet covered with 500 to 1,000 feet of deposits at the crest and flanked with up to 2,500 feet of sediments, off structure. There appears to be little convergence or thinning of overlying rocks on the structure.

An anomalously high area was found at SP 75 Line M16S which has been optimistically contoured as indicative of possible closure to the northwest. Other leads are possible nosings opposite Merrimbula Bay and at SP's 80 and 125 on Line M27S trending into the cape, north of Disaster Bay.

Turnover in very deep water was seen on the southwest end of Line M18S.

Along the eastern permit boundary, strong faulting and slumping were observed on the shelf. A down-to-the-

northwest normal fault is postulated opposite Horseshoe Bay.

3. Quality and Reliability Critique

As a reconnaissance tool in the South Sydney Basin the field and interpretive methods employed are thought to be inadequate in defining section thickness. Were it not for the onshore geologic indications the offshore section results would require a pessimistic appraisal of the permits hydrocarbon potential. Although areas of hydrocarbon production from equally shallow Tertiary depths are known (Central Sumatra and northern Honshu, Japan for example) the Permian potential remains unknown.

Numerous probable unconformities and possible basalt flows at differing geologic times contribute to geophysical problems in seismic and magnetic surveys of the area. Possibly, refraction profiles or multi-coverage seismic surveying could define basin thickness.

Velocity analyses performed on part of CDP Line M32S indicated little probability of pre-Tertiary section. The location for the CDP line was selected in the southern part of the permit because of the clearly defined (on sparker profiles) anticlinal feature at Lines T-6 and T-7 and M22S. In retrospect it would have been worthwhile obtaining some CDP data in the northern part of the permit in an attempt to gain information about the Permian section.

More information is required with respect to the nature of the Permian sequence and to the significance of the rolling surface presently mapped as Basement, but which could reflect folded Permian strata, before any conclusions as to the hydrocarbon potential of the northern part of the permit can be made. On the other hand, the definite

southern domal structure, previously described, is a drillable prospect but offers only a thin prospective section.

At the deep-water ends of sparker profiles clarity is obtained in the definition of reflecting horizons to the maximum depth of seismic source penetration because of the "window" in water bottom multiples. Where practical sparker lines should always be continued into sufficiently deep water to exploit this advantage.

Constant vessel speed and straight survey lines should be maintained during the recording of magnetic anomalies as they are seen to develop on the concurrently obtained graphic display.

B. EAST GIPPSLAND BASIN AREA

1. General

Three sets of data will be treated separately in this part of the report:

a) Sparker profiling of the N.S.W.-Victoria Tie Line (M45S) and in permits VIC/P3, T/1P and T/9P.

b) Multi-coverage digital air-gun data in T/1P (Line M55T through M60T) (See Section VII.B for GSI's processing report).

c) Reprocessing of multi-coverage digital Aquapulse data from the East Gippsland Marine Seismic and Magnetic Survey, June, 1969. (See Section VII.A for Western's processing report).

Illustrations prepared for this interpretive discussion include a Water Depth Map (Plate 6), a Basement Time Map (Plate 7), and a Water Bottom-Basement Time Interval Map (Plate 8) at a scale of 1:250,000 which illustrate sparker results. In addition, revised versions of the depth maps presented with the East Gippsland Marine Seismic and Magnetic Survey, June, 1969, have been prepared for the interpretation of Lines M55T through M60T. These include three Structure Contour Maps at Mid-Miocene (Plate 9) Top Latrobe Complex (Plate 10) and Basement (Plate 11) Levels, a Water Depth Map (Plate 12) and two isopachs (Plates 13 and 14) all on a scale of 1:100,000.

2. N.S.W. - Victoria Tie Line (M45S)

About 74 miles of sparker profiling and marine magnetics were recorded to relate section thickness and stratigraphy between permits NSW EPP/1 and VIC/P3. These data were taken on a Shell permit with their permission and studied in conjunction with reconnaissance data using four-fold analog dynamite shooting. (For details of this work see Shell's subsidy report "Offshore Gippsland Seismic Survey"; Victoria PEP57; March, 1966).

Shell contoured the "Base of Tertiary" in this area at roughly .7 seconds (two-way sub-sea time) obtaining an approximate thickness of 2,500 feet for Tertiary deposits. This interpretation was confirmed on Line M45S by both sparker and magnetics data. The reflecting section resembles that found in New South Wales for 20 miles southwestward along M45S. The low amplitude, high frequency appearance of this thin section suggests absence or, at most, a thin veneer of the basal Tertiary Latrobe Complex.

From about SP 150 southwestward the section gradually thickens and changes appearance to that of the Gippsland Basin with high-amplitude, low-frequency

reflections at the base of the Tertiary section. The continental slope is crossed at about SP 270 where a down-to-the southwest fault is postulated. Thereafter, the section thickens to about 5,000 feet on entering Magellan's permit VIC/P3. Foreset bedding is evident on the slope in the shallower beds. As the Tertiary begins thinning towards the abyssal plain the pre-Tertiary thickens maintaining at least 1.0 second of total reflecting section.

No structural leads worthy of comment were noted. As far as basinal configuration is concerned the tie-line simply confirmed the pre-supposed northeastern boundary of the pre-Miocene (?) Gippsland Basin deposition. The stratigraphic relationship of VIC/P3 to NSW EPP/1, was slightly clarified by this evaluation.

3. Sparker Profiling and Magnetic Results in T/1P and T/9P

In T/1P, results (M54T) have added to tectonic information of the Gippsland Basin. Referring to Plate 7, the large basement ridge found in previous work (trending southeast in the vicinity of the Tasmania-Victoria border) is seen to continue beyond the eastern permit boundary. Superimposed on the southwest flank of the ridge is a large graben crossing Lines M54T3 and M54T4. Plate 15 (sparker profile of M54T3) shows the basement high and associated graben. The region southwest of the ridge in T/1P and extending into T/9P may lie in a sub-basin.

The northern part of T/9P contains more than 5,000 feet of sediments draped over a very rough basement topography. These sediments are strongly unconformable to the water bottom and dip north east indicating recent tilting along a northwest-southeast strike line.

A large basement uplift dominates the Basement contour map in the northern part of T/9P. It was crossed several times by sparker profiles (for example see Plate 16) and lies in water depths of 3,000 to 5,000 feet. Strong convergence of the "Basal Tertiary" (?) sediments are seen on all flanks. A thin section of probably late Tertiary sediments (1,000 to 1,500 feet) remains on the crest. The basement high is about 10 miles long and varies in width from 8 miles in the north to 4 miles in the south. It is associated with flanking faults on the east and west, down-thrown to the west.

The remainder of the prospect is mostly in deep water (6,000 feet to 10,000 feet) and has a thin section of disturbed sediments on a faulted and rough basement surface. Possible reef buildups were noted near SP 110, M4E and SP 20, M8E.

The planned shooting program was greatly modified in T/9P while the data were being collected. Lines were added in the north to delineate structural leads and lines were deleted in the south when insufficient section and deep water was observed. This is a good example of the flexibility available in the reconnaissance method used.

4. Multi-Coverage Results in T/1P

a) Air-Gun Data:

Seventy-one miles of 48-fold air-gun data were digitally recorded and processed to define an interpreted elongate anticline in T/1P referred to as Feature VII and so labelled on submitted maps (see East Gippsland Marine Seismic and Magnetic Survey; June 1969). A single long line (M60T) was included in the work to add detail to the previous survey in

the south part of T/1P where lines were widely spaced. Maps from the previous report were revised to incorporate these results.

The major changes to these maps are described below:

Horizon B (Top Latrobe Complex), Plate 10

1) The north plunge of Feature VII at Horizon B level became a separate culmination. This resulted from lack of turnover on Line M57T where expected, and, turnover on the crest Line M55T at Line M19T.

2) Although the remainder of the feature resembles previous mapping, the western flanking area took on additional potential with the development of a structural nose paralleling the anticline with a crest line along Line M56T between M19T and M20T. The nose lies on trend with an anomalous high in the west-adjoining permit southwest of Line ET83R between EC161 and EC162. Another southeast plunging nose is interpreted south of Fault W relating turnover on Line M21T at SP 3977 and on M40T at SP 4610. This nose is also on trend with an anomalous high on Esso Line EH-181.

3) The speculative anticlinal Feature VIII, north of M23T on M60T, was confirmed. About 350 feet of vertical closure is mapped over approximately 7 square miles in 1,300 to 1,600 feet of water.

Horizon C (Basement), Plate 11

1) The trend of Feature VII at Basement level is shown to be southeasterly which better conforms to aeromagnetic mapping.

2) Complex fault patterns in the west-adjoining permit near Feature VII now appear to be related to a large area of uplift and faulting underlying the anomalous area.

3) Line M60T suggests a generally high basement ridge from near its northern extremity to a mile north of M24T.

4) Fault interpretation in the south central area has been revised drastically. Fault X has been reduced in length and no longer appears to cut Line M23T. The orientation of Fault Y has been changed to northeast and it now appears to cross M23T. A new fault AA has been mapped crossing Line M41T at SP 4343 down-thrown to the south and a revised Horizon C picked in its vicinity. The orientation of Fault W has been reinterpreted as being more northerly and it now crosses neither M21T nor M39T.

Isopach B-C, Plate 14

1) Fault orientation has been revised to conform to Horizon C. Other than this the main revision on this map reveals a "thin" trend along the basement ridge found on the northern part of M60T.

Only minor changes have been made on Horizon A (Plate 9) and the A-B Isopach (Plate 13) by the addition of the new data. The Water Depth Map (Plate 12) has revealed present day channels crossing M60T at SP's 50, 90 and 145.

The air-gun lines were placed on top of Feature VII for the most part. As a result they exhibit the same "wormy" appearance in the Latrobe sequence as previously noted on Line M37T. Except for the northeast end of Line M58T (which is off structure) this phenomenon reflects the influence of basement control on the feature very clearly. A geologic explanation is required for this appearance because a duplicated portion of an Aquapulse line (where "worminess" is not seen) in the non-subsidy area had equally continuous reflections thus eliminating the differing source and processing as possible causes of the "wormy" appearance.

Differential erosion, small tension faults and/or facies changes such as a higher proportion of sands on structure are postulated to explain the "worminess". The top of Marlin field, as seen on a subsidized Esso (EG-38) seismic section, also exhibits this appearance. In picking the Top of Latrobe horizon the "wormy" section was followed because continuous reflections were absent and phantomed dips are thought to be meaningless.

5. Reprocessing of Feature VII Lines

Those portions of seismic lines obtained in the East Gippsland 1968 survey and pertinent to the delineation of Feature VII were reprocessed by Western to obtain maximum results for interpretation. A major increase in processing effort as compared to the previous GSI processing incorporated a 2 on 1 vertical stack followed by a 24-fold horizontal stack as compared to the former 4 on 1 vertical stack followed by a 12-fold horizontal stack. In addition,

deconvolution was done prior to horizontal stacking in the reprocessing compared to deconvolution after stacking in the original work. This change of effort plus the use of improved display equipment resulted in superior sections.

The major gain was in resolution between the discontinuous Latrobe section and the overlying continuous Mid and Late Tertiary section. Thus the erosional unconformity picked as the "Top Latrobe Complex" could be more easily mapped. Particular examples of increased reliability are listed below:

a) Turnover at SP 3714, M19T. Improved continuity provided recognition of convergence on both flanks.

b) Southwest dip is more easily seen on Line M20T from SP 3750 to 3775 on the unconformable surface by differentiation between continuous overlying beds and "wormy" Latrobe sediments.

c) Southeast dip in deep data is clarified between SP 3392 and 3402, M36T.

d) Fault indications such as dip changes at SP 4620, M40T are more definite. The possibility of channel scouring and subsequent filling with flat-lying post-Latrobe sedimentation is suggested between SP's 4620 - 4635 on the reprocessed data.

e) The same channel appears to trend along the western flank of Feature VII as shown on reprocessed sections M19T and M20T.

In the reprocessed sequence, replacement statics for minimizing the effect of variable water depths were not used. This had the adverse effect of deterioration of shallow reflections but does not seem to have degraded the prime reflections of interest at and below one second. The saddle between the two turnovers on Line M21T appears exaggerated on the reprocessed section because of the increased travel time due to deeper water.

Little advantage was gained in reinterpreting the area near SP 4930, M39T in spite of improved continuity and resolution in the reprocessed data. The fault previously interpreted here is not greatly clarified but is confirmed by dip changes and distortion.

074034 GS-M-05-3 PART 2

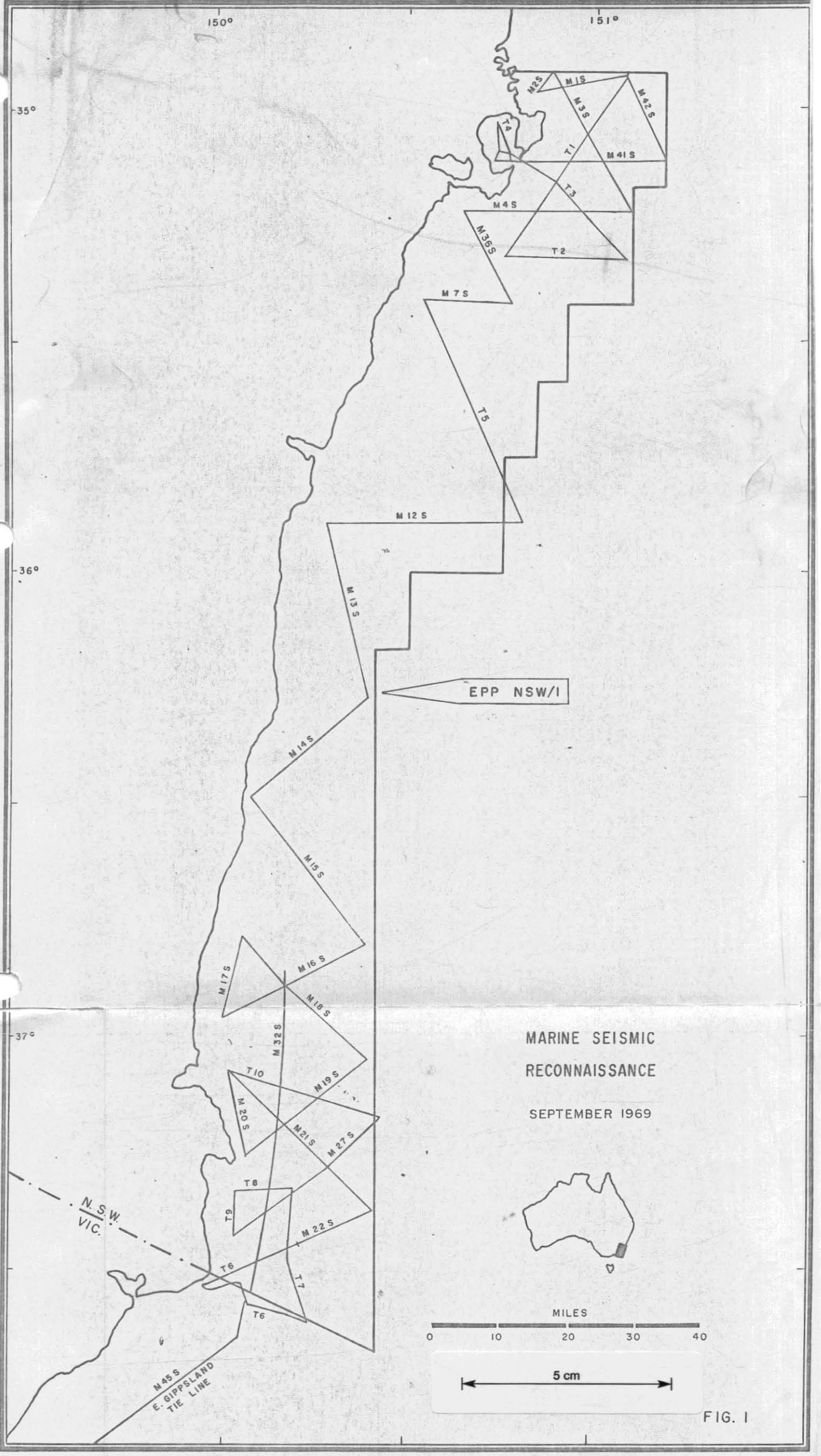


FIG. 1

074035 GS-M-05-3 PART 2

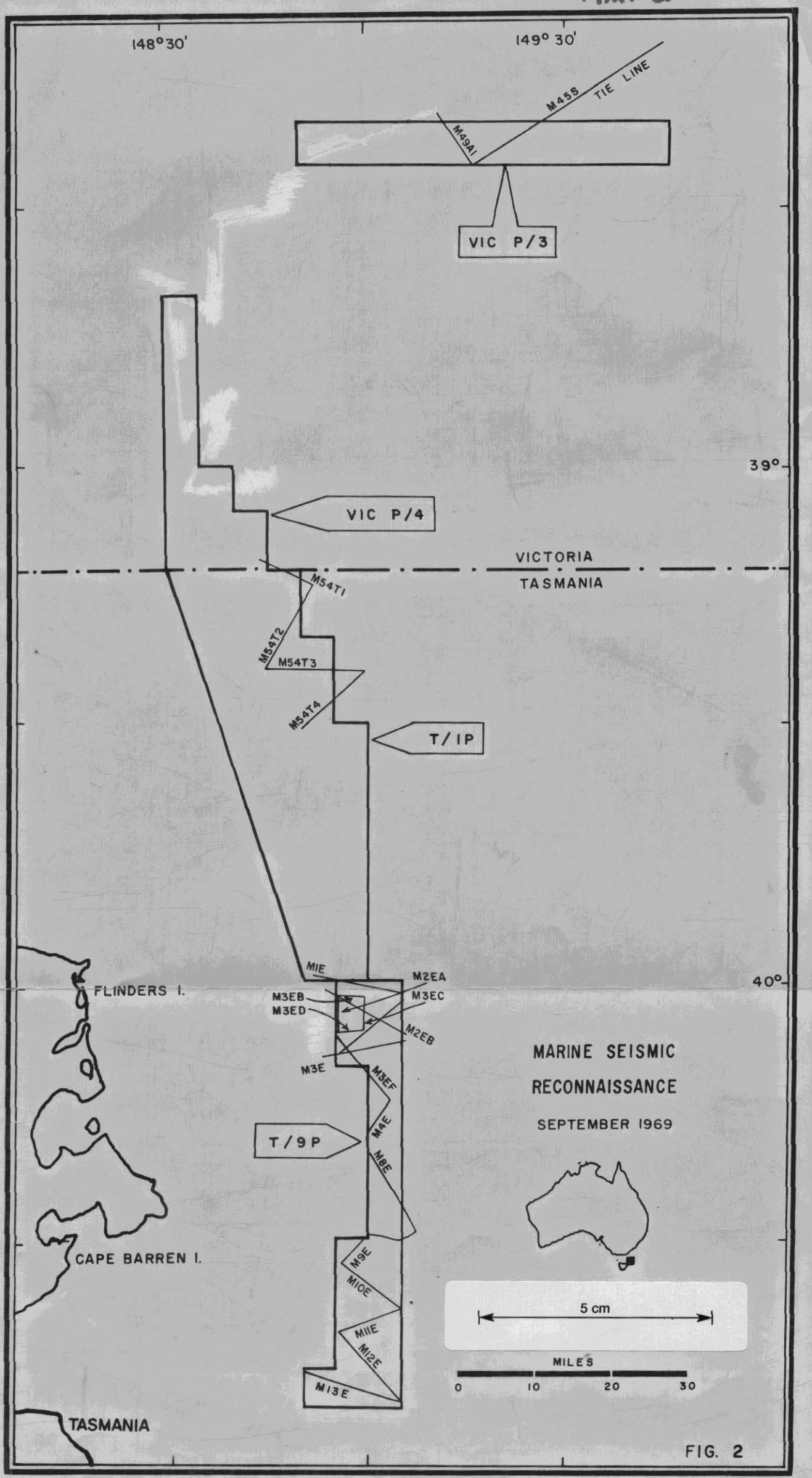


FIG. 2

074036

GS-M-05-3
PART 2

143°

144°

VICTORIA

TASMANIA

M40A
M20
M40
M360
M50
M70
M80
M100
M330
M320
M110
M130
M120
M400
M300
M310
T/2P
M290
M150
M140
M160
M170
M280
M260
M180
M190
M270
M250
M230
M410
M240
M200
M220
M210
M9W
M8W
M7W
M6W
M5W
M4W
M3W
M2W
M1W
M11W
T/10P

KING
ISLAND

TASMANIA

MARINE SEISMIC
RECONNAISSANCE

SEPTEMBER 1969

MILES
0 10 20 30 40

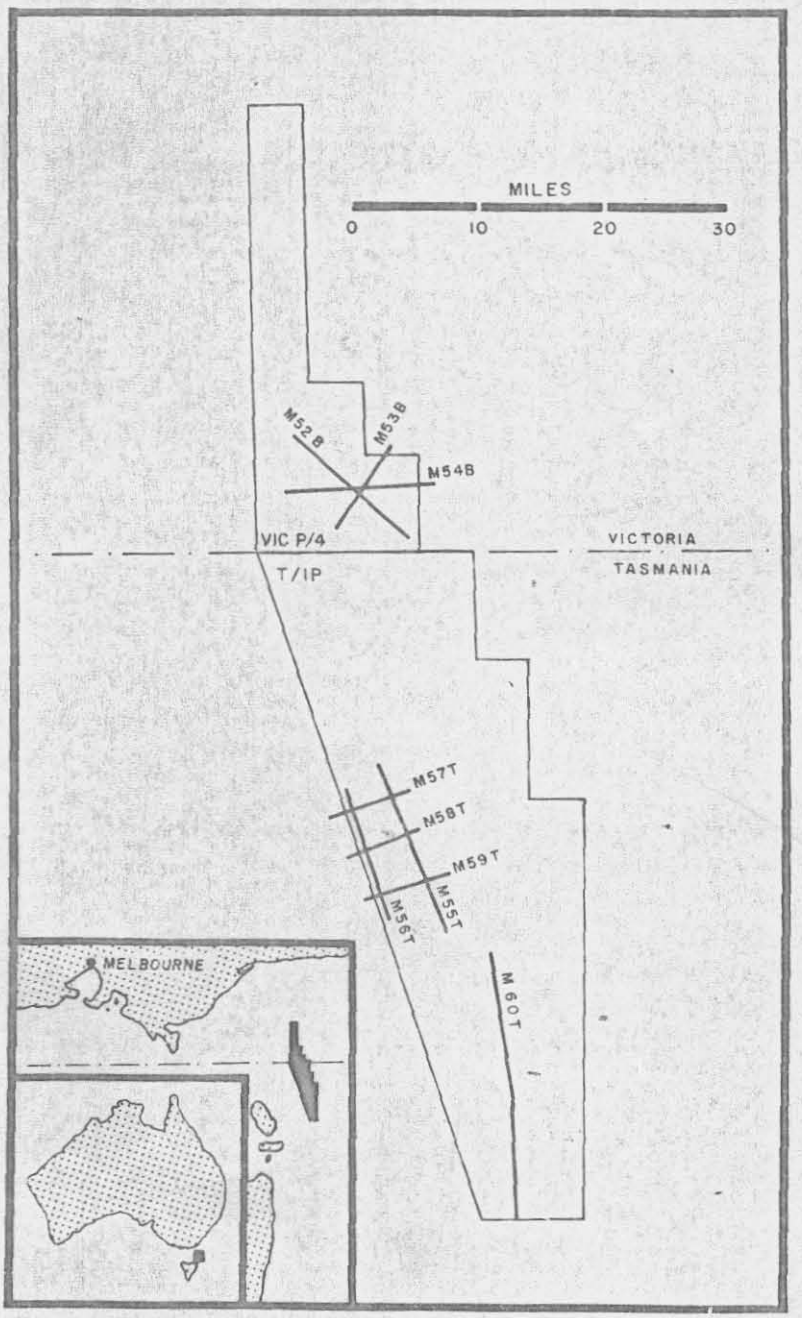
5 cm

FIG. 3

FILE NO B38

074037

GS-H-OS-3
PART 2



MARINE SEISMIC SURVEY

TASMAN-BASS STRAIT

COP PROCESSED LINES

NOVEMBER 1969

FIG. 4

5 cm

074038

SECTION V

FINAL INTERPRETATION

TASMAN-BASS STRAIT MARINE SEISMIC SURVEY
NORTHWESTERN TASMANIA AREA

PERMITS T/2P & T/10P

for MAGELLAN PETROLEUM AUSTRALIA LIMITED

by

J.E. MILNER
CONSULTING GEOPHYSICIST

DECEMBER 1969, BRISBANE,
QUEENSLAND.

ILLUSTRATIONS

Plate 1 Horizon Approximate Top Magnetic Basement
2 Horizon Approximate Base of Tertiary
3 Events between Basement and Tertiary Section
4 Water Depth Map
5 Section Line M-2-0
6 " Line M-8-0
7 " Line M-14-0
8 " Line M-28-0
9 " Line M-40-0 (SP 21-65)
10 " Line M-2-W

Figure 1 Location Map

NOTE: THE ABOVE NOT RECIEVED WITH THIS REPORT.

074040

ABSTRACT

A reconnaissance seismic sparker and magnetic survey was conducted by Teledyne Exploration for Magellan Petroleum Southern Pty. Ltd. in Exploration Permits T/2P and T/10P offshore Northwestern Tasmania, during September, 1969.

Results showed that approximately 175 sq. miles of the Permits lie within the 100 fathom line and the sea bed makes a steep western plunge from that line to depths of approximately 7,500 ft. Magnetic Basement was successfully located over most of the southern two-thirds of the area, and base of Tertiary over all of it. Events between these two horizons lie in water deeper than 3,000 ft. and could be followed only over limited areas.

Within the 100 fathom line approximately 3,000 ft. of Tertiary rocks lie close above basement. Potential hydrocarbon accumulation in this area would be in situations where these Tertiary rocks form drape structures over, or stratigraphic traps against Basement anticlinal features, however only one basement anticline has been traced into this shallow water area. The Tertiary rocks thin from north to south and east to west; approximate thicknesses in the North are: east side, 5,000 ft. to west side, 3,000 ft. and in the South: east side, 3,000 ft. to west side, 1,000 ft.

Westward from the 100 fathom line to approximately 6,000 ft. depth of Basement (roughly coincident with the 600 fathom line) in the southern half of the Permits the sedimentary section increases to approximately 4,000 ft. the increase being taken up by pre-Tertiary rocks. West of the 600 fathom line these pre-Tertiary rocks increase rapidly in thickness and diversity to in excess of 10,000 ft. in the north, thinning to approximately 6,000 ft. in the south, and provide a potential source of hydrocarbon accumulations.

Further exploration will require refined methods employing multiple coverage and digital processing; re-evaluation of data from adjoining permits would be necessary. Established leads are confined to the one basement anticline traceable under the shallow water area at SP 05 Line M-28-0.

074041

RESULTS

GENERAL

The quality of the seismic results was fair to good over almost all the area. Below approximately 100 fathoms a distinct event was received from the sea bed. A generally strong event occurring close to the base of Tertiary section was present over all the area (Plate 2). Over most of the southern two-thirds of the surveyed area an event approximately corresponding to the magnetic basement was present. Between these two horizons a series of other events could be seen; their extent and comments on their appearance are shown on Plate 3.

In addition to these primary events the following multiples appeared variously over the area:

First multiple of sea bed.
First multiple of Tertiary horizon.
First multiple of Basement horizon.
Multiple of sea bed-surface-Tertiary-surface.
Multiple of sea bed-surface-Basement-surface.
Sundry multiples of sea bed-surface-random event-surface.
Parts of the shallow water area showed a tendency to sea bed-surface reverberations.

The magnetic data tended on occasions to be very noisy, however several useful anomalies were apparent and estimates to basement from them are included on the Basement map Plate 1.

The horizons mapped on Plates 1 and 2 have been prepared in two way time. A replacement correction was made for the water depth using a replacement velocity of 6,000 ft/sec.

Whenever possible the data has been tied to the existing data from adjacent leases, and horizons have been identified from reports on that data. In particular, the results were integrated with those from the following reports:

Offshore Otway Basin Marine Seismic and Magnetic Survey, EP-67; Offshore Otway ER-68 Seismic and Magnetic Survey; and Tasmania EE-68 Marine Seismic and Magnetic Survey (all by Esso Exploration and Production Australia Inc).

WATER DEPTH MAP (Plate 4)

Except in the shallow water area (where the fathometer tapes were used) this map was constructed from the water bottom event occurring on the sections. A velocity of 5,000 ft/second was used to convert time to depth and the map was integrated with adjacent data. It is apparent that a rapid deepening of water is occurring westward, and the shelf slope is often heavily channelled (Plates 5 to 10).

Approximately 175 sq. miles of the permit lie within the 100 fathom line and the westward plunge shows water depths of up to 7,500 ft.

APPROXIMATE MAGNETIC BASEMENT (Plate 1)

Over the area of their occurrence reflections on this horizon varied from poor to good, the enclosed plates 7, 8, 9 and 10 show the variation in quality.

Generally speaking, the relief on the horizon is large and from approximately line M-25-0 southwards the features trend NNW-SSE, approximately the trend of the edge of the continental shelf. The trend north of line M-25-0 is north-south. At least one of the possible anticlines (that at M-28-0, SP 05) extends under the area of shallow water. It was not possible to determine whether other anticlinal features continued under this region due to the generally poor quality of results here and the short eastward extent of most lines from the edge of the shelf. The reports previously mentioned did not contain a basement map for the adjacent area.

In at least one location (Plate 8, M-28-0, SP 75) the surface giving rise to the reflection was an erosional high and tertiary beds sit immediately on basement.

074043

As mentioned before the magnetic data tend on occasions to be noisy, however, at the locations where estimates have been made the respective anomalies are well defined. All estimates from such anomalies appear to agree well with the approximate depth of the Basement reflection, and can be considered reliable within the limitations of the method. The method used was to equate magnetic depth to the horizontal length of the constant gradient of a total magnetic intensity positive anomaly.

Depths to basement vary from approximately 3,500 ft. in the region of lines M-12-0, M-30-0, M-15-0, M-27-0 and M-18-0 increasing to approximately 6,000 to 7,000 ft. at the arc NNW-W-S-SSE at approximately 10 miles from these lines and then plunge rapidly to depths in excess of 10,000 ft. over the remainder of the permits. Water Depths over the same limits vary from 400 ft. to 3,500 ft. to 7,500 ft. giving total sediment thickness of 3,000 ft. to 4,000 ft. to well in excess of 7,000 ft. respectively.

TERTIARY BEDS (Plate 2)

Results on the horizon approximating Base of Tertiary were good over all the area except the shallow water areas. It is felt this event arises from some unit within the lower Tertiary and very close to its base. Examination of several of the sections show that small amounts of Tertiary sediments may exist below this very strong event.

Except for the region immediately below the sea bed surface, where events follow the shape of the sea bed, most of the section to the Base Tertiary event appears to be conformable with that event and is probably all of Tertiary age. These beds appear to have been deeply eroded prior to the deposition of recent sediments and have been cut by several deep channels (Plates 5 - 10).

Generally speaking the interval Base Tertiary to Sea Bed is thinning fairly rapidly to the west. In addition, it is much thinner in the south than the north (Compare Plates 5 and 6 with 7, 8 and 10).

Thicknesses vary from the north: east side, 5,000 ft. to west side, 3,000 ft. to the south: east side, 3,000 ft. to west side, 1,000 ft.

The deterioration in quality of the Base Tertiary event in the shallow water areas appears to be due to a combination of reverberations and defractions. However, in certain areas the unit giving rise to this event may not have been deposited (see Plate 8, M-28-0, SP 20 to 010). In all the shallow water area the event is close to magnetic basement.

There are no structural leads apparent on the Base Tertiary event.

The horizon was tied to available subsidy maps for data in adjacent areas. The ties were not absolute and small modifications had to be made to previous contours. The portion of these maps so modified is defined by a broken line on the enclosed Plate 2.

EVENTS BETWEEN BASEMENT AND TERTIARY (Plate 3)

Plate 3 was designed to summarise the events occurring between the two principal horizons. Three of the events are traceable over several lines and are worthy of mention.

Event A occurs on most of the sections from about the centre of the survey going northwards (Plates 5, 6 and 7). It occurs closely below the Base Tertiary event, but is not conformable with it. Tertiary events converge on Event A at the western side of its southern limit of occurance and at the northern extremity. To the east it is generally lost in multiples, but thickening of the interval A-Tertiary is evident eastward. Event A locally shows terracing in contrast to general west dip. These localities have the appearance of indicating former high zones on this horizon.

Event B (Plate 9) situated south of central is again an event occurring just below the Base Tertiary and unconformable with it.

074045

It shows evidence of being overlapped by Tertiary to the north, west and south and like Event A is lost in the multiples to the east. This event originates from a horizon older than Event A.

Event C (Plate 9) is the oldest horizon of the three and occurs over most of the area occupied by Event B and is overlapped by it in all positions except to the south-west in which direction the B-C interval appears to be thickening. Event C shows one distinct anticlinal and one distinct synclinal trend and is unconformable to other events.

To the south of the area covered by the B and C events all lines show several events in the interval Tertiary-Basement which are generally conformable to the Tertiary events (Plate 10).

In general the interval Tertiary-Basement thickens rapidly with the steep western plunge of the basement marker, and the rocks in this interval are increasing in diversity and thickening to the west. As with the Tertiary the interval is thinning from north to south (Compare Plate 5 with Plate 10). However, less than 500 ft. of these rocks appear east of the approximate 100 fathom water depth line and a gradual increase to a thickness of approximately 1,500 ft. occurs from this line west to the approximate 6,000 ft. depth of Basement line (approximately coincident with the 600 fathom line in the southern half of the permits). The rapid westerly Basement plunge starts at the 600 fathom line. West of this dropoff thicknesses vary from approximately 6,000 ft. in the south to in excess of 10,000 ft.

CONCLUSIONS AND RECOMMENDATIONS

The EP-67 report, previously mentioned, postulated a long basement ridge extending southward from King Island. The southern half of this survey successfully defined the western edge of that ridge where it appears in T/2P and T/10P. It seems reasonable to assume that this ridge separates the Otway from the Bass Basin and that the thick sequence of sediments occurring west of the basement high are a southern extension of the Otway Basin. It is recommended that a comparison of the data from Prawn No. 1 well and Clam No. 1 well be made to test the strength of this hypothesis.

The same report showed a line depicting Basement Sub-crop on the Base Tertiary horizon extending into Magellan's area. However, both Base Tertiary and Basement events are recognisable over most of the permit area within that line, but converge in the shallow water area.

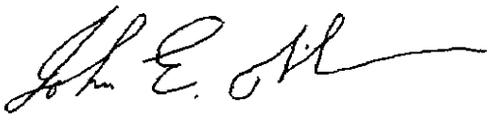
The extension of basement features such as the anticline passing through approximately SP 05, line M-28-0 provide the best chance for entrapment of hydrocarbons within the 100 fathom line both in drape structures over them and stratigraphic traps along their flanks. The quality of current data is such that the only Basement feature recognisable as extending into this shallow water area is the one on line M-28-0. Further work will have to be undertaken to determine the presence of others. The existence of reverberations and the precision required for the location of stratigraphic traps necessitates the use of a refined method employing multiple coverage and digital processing for exploration of this area of the permit. As possible traps are likely to extend into adjacent leases a complete review of data from these leases should be undertaken, however these data have poor quality and sparse coverage exists along most of the common boundary. Therefore, future exploration should extend into the adjacent lease.

Also of interest as a potential trap is the thick sequence of Pre-Tertiary sediment onlapping the western Basement plunge. Events A and B from this sequence are overlapped by Tertiary rocks principally on the western side, and show thickening to the east. This suggests that a small sub-basin existed between the basement ridge mentioned above and the western margins of the area, at least in immediate pre-Tertiary time. The former anticlinal axis postulated for Event A would have been close to the western edge of this sub-basin. Event C however is more in keeping with the westward synclinal axis indicated by the general basement structure. The principal problem associated with delineation of this sequence is the lack of reflection from it requiring refined methods of exploration. It should be pointed out that the region of rapidly increasing thickness in these rocks lies in water deeper than 3,500 ft.

074047

The survey tools used were successful in reconnoitering the area and the results are felt to be reliable. With the exception of the modifications mentioned above the results agreed with the finding of previous surveys, and provided a logical westward extension of them.

Respectfully submitted,



J.E. Milner,
Consulting Geophysicist

SECTION 6A

074048

OPERATIONS REPORT

TO

MAGELLAN PETROLEUM AUSTRALIA LIMITED

ON A

COMBINED

CDP - SSP

SEISMIC SURVEY

OFFSHORE AUSTRALIA

(MS - 708 - 5)

074049

OPERATIONS REPORT

TO

MAGELLAN PETROLEUM AUSTRALIA LIMITED

ON A

COMBINED

CDP - SSP*

SEISMIC SURVEY

OFFSHORE AUSTRALIA

(MS - 708 - 5)

A combined seismic survey using the Teledyne Exploration 160,000 Joule (SSP)* single channel survey system and CDP survey system using PAR Sound Source was conducted for Magellan Petroleum Corporation in the South Pacific Ocean, offshore New South Wales, Victoria and Tasmania, Australia. Teledyne Exploration International, Inc. furnished the vessel, personnel and equipment.

1. Personnel

Don Bowman	Supervisor
Jim Springer	Party Manager
John Downs	Senior Observer
Robie Surle	Digital Engineer

* Teledyne Trademark

Operations Report to
MAGELLAN PETROLEUM AUSTRALIA LIMITED
On a COMBINED CDP AND SSP* SURVEY OFFSHORE AUSTRALIA
(MS 708-5)

Mark Sol	Observer
Colin Green	Senior Technician
Ivan Perez	Technician
Tony Astorga	Deck Technician

2. TELEDYNE EQUIPMENT

A. 200,000 Joule (SSP)* system.

A-1. Three each PAR Air Guns, 40 to 300 Cubic inches.

B. Teledyne Exploration seven channel FM Magnetic Tape Recorder, Model SP 300

B-1. Twenty-four trace SDS Series 1010 Binary Gain Ranging Digital Recording System.

C. Hydrostreamer*, Model 24257 with 100 detectors in a 130 foot active section.

C-1. 24-group Paisley hydrophone streamer cable.

D. Power reels for items C and C-1.

E. Pneumatic depth controller for Hydrostreamer .

F. Facsimile recorder, Model 24255.

G. Operating supplies and spare parts.

H. Varian Proton Marine Magnetometer, Model 4970

3. EQUIPMENT DESCRIPTION (CDP)

A. Three Bolt Model 1500-A air guns (40, 120, and 300 cu. in sizes) were used as a sound source. These guns were towed 100 feet astern of the vessel at a

* Teledyne Trademark

depth of 25 feet, fired at 9-15 second intervals and operated at 2000 PSI.

B. One 24-group Paisley streamer cable equipped with depth controllers and designed for continuous tow with offsets to 1800 feet and group intervals of 300 feet was used. Seismic Engineering Company Model DI-104B depth indicators and Model DT-103 depth transducers were used along with Condeps to control cable depth. The cable was balanced to tow at a depth of 45 feet at a towing speed of 6-1/2 knots without Condeps. When surveying, the Condeps were used at a towing speed of 4.4 miles per hour with the cable at a depth of 50-55 feet.

C. One 24 trace SDS 1010 Binary Gain Ranging Digital Recording System (9 track, 1/2 inch tape) was used to record the data. The master control panel had pre-data constants used for day, month and year. Five second records were taken with a 2 ms sampling rate, while release rate was set at "MEDIUM" and trip sensitivity varied from -24 to -30 db. The early gain was staggered from approximately 24 db

* Teledyne Trademark

for trace No. 24 to 42 db for tract No. 1. On the binary gain amplifiers filters were 75 HZ on the high side to "out" on the low side with the Alias filter set at "medium" (125HZ). The playback amplifiers were set with no AGC, 75 HZ on the high side and "OUT" on the low side.

D. A facsimile recorder, Model No. 24255 modified Raytheon PFR-193 was used for a section monitor.

E. Varian Model 4970 magnetometer with supplies.

F. All operating supplies, spare parts, expendables and consumables.

4. VESSEL

M/V TELEDEX IV was leased to Teledyne from Dearborn Marine Services of Freeport, Texas, for this program. This is a steel hulled, twin screw vessel with the following dimensions: 127' x 27' x 12' with 8-10 feet of draft. During the survey the vessel was staffed by the following personnel:

Lawrence Langley	Captain
T. Davies	Engineer
R. Corona	Cook

* Teledyne Tradesmark

B. Rose	Deck Hand
Wayne Newcomb	Deck Hand

The vessel is equipped with the following: recording fathometer, Raytheon marine Telephone, SSB radio, Two 100 KW generators, freezers and coolers and air conditioned sleeping and messing accommodations for 20 people and has a cruising speed of 12 knots.

5. POSITIONING

The service of a Shoran crew was obtained from Offshore Navigation, Inc., of New Orleans, Louisiana. This positioning was used on all work that could be reached by the on-shore stations. Ship radar and celestial navigation was used when Shoran positioning was not available.

Mr. Al Sabitay, Mr. Sam Pees, or Mr. Mick Rose were on the vessel during the survey representing Magellan.

6. OPERATIONS

The survey consisted of several areas which are listed on the operations summary. The average vessel speed was slightly over eight (8) miles per hour while conducting the SSP* work. The Hydrostreamer* was towed at an

* Teledyne Trademark

was towed at an average depth of 35 feet while the SSP* cables were towed at an average depth of 25 feet. Signal from the Hydrostreamer* was paralled to two (2) Geo Space III Amplifiers in the facsimile recording system and to two (2) other Geo Space II Amplifiers in the magnetic tape recording system. The facsimile recording system normally used filter settings of 47-1 to 16-2 while the magnetic tape recording system used filter settings of 125-1 to 16-2. The seven (7) channels on the magnetic tape recorder were used as follows:

Channel No.	Mode	Recording
1	FM	Fixed gain seismic data
2	FM	Fix marks
3	AM	Time break and audio
4	AM	1200 H_z
5	AM	1000 H_z
6	AM	Time break
7	FM	AGC Seismic data

A varian Proton Marine Magnetometer, Model 4970 was used along with the SSP* survey. The use of magnetic surveys is described in an attachment to this report. Fathometer

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074055

Operations Report to
MAGELLAN PETROLEUM AUSTRALIA LIMITED
On a COMBINED CDP AND SSP* SURVEY OFFSHORE AUSTRALIA
(MS 708-5)

recordings were also taken on the lines surveyed.

All facsimile, magnetometer, and fathometer records were delivered to a Magellan representative.

A towing diagram showing the relative positions of the SSP* cables, magnetometer, and Hydrostreamer* is included in this report.

A total of 75 analog tapes were used during this survey.

AREA	NO. OF STATUTE MILES	DATES
NSW - EEP-1	628.3	Aug.16,1969 to Aug. 21, 1969.
NSW - EEP-1	69.1	August 29, 1969
East Gippland	8.3	August, 29, 1969
East Gippland	44.8	August 31, 1969
East Tasmania	59.3	September 2, 1969
East Tasmania	115.9	September 3, 1969
West Coast Tasmania & West Otway T2-T10P	414.4	September 8-10, 1969
West Otway T/2P & West Tasmania	436.9	September 11, 1969 - September 14, 1969
~~NSW - EEP - 1~~	~~57.5~~	~~September 17, 1969~~

N/S 107.5

1777.0

1834.5 #129 INCLS NSW CDP see p.s. 8

During the marine seismic survey for Magellan Petroleum Australia Limited in waters offshore Australia, CDP surveying with PAR Sound Source was conducted as follows

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Operations Report to
MAGELLAN PETROLEUM AUSTRALIA LIMITED
On a COMBINED CDP AND SSP* SURVEY OFFSHORE AUSTRALIA
(MS 708-5)

recordings were also taken on the lines surveyed.

All facsimile, magnetometer, and fathometer records were delivered to a Magellan representative.

A towing diagram showing the relative positions of the SSP* cables, magnetometer, and Hydrostreamer* is included in this report.

AREA	NO. OF STATUTE MILES	DATES
NSW - EEP-1	628.3	Aug.16,1969 to Aug. 21, 1969.
NSW - EEP-1	69.1	August 29, 1969
East Gippland	89.6	August, 29, 1969
East Gippland	26.2	August 30, 1969
East Gippland	44.8	August 31, 1969
East Tasmania	59.3	September 2, 1969
East Tasmania	115.9	September 3, 1969
West Coast Tasmania & West Otway T2-T10P	414.4	September 8-10, 1969
West Otway T/2P & West Tasmania	436.9	September 11, 1969 - September 14, 1969
~~NSW - EEP - 1~~	1884.5 ~~57.5~~	~~September 17, 1969~~

See page 8

During the marine seismic survey for Magellan Petroleum Australia Limited in waters offshore Australia, CDP surveying with PAR Sound Source was conducted as follows

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074057

Operations Report to
MAGELLAN PETROLEUM AUSTRALIA LIMITED
On a COMBINED CDP AND SSP* SURVEY OFFSHORE AUSTRALIA
(MS 708-5)

DATE	AREA	MILES OF LINE	RECORDING HOURS
Aug.29	NSW-EEP-1	5.4	1.5
Aug.31	East Gippsland	16.6	2.6
Sept. 1	East Gippsland	38.7	9.0
Sept. 2	East Gippsland	24.4	5.3
Sept.17	NSW-EEP-1	57.5	12.5
	Totals	142.6	30.9

During the CDP surveying the average survey speed was approximately 4.4 miles per hour.

There are SDS 1010 System checks on the following reels of digital tape:

Reel 1	Tape No. 0008810
Reel 40	Tape No. 0008802
Reel 59	Tape No. 009042

The digital magnetic tapes were used as follows:

Reel Nos.	Area	Firing Rate	Line No.
1 - 7	N.S.W.	9-15 sec.	M-45-S

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074058

Operations Report to
MAGELLAN PETROLEUM AUSTRALIA LIMITED
On a COMBINED CDP AND SSP* SURVEY OFFSHORE AUSTRALIA
(MS 708-5)

DATE	AREA	MILES OF LINE	RECORDING HOURS
Aug.29	NSW-EEP-1	5.4	1.5
Aug.30	East Gippsland	22.0	6.3
Aug.31	East Gippsland	29.7	5.8
Sept. 1	East Gippsland	38.7	9.0
Sept. 2	East Gippsland	24.4	5.3
Sept.17	NSW-EEP-1	57.5	12.5
	Totals	117.7 / 177.7	40.4

During the CDP surveying the average survey speed was approximately 4.4 miles per hour.

There are SDS 1010 System checks on the following reels of digital tape:

Reel 1	Tape No. 0008810
Reel 40	Tape No. 0008802
Reel 59	Tape No. 009042

The digital magnetic tapes were used as follows:

Reel Nos.	Area	Firing Rate	Line No.
1 - 7	N.S.W.	9-15 sec.	M-45-S
1 - 15	East Gippsland	10-14 sec.	M-54-B
16 - 25	East Gippsland	10-14 sec.	M-53-B

* Teledyne Tradesmark

074059

Operations Report to
MAGELLAN PETROLEUM AUSTRALIA LIMITED
On a COMBINED CDP AND SSP* SURVEY OFFSHORE AUSTRALIA
(MS 708-5)

Reel Nos.	Area	Firing Rate	Line No.
40 - 49	East Gippsland	10 - 14 sec.	M-56-T
50 - 58	East Gippsland	10 - 15 sec.	M-59-T
59 - 66	East Gippsland	10 - 15 sec.	M-58-T
67 - 72	East Gippsland	10 - 15 sec.	M-57-T
73 - 88	East Gippsland	10 - 15 sec.	M-55-T
89 - 111	East Gippsland	10 - 15 sec.	M-60-T
112 - 166	NSW - EEP-1	11 sec.	M-32-S

Line M57-T (reels 67-72) and line M-58-T (reels 69-66) were shot with the binary gain amplifier high cut filter set at 100 HZ.

A total of 118 digital tapes were used during this survey. All tapes and monitor sections have been turned over to the client.

Included with this report as appendices are:

1. Cable Diagrams
2. Brochure on PAR Sound Source
3. One PARAGON Systems Inc. brochure on 1010 Seismic Digital Field Recorder
4. Varian Magnetometer Brochure

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074060

7. CONCLUSION

Primary objectives as set forth by Magellan was conducted by Teledyne Exploration.

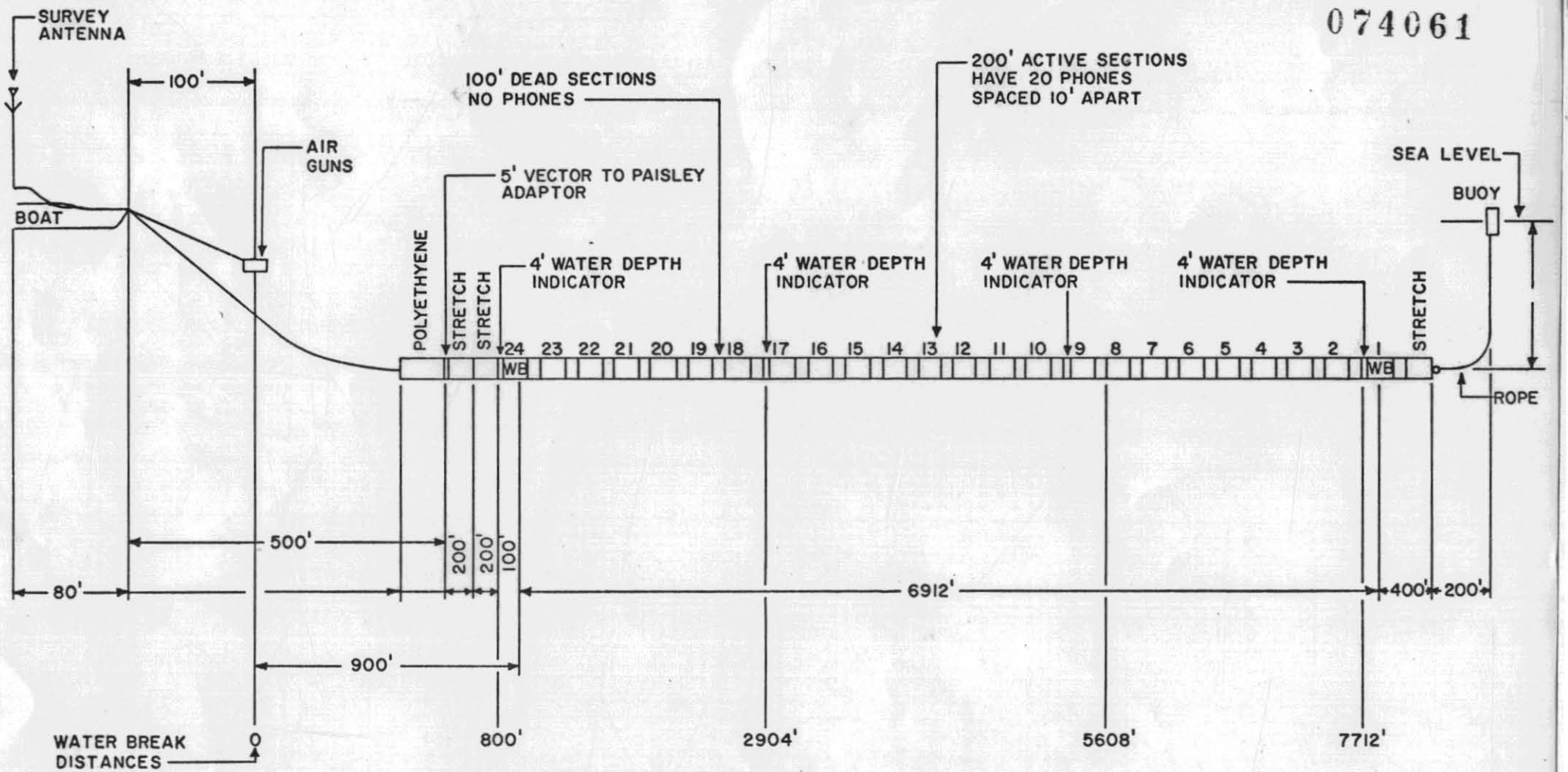
The co-operation of Client Representatives, Mr. AL Sabitay, Mr. Sam Pees and Mr. Mick Rose was appreciated throughout the survey.

Respectfully submitted:

Donald L. Beale

* Teledyne Tradesmark

074061



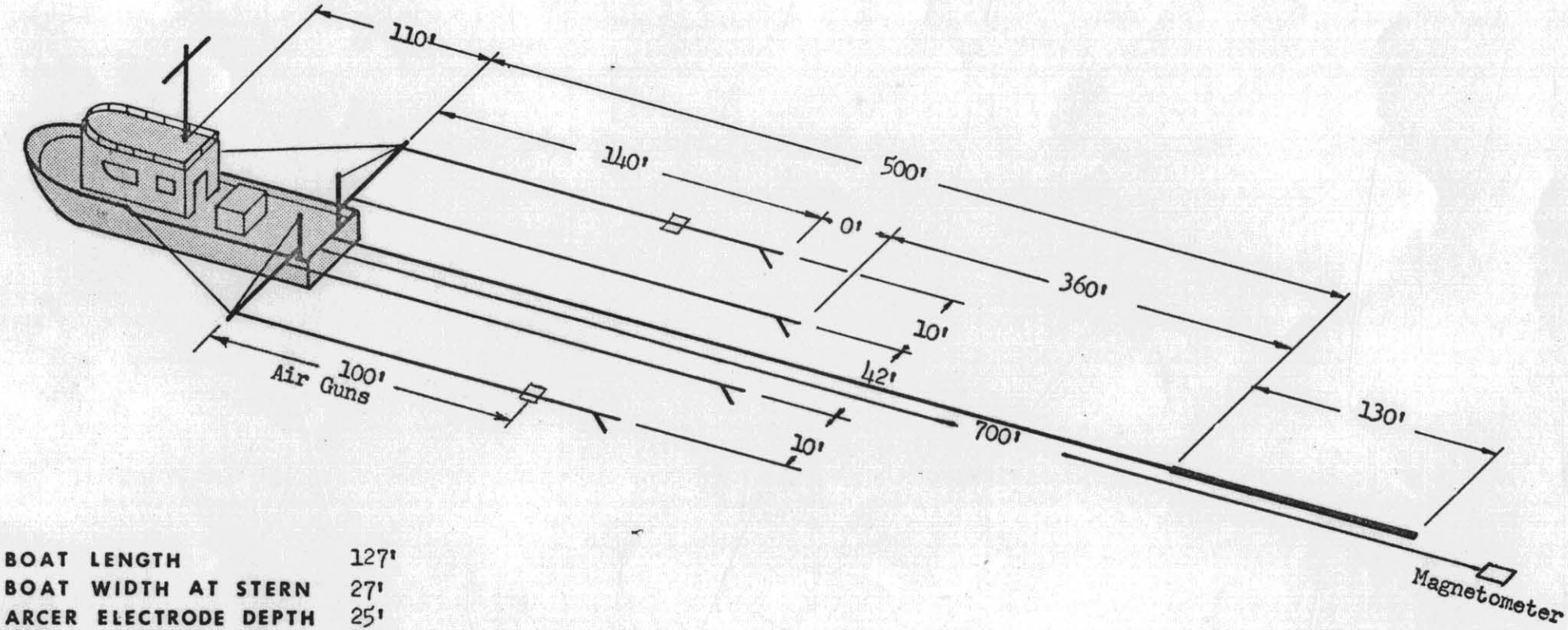
CABLE DIAGRAM

SEISMIC ENGINEERING STREAMER

(300' TRACE INTERVAL)

5 cm

074062



BOAT LENGTH	127'
BOAT WIDTH AT STERN	27'
ARCER ELECTRODE DEPTH	25'
HYDRO STREAMER DEPTH	35'
PHONE SPACING	1.3'

5 cm

SSP TOWING ARRAY

074063

PROSPECTING BY MAGNETOMETER

Teledyne Exploration Company
P. O. Box 36269, Houston, Texas

The marine magnetometer system operated by Teledyne Exploration, A Teledyne Company, is of the proton precession type, as manufactured by Varian Associates. Its principles of operation are described in the attached extract from a Varian publication.

Surveys of the variations in the earth's magnetic field are widely used as prospecting tools by petroleum and mining companies. The major value of the magnetic information is presented in contour maps of the earth's total magnetic intensity. These maps represent high and low values of the magnetic field strength, much as illustrated in the attached perspective view of magnetic survey results. The two horizontal dimensions of the picture are in common measures such as feet, and the magnetic intensity is mapped in gammas. This must be done to great precision since as few as five gammas are about one thousand millionth part of the earth's total field.

The attached extracts from a publication by Geometrics discuss in detail the kinds of data processing which may be done to magnetic survey results in order to enhance its meaning for prospecting purposes.

Magnetic maps are used by geologists and geophysicists to interpret the most likely position and size of bodies of magnetic rock beneath the surface of the earth or sea. Frequently, areas of shallow volcanic or other igneous

rocks may be located, or zones of mineralization and even isolated orebodies or oilfields discovered by use of the magnetic method of prospecting.

Application of the magnetometer survey in a new and untested area, such as many of those prospected by Teledyne Exploration, is always a mission of discovery. It is rarely possible to predict in advance what may be found, and even after completion of the survey many months of data processing and study may be required to complete an interpretation. The value of such surveys grows with time as more knowledge of each area is gained from additional geophysical instruments such as the gravitymeter and seismograph, and from the results of drilling wells.

Principles of Operation

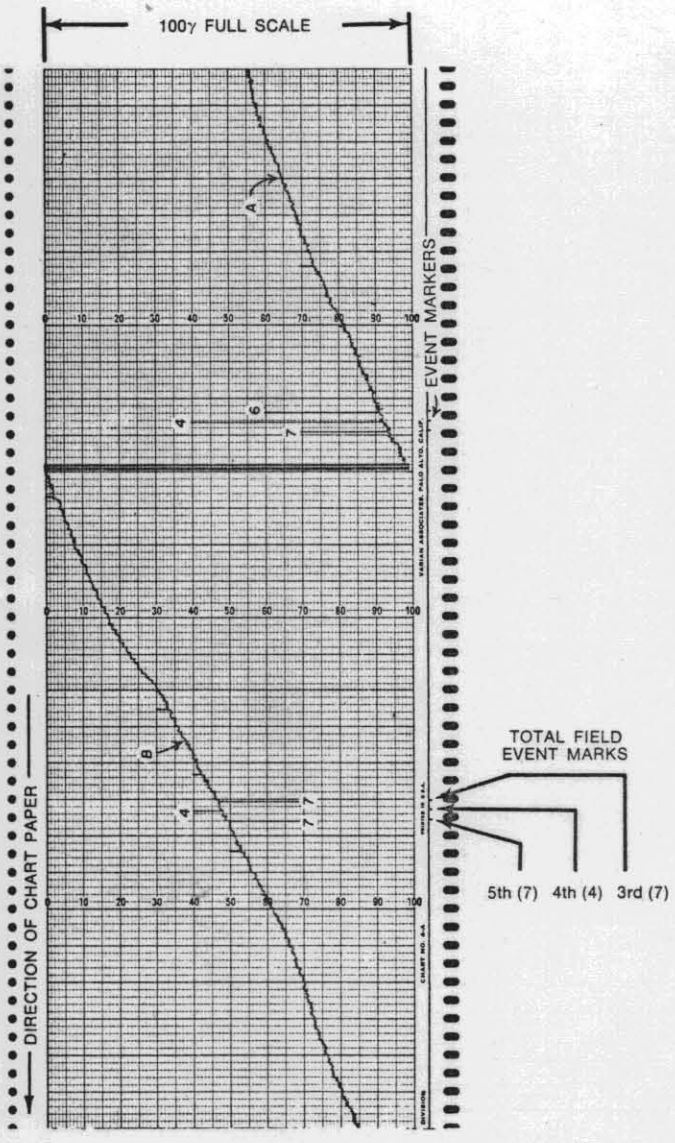


Figure 10: Analog Program Record. The Total Field Programmer option provides an automatic means for making the total field on the analog strip record. Every 30 minutes the programmer controlled digital-analog converter will sample the fifth, fourth and third place digits at 30-second intervals respectively. The single digits are analoged on the recorder and identified by event marks on the edge of the chart papers. In the example above, the total field at point A reads 74665 gammas and at point B the field changes to 74738 gammas. The need for a mechanical printer has thus been eliminated.

Total Field Programmer Option:
Varian Part No. 980413

The use of the analog total field programmer will provide a permanent record of the complete field value. The three most significant digits displayed on the counter will be recorded on the strip chart once each 30 minutes as a reference for the minor magnetic variations otherwise present on the chart. Figure 10 gives an example of this display. This feature eliminates the necessity for hand recording the first three digits of the total field or employing a mechanical printer.

Digital Data Recording Systems

Varian will furnish a number of different types of digital recording equipment to record the magnetometer data, time, location, and other parameters on either paper punch or an incremental magnetic tape recorder to suit individual customer requirements. A digital clock can be integrated into the data acquisition system that is capable of automatically recording hours, minutes, and seconds. Means for manually selecting calendar data (day, month, year) are also provided. The recorded data can be supplied in any one of several computer formats including IBM 8-level code. A coupler in the digital recording system accepts digital information in parallel form from the magnetometer electronic counter and registers the values in serial form on paper tape or magnetic tape.

A digital printer can be utilized when only a permanent digital record on a strip of paper is desired and computer entry is not necessary.

For further details, write stating your particular data acquisition requirements, i.e., total number parameters to be recorded, sampling sequence, paper punch code or magnetic tape code, voltage levels and polarity.

PRINCIPLES OF OPERATION

All elementary particles of the atom spin about their axis. The proton being no exception spins continuously with a precise angular momentum. Due to its positive charge the spinning proton also possesses a magnetic moment; it can be thought of as a tiny spinning magnet. If these "nuclear" magnets are subjected to an external magnetic field of sufficient strength their axis will try to align themselves with the applied field. Instead of jumping directly into alignment, however, the proton axis will precess (rotate) about the external field vector. The frequency at which the protons precess is directly proportional to the strength of the external field and is given by the relationship:

$$H \text{ gammas} = 23.4875\ f_p \text{ Hz}$$

where f_p = precession frequency

The proton constant (23.4875) is an immutable constant of physics and has been measured by the National Bureau of Standards to an accuracy of 8 parts per million. The immutability of the proton constant along with the fact that frequency

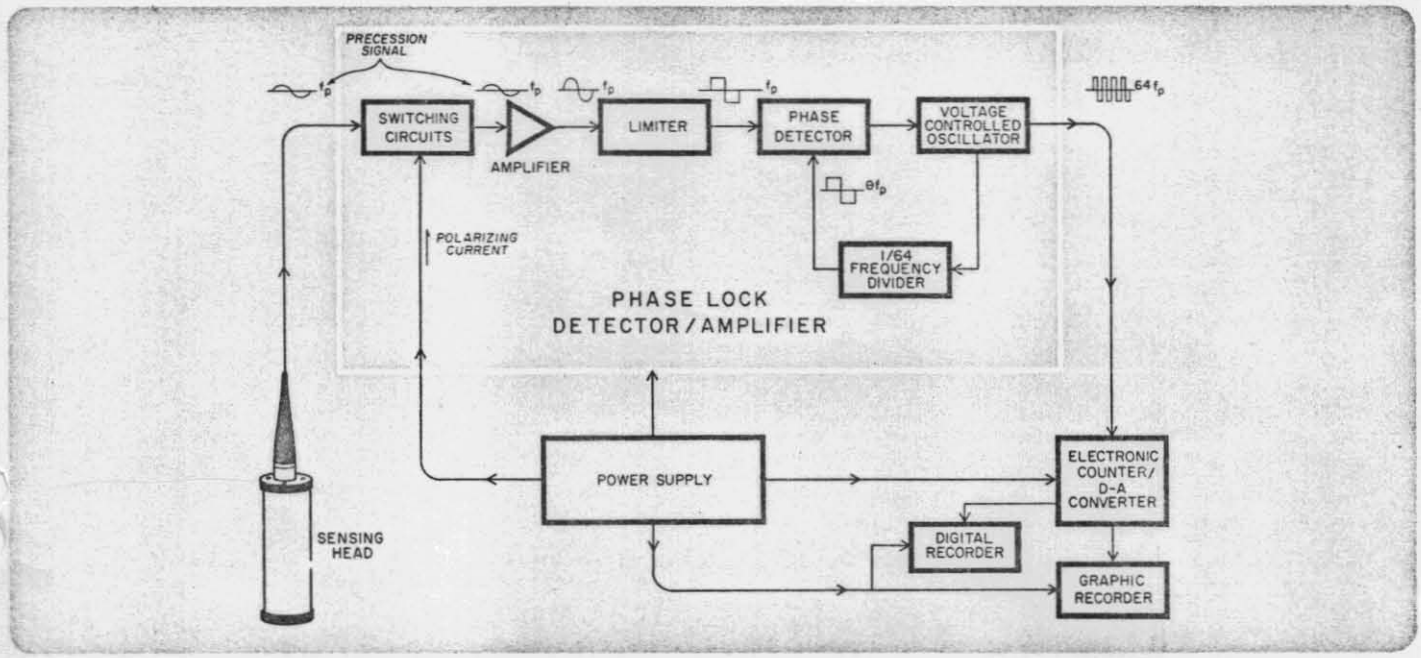


Figure 11: Block Diagram of V-4970.

is one of the most accurately measurable variables in electronics provides us with an extremely precise method of measuring magnetic fields, in our case, the earth's magnetic field.

Any hydrocarbon fluid is an excellent source of protons. In open atmosphere, protons in a fluid sample will be randomly oriented because the earth's field is too weak to cause alignment. How then are the protons made to precess about the earth's field? A strong magnetic field is applied, at an angle to the earth's field, to the fluid sample from an external coil surrounding it. This strong field polarizes the protons in one direction. The field is suddenly removed and the protons, trying to align themselves with the earth's field, precess around it and induce a voltage in the coil at the precession frequency. It is this signal that is used to measure the earth's magnetic field strength (see Figure 12).

The use of two polarizing coils mounted perpendicular to each other prevents the possibility of the polarizing field being in the same direction as the earth's field. Therefore, a signal will always be induced into one of the coils, and we have an instrument that is insensitive to changes in orientation—a marked advantage over other magnetometers.

After the sensing head has been polarized the induced signal is amplified and squared and enters the phase detector. The output of the phase detector directs the voltage controlled oscillator (see Figure 11). The VCO generates a signal approximately 64 times the precession frequency. A portion of this signal is fed back to the phase detector through a $\frac{1}{64}$ frequency divider (bringing it down to almost f_p). The frequency difference between f_p and θf_p will generate a dc voltage to change the VCO frequency to exactly 64 f_p. If the 64 f_p signal is now counted for the correct gate period, the digital frequency counter will count exactly 23.4875 times f_p. The earth's magnetic field is thus read directly from the digital frequency counter. Using a digital-to-analog converter the output of the counter can be presented on a strip-chart recorder for a permanent record (see Figure 10).

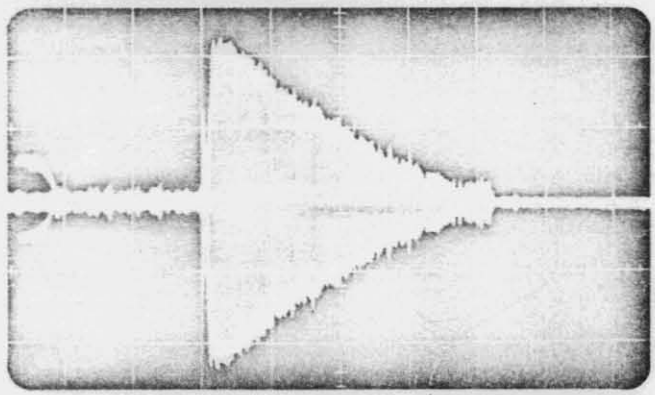
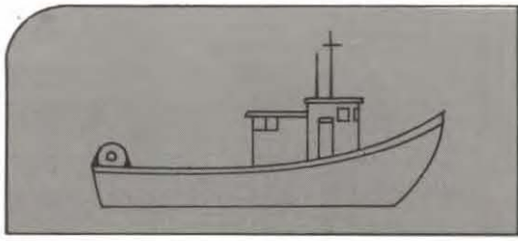


Figure 12: Proton precession signal as it is viewed on an oscilloscope.

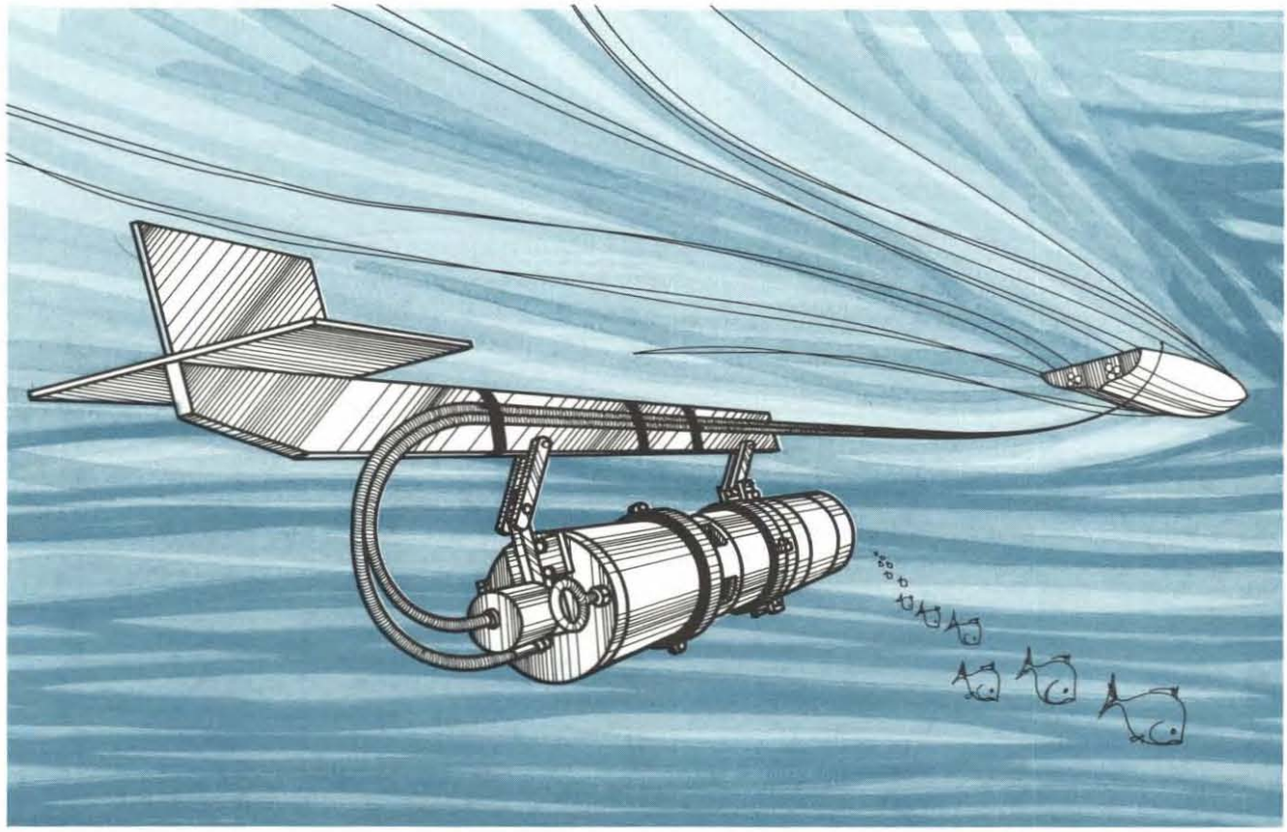
074067



MARINE

AIR GUN SEISMIC

PNEUMATIC MARINE SEISMIC ENERGY SOURCE



NOW, advanced technology has introduced a new tool, the *PAR Sound Source, for meaningful, fast, and economical marine seismograph surveys.

High Energy Yield, comparable to that obtained from usual chemical explosives, but of minimum destructivity, is attained by explosive release of high-pressure air charged by ship-borne compressor. Output energy is concentrated (80-90%) in the most useful seismic frequency band (5-50 Hz.).

Data Quality is demonstrated comparable or superior to that obtained utilizing other seismic energy sources. (See inside pages for example.)

Flexibility is afforded by the use of a single source or an array of sources of identical or various sizes, designed for fixed and towed installations. "Charge size" and frequency content of pulse are controllable. Multiple arrays can be fired simultaneously or with programmed delays for optimum application of auto-correlation and other sophisticated techniques. Firing intervals vary from as short as 4 per second, using the Model 600, to 8 seconds using the Model 1500.

Economy is afforded by elimination of conventional explosives, by the use of a single ship for both "shooting" and recording, by fewer operating personnel, by the speed of continuous-tow operations, and by simplified logistics.

*Bolt Associates, Inc., patent and trademark.

TELEDYNE EXPLORATION COMPANY

5 cm

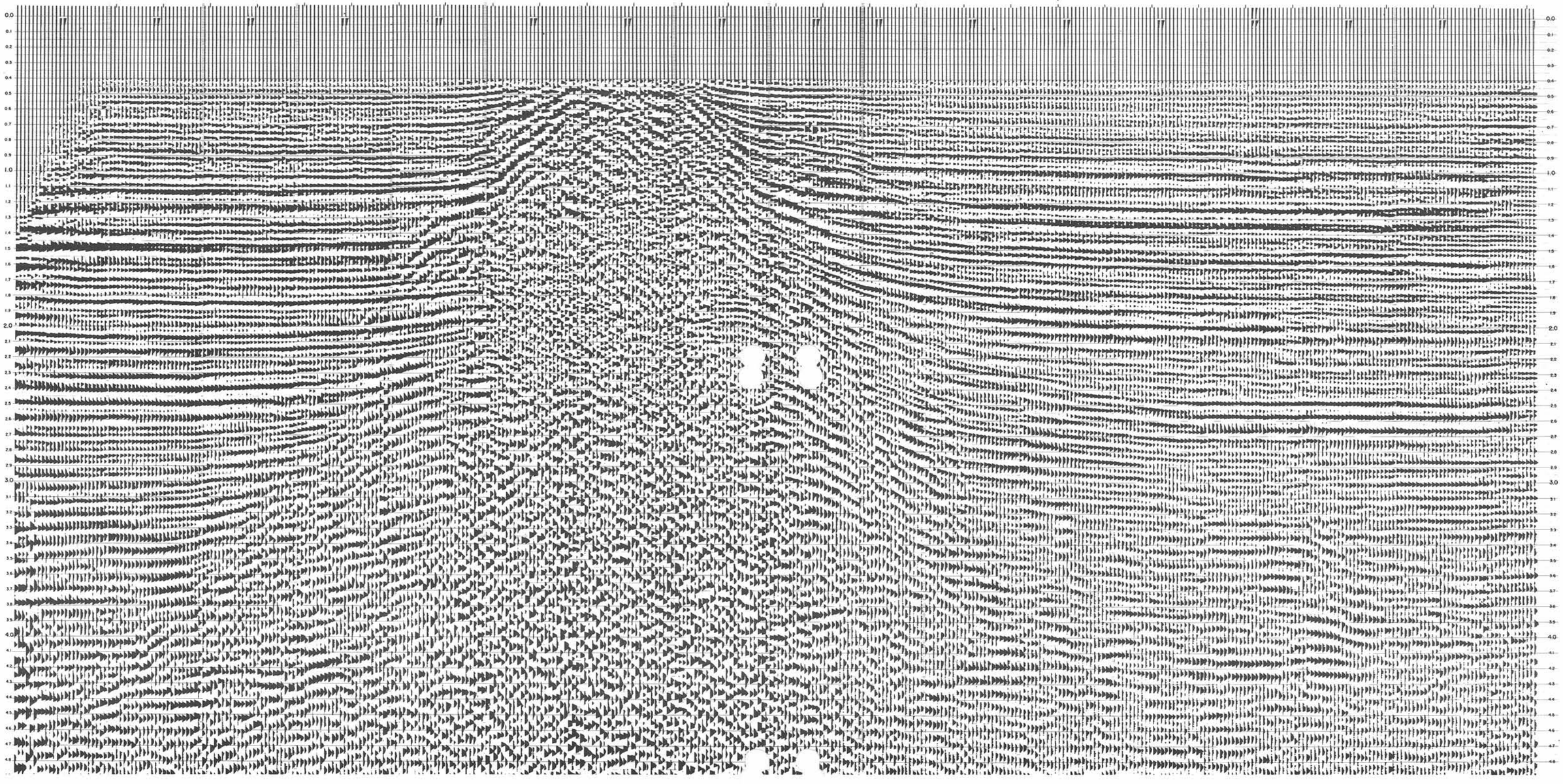
INDEPENDENT EXPLORATION COMPANY
A TELEDYNE COMPANY

Job Number: IX 495
Party Number: III
Date: 3-21-67

PROSPECT: AIR GUN DEMONSTRATION
Location: Offshore Louisiana — Line Number: II
Datum Plane: Sea Level — Trace Interval: 300 Ft.
Digital Operator: T.V. Filter — Plot Filter: Out—1/100
Plot A.G.C.: Slow — Mix: None
Presentation: 12-Point Stack
T.V. Filter: 0.4-4.0 Sec's., Out—37
1.0-5.0 Sec's., Out—14

EAST

3600 ft.



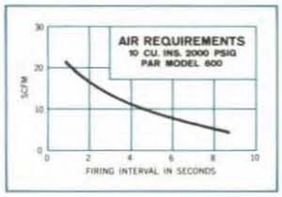
EXAMPLE AIR GUN SEISMIC SECTION

Field recordings made using two PAR Sound Source, model 1500-A, units discharged simultaneously, SDS Series 1010 Digital Recording System with gain ranging amplifiers, and 24-trace detector cable in continuous tow operations at 4 m.p.h. Record filters: Low—10 Hz., High—125 Hz. (alias). Water depth 130 feet.

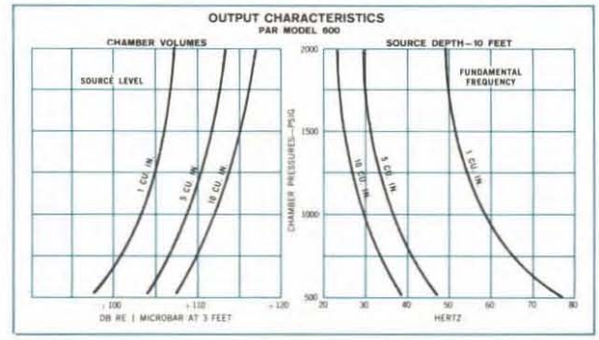
074068

SPECIFICATIONS

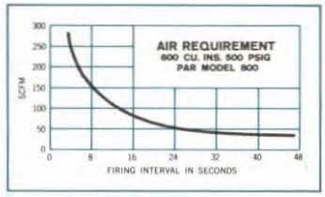
PAR Sound Source Model 600



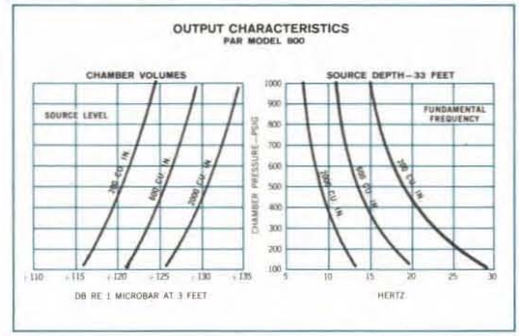
Standard chamber volumes:
1, 5, and 10 cu. in.
Operating pressures:
200 to 2,000 psig.
Solenoid firing control:
24 VDC, 40 watts max.,
20 msecs. min. firing pulse.
Seal life:
300,000 cycles min.
Acoustic efficiency: 12%.
Weight: 26 lbs.



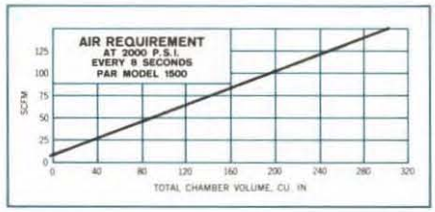
PAR Sound Source Model 800



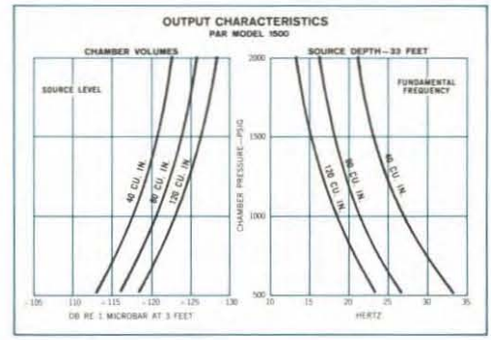
Standard chamber volumes:
200, 600 and 2,000 cu. in.
Operating pressures:
300 to 1,000 psig.
Solenoid firing control:
24 VDC, 60 watts max.,
20 msecs. min. firing pulse.
Seal life:
100,000 cycles min.
Acoustic efficiency: 10%.
Weight: 500 lbs.
(approximately).



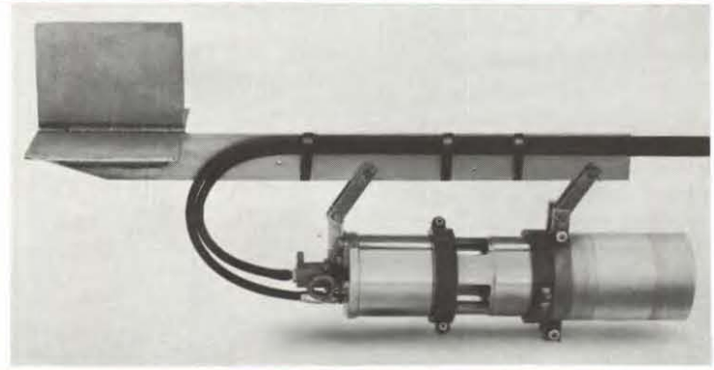
PAR Sound Source Model 1500



Standard chamber volumes:
40, 80 and 120 cu. in.
Operating pressures:
300 to 2,000 psig.
Solenoid firing control:
24 VDC, 100 watts max.,
20 msecs. min. firing pulse.
Seal life:
100,000 cycles min.
Acoustic efficiency: 12%.
Weight: 150 lbs.
(approximately).



PAR Sound Source Model 1500-A
Specifications similar to Model 1500.
Standard chamber volumes: 40, 120 and
300 cubic inches.



TELEDYNE EXPLORATION COMPANIES

NATIONAL GEOPHYSICAL COMPANY
2345 West Mockingbird Lane
Dallas, Texas 75235

INDEPENDENT EXPLORATION COMPANY
5825 Chimney Rock Road
Houston, Texas 77036

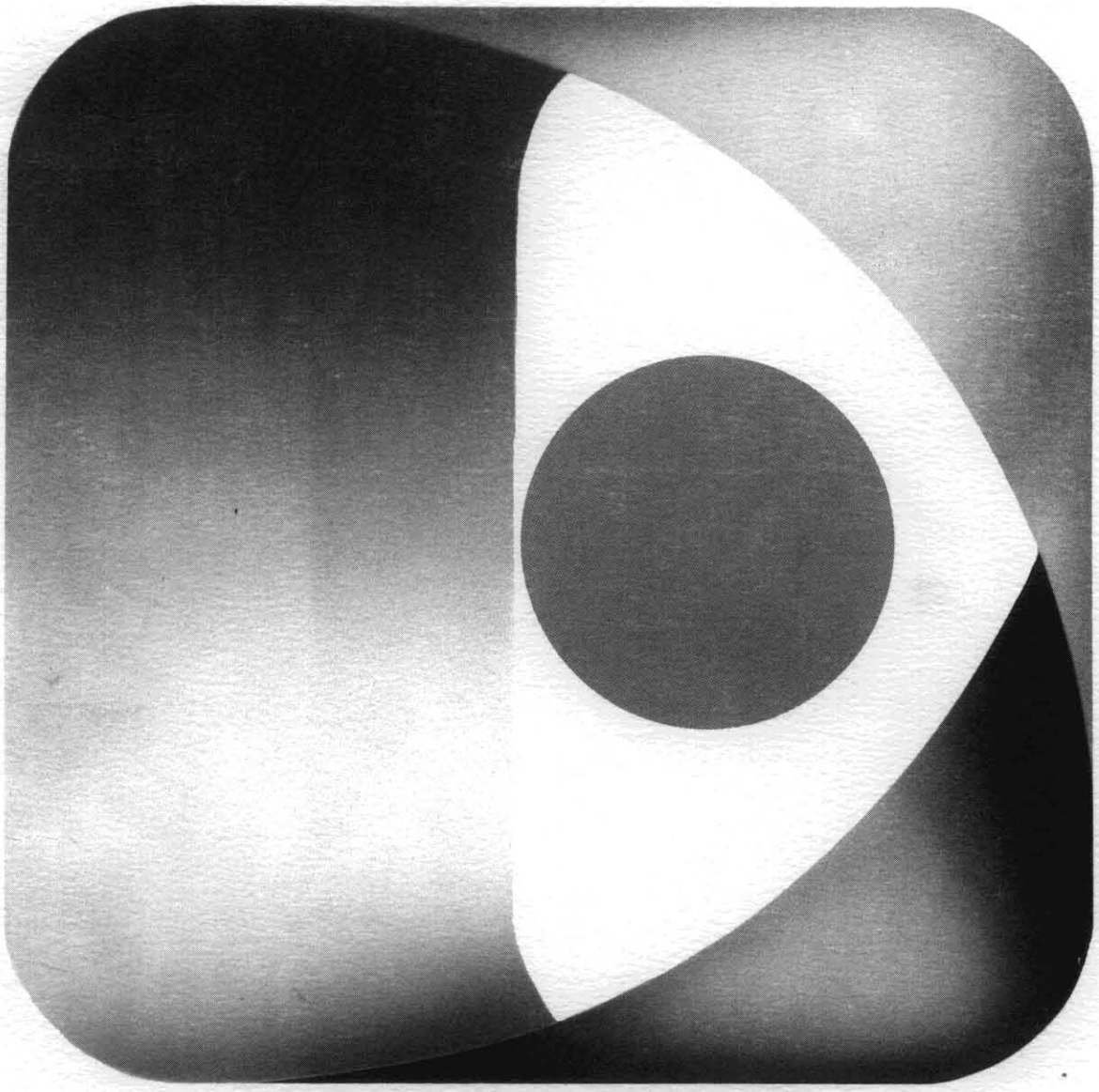
CONTINENTAL GEOPHYSICAL COMPANY
710 Continental Life Building
Ft. Worth, Texas 76102

non subsidy data

074069

PARAGON
SYSTEMS, INC.
a subsidiary of
scientific
resources
corporation

Major Characteristics of the 1010 Seismic Digital Field Recorder

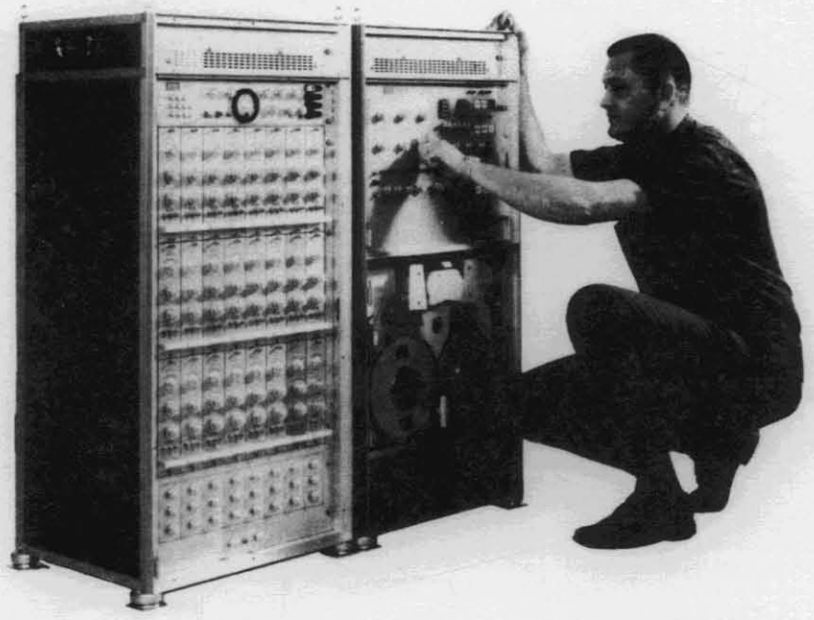


074070

SERIES

1010

GEOPHYSICAL
DIGITAL
RECORDING
SYSTEM



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MAJOR CHARACTERISTICS OF SEISMIC DIGITAL FIELD RECORDER: DYNAMIC RANGE, BURST-OUT CAPABILITY, DIGITALLY CONTROLLED GAIN, AND SMOOTHED PLAYBACK

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SUMMARY

Analog techniques for recording and analyzing seismic data have reached a limit of accuracy and dynamic range far short of newly developing requirements. To achieve new levels of performance, necessary to identify more complex and deeper geological structures, digital techniques must be employed.

These techniques include the digital computer which permits more sophisticated mathematical procedures to be applied to the seismic data; the digital recorder which freezes data accuracy in digital form at an early stage; and the seismic amplifier with digitally-switched gain levels.

The Model 72 Automatic Gain-Ranging Amplifier, developed by SDS Data Systems (patent applied for), provides a digital resolution of 84 db---15 gain levels each doubling the preceding gain. As part of the Series 1010 Geophysical Digital Recording System (capable of 15-bit resolution or 84-db dynamic range), overall system digital resolution totals 168 db.

Harmonic distortion of the amplifier is an order of magnitude better than most seismic amplifiers--less than 0.1%. Gain accuracy is 0.02% between levels on a single channel and 0.1% between channels. Gain linearity is held to 0.1%. Gain is recovered--for computation or playback--with digital precision, since each gain step is recorded on the digital tape in 4-bit code.

The new field recording system is a tool of unprecedented capability for geophysical exploration.

THE EXPLORATION TASK

The purpose of seismic data processing is to extract usable information about underground geological structures from a vast mass of detailed signals and noise. This assignment has always been a difficult one, and the exploration industry has typically employed the most advanced technology as an aid.

In recent years the search for oil has had to penetrate deeper into the earth and to delineate more complex oil-trapping structures. Offshore prospecting has introduced additional complications, as well as substantially increasing the sheer volume of data recorded. As a result of all these factors, the wanted signal is often smaller. It may lay below the noise level. The most effective way to recover these extremely low-level signals is by mathematical procedures in a digital computer. Furthermore, the computer brings great flexibility to the data reduction task; to change procedures, it is necessary only to revise the computer program--not redesign and re-arrange physical hardware.

INSTRUMENTATION REQUIREMENTS

The digital computer, unlike analog processing methods, can process seismic data with any desired degree of precision, depending on the number of binary bits employed. Consequently, the overall data acquisition and processing system is limited--not by the precision of computation, but by the capability of the analog input amplifiers or of the digitizing and recording units.

At the speed required by seismic work, 1000 samples per second per channel, modern electronic units are capable of digitizing and recording 15-bit samples (equivalent to 84 db dynamic range). This capability pushes the limiting element back to the seismic amplifiers.

Consequently, to take full advantage of the dynamic range of the digitizer and recorder, the seismic amplifier must be re-examined. As a first requirement, it should be capable of passing a dynamic range of at least 84 db, so that it does not degrade the performance of the rest of the system. If, by means of amplifier design, additional range could be added to the system, that would be a plus. Before considering the seismic amplifier in detail, however, the capability of current analog recording techniques will be reviewed.

ANALOG RECORDING TECHNIQUES

The dynamic range which may be achieved with analog recording devices extends from perhaps 35 to 40 db for recording oscillographs (cameras) up to 72 db for

analog magnetic tape under ideal conditions. The discrimination of distinct amplitude levels possible for an oscillograph record is equivalent to only 7 or 8 binary bits.

The dynamic range of analog tape recording systems is limited, under good operating conditions, to about 45 db for direct (AM) recording and about 60 db for frequency-modulated (FM) recording. Under ideal conditions, somewhat better values may be obtained; but it is doubtful if many systems reach even the cited values under field conditions. Ranges of 36 to 40 db for AM recording and 48 to 54 db for FM recording are more realistic.

In the case of AM recording, the overall limitation is set primarily by the tape media. The upper limit is the highest signal amplitude which can be recorded without distortion caused by magnetic saturation. The lower limit is the lowest amplitude which can be detected without distortion by background tape noise. In FM systems, the limits are set by the frequency-resolving power of the tape and equipment in combination. At low modulation frequencies, the signal output of the pickup heads is low, resulting in a tendency for the demodulators to drop out and free run. At high frequencies, the signal may not be resolved, and the same dropout condition occurs.

To increase the dynamic range of the analog amplifier, several methods of increasing the gain automatically as the seismic signal declines have been developed. The earliest and most common method, still, is the use of automatic gain control (AGC) circuits utilizing losser elements. With this method an analog gain-indicator signal, directly proportional to the amplifier gain over the period of the data run, is recorded on one of the channels of the analog tape. From this gain signal, the actual amplifier gain can be recovered on playback with an accuracy on the order of ± 5%.

The second method of increasing the amplifier gain-range is Programmed Gain Control (PGC). Gain is increased at specific times set in advance by the operator. With this method, the gain at each point on the record could, in theory, be known precisely. Unfortunately, in practice, the gain is recorded as an analog signal, still subject to a recovery of ±5%.

A combination of AGC and PGC has also been used. The early part of the record is handled with AGC; the latter part with PGC. The time of the changeover is selected by the operator, together with the time of further programmed-gain changes. This combination accomplishes smooth gain increases and has little adverse effect on the phase of the seismic signals. The drawback still persists, however, that the analog record of the gain is inaccurate. The operator must still be relied upon to predict accurately the behavior of the signal.

The best of the systems currently available combine AGC or PGC types of amplifier gain control with digital recording of the seismic traces, using 12 to 14 bits to record each sample. The recording resolution of these systems is, thus, in the neighborhood of 66 to 78 db. If the amplifier's static range is less than this digital capability, the precision of the digital recording is degraded to a corresponding degree. Furthermore, these combined systems are not able to recover amplitude any more accurately than the all-analog systems.

The main disadvantages of analog recording techniques, as compared with the possibilities of digital techniques, may be summarized as follows:

Limited dynamic range: Analog recording techniques have essentially reached a limit substantially short of digital recording.

Amplitude inaccuracy: This factor has been so poor that few companies have even attempted to analyze their seismic records by amplitude.

Poor time correlation: Comparison of the time relationships, trace to trace, can be no better than the accuracy of the analog tape recording. Inaccuracies are caused by variations of tape speed (wow and flutter) and track-to-track skew and can be overcome only partially by use of a timing reference track.

Operator judgment: The determination of the times and amounts of programmed gain requires considerable judgment on the part of the operator. Moreover, one or more test shots may have to be made in each shooting location to enable the operator to determine when the gain changes should be made.

Also, in order to assure that the signal can be held within the limited bandwidth characteristics of typical AGC amplifiers, the operator may have to make a selection from ten, or so, low-cut filters and an equal number of high-cut filters. Furthermore, the selection of early gain requires more judgment on the part of the operator.

Operator attention: Analog recording requires a great deal of attention by the operator--to match and balance losser circuits, to adjust and trim circuits, and to make the repetitious manual adjustments necessary to change back and forth between record and playback.

Processing degradation: In addition to the initial inaccuracy of analog recordings, the signals are degraded further by every following analog processing step in contrast to digital processes where, once digitized, sample values remain the same, from an accuracy standpoint, through all further digital processing.

SEISMIC AMPLIFIER REQUIREMENTS

As computer processing forces the use of digital recording, the weak link in the chain of equipment, from geophone to computer, becomes the seismic amplifier. To meet the newly emerging needs, the seismic amplifier should fulfill the following requirements:

The dynamic range, as a minimum, should not constrain the digital recorder. Preferably, its range should add to that of the recorder.

Selection and recording of gain values should be fully automatic.

Signal amplitude, including gain steps, should be recovered with all the resolution that digital techniques make possible--at least an order of magnitude better than the best analog recording.

Time correlation, similarly, should be recoverable to digital standards of accuracy.

Furthermore, the amplifier design should embody the latest state-of-the-art with respect to linearity, stability, distortion, solid-state components, size, power, and environment. Operator adjustments should be minimized. Test and calibration capabilities should be complete and easy to use.

BLOCK DIAGRAM ANALYSIS

The Automatic Gain-Ranging (AGR) Amplifier, developed by SDS Data Systems to meet these geophysical exploration needs, is shown in simplified block diagram form in Figure 1. The unit accepts the signals normally provided by velocity pickups (geophones) with a source impedance of 500 ohms over twisted-pair lines, unshielded, with no particular restriction on the distance from the geophones to the amplifier. Variable resistance and capacitance are provided to balance the input lines in order to reject 60-cycle interference, improve common-mode rejection, and eliminate high-line noise.

The balanced input is transformer-coupled to a fixed-gain preamplifier. Filters limit the signals to the frequency range selected by the operator. Low-cut filters reject high-amplitude "ground roll," preventing it from masking data of interest. Aliasing filters prevent aliasing errors (or frequency foldover). High-cut filters reject other frequencies not desired in the recorded data.

Beyond this point in the AGR amplifier, the operations are controlled by a digital gain code derived from the digitizer. In general, when the values being digitized fall below one-quarter of digitizer full scale, the next higher gain code is originated by the gain control unit. Similarly, whenever the digital output exceeds one-half full scale, the next lower gain code is produced. The

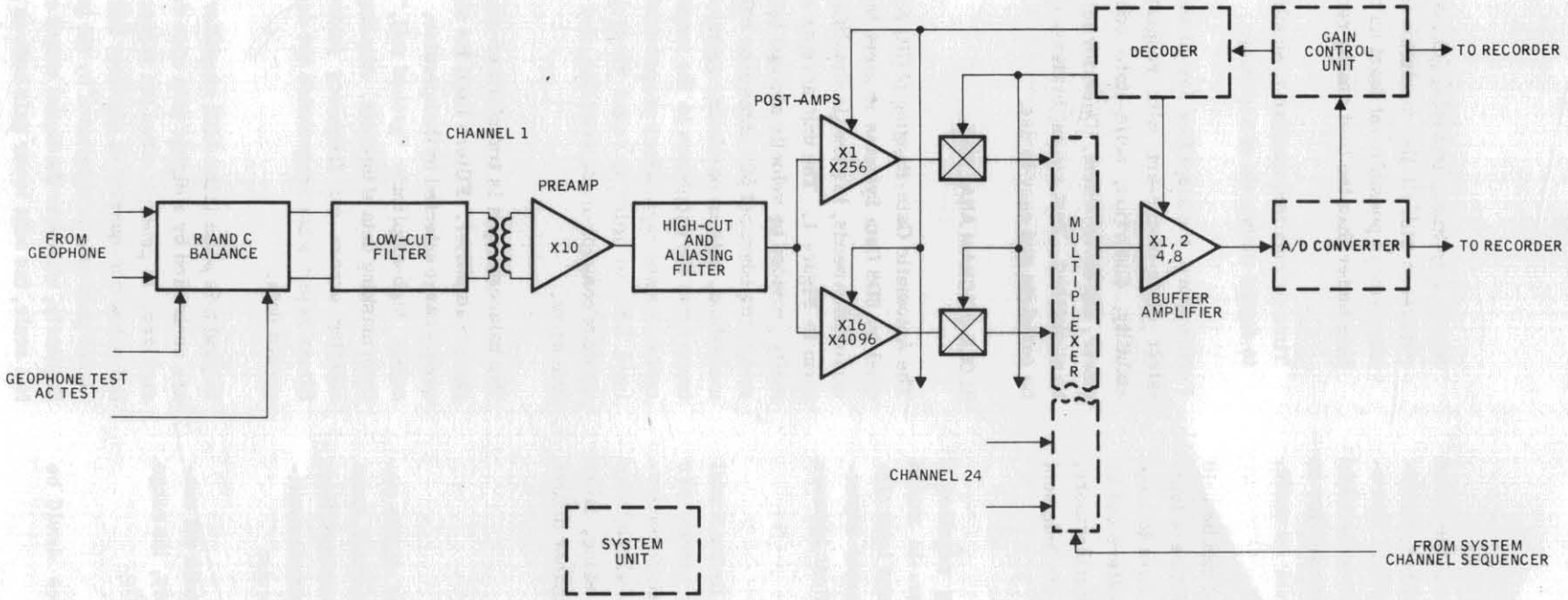

FIGURE 1

Simplified block diagram shows the operation of the automatic gain-ranging amplifier.

gain code is a 4-bit binary code which is decoded into 15 gain levels.

The first function controlled by the gain code is the two gain levels of the parallel post-amplifiers. The second function controlled by the gain code is the selection of the output of the upper post-amplifier or the lower post-amplifier. The amplifier output, selected in this way, is then commutated by the system channel multiplexer with the other seismic channels--each with an AGR amplifier. The channel-multiplexed output then goes to the final amplifier--a buffer amplifier with four gains under the control of the gain code. The output of this amplifier is the output of the AGR amplifier and is applied to the system digitizer.

MEETING SEISMIC NEEDS

The advanced gain-ranging amplifier meets the needs of geophysicists for wide dynamic range, automatic gain selection and recording, accurate amplitude recovery, and precise time correlation. Drawing upon the latest knowledge in electronic and digital design, the amplifier exhibits excellent gain-step accuracy and gain linearity, very low harmonic distortion, and close-to-theoretically-minimum noise. How these objectives have been achieved will be the subject of the following sections.

Wide Dynamic Range

In order to take full advantage of the precision with which the digital computer can process seismic data, the Series 1010 system is designed to accommodate a very wide range of signal amplitude. This range is customarily expressed, in digital systems, as resolution and, in analog systems, as dynamic range.

Resolution

First, the amplifier supplies half of the total resolution. With the lowest gain taken as 1, each succeeding level doubles that value, that is, 2, 4, 8, etc., up to the fifteenth level, 16,384. In other words, the static range of the amplifier is doubled automatically fourteen times to accommodate the declining seismic input signal. If the lowest range is considered to be a resolution of 1, then the highest range represents a resolution of 16,384. In effect, the gain code reporting the gain level in use also indicates the resolution being achieved by the amplifier.

Second, the digitizer supplies the other half of the total resolution. When the output signal on any one of the amplifier ranges is applied to the digitizer, it is separated into 16,384 amplitude levels. This is the resolving power of a 14-bit-plus-sign analog-to-digital converter. In the binary number system, each bit added, after the first one, doubles the resolution.

Thus, the resolving power of the amplifier-digitizer combination is one part in 2^{28} or one part in 268,435,456.

Dynamic Range

Dynamic range is the ratio of the maximum signal handled to the minimum signal distinguishable. By using the following relationship, dynamic range can be expressed in decibels:

$$\text{db} = 20 \log_{10} \frac{e_{max}}{e_{min}} = 20 \log 2 = 20(0.301) = 6$$

Thus, each time the gain level is doubled or each time the binary resolution is doubled, the dynamic range is increased by 6 db. With 14 gain changes, the amplifier resolution may be expressed as 84 db. Similarly, 14 binary bits after the first one are also equivalent to 84 db. Together the amplifier and the digitizer cover a dynamic range, derived from their resolution figures, of 168 db. On the basis of analog experience, this figure may seem unrealistically high.

In the case of the amplifier, the maximum signal is 1 volt and the noise--which sets the lower distinguishable level in analog work--is specified to be typically 0.1 microvolt rms, both referred to input. This ratio is 10^7 or 140 db. Maximum noise is specified to be 0.2 microvolt rms. On this noise basis, the dynamic range would be reduced to 134 db.

The calculation of dynamic range for the digital recorder is made at the digitizer. Following the digitizer, the signal is in digital form and noise can no longer degrade it. Full-scale input to the digitizer is always 10 volts, regardless of the amplifier level in use. The noise at the analog input to the analog-to-digital converter is composed of two components. One component is the output noise of the amplifier which increases as gain is increased. On the lowest gain level, with a gain of 10, the input noise, 0.1 microvolt, multiplied by the gain gives an output noise of 1 microvolt. To this must be added a small amount of referred-to-output noise, on the order of 100 microvolts. Thus, the total noise at the output of the amplifier is approximately 101 microvolts. As the gain increases, this referred-to-output noise becomes unimportant, relative to the amplified input noise. Thus, at the highest gain level, 163,840, the noise at the output of the amplifier is approximately 16, 484 microvolts rms.

The second noise component is the system noise from the analog multiplexer up through the analog portion of the analog-to-digital converter. This noise is specified as 0.03% of full scale peak-to-peak, or 0.001 volt rms. This noise remains the same, regardless of the amplifier level in use.

The total noise up to the point of digitization is the root-mean-square sum of the amplifier noise and the system noise. At the lowest gain level, the amplifier noise (101 microvolts) is negligible compared to the system noise (1000 microvolts), and the rms combination is still, for practical purposes, about 1000 microvolts. At this gain level, the ratio of full scale (10 volts) to noise (0.001 volt) is 80 db.

As each gain level is calculated, it is found that amplifier noise remains negligible, compared to system noise, up to gain level 10.

In the higher gain levels, as amplifier noise (after amplification) becomes significant in relation to the system noise, the dynamic range at the digitizer falls off. It should be noted, however, that the final column in Table 1 represents the dynamic range only on a single gain level. The dynamic range, represented by the automatic gain-ranging capability of the amplifier (that is, 84 db), must be added to these figures to

TABLE 1

Amplifier noise is negligible, compared to system noise, up to gain level 10. On the highest gain levels, because of the large gain, amplifier output noise becomes the dominant element in the total noise.

Gain Level	Gain	Amplifier Noise	System Noise	RMS Combined Noise	Dynamic Range--db (at Digitizer)
0	10	101 uv	0.001 v	0.001 v	80
-	-	-	-	-	-
10	10,240	1,124	0.001	0.0015	77
11	20,480	2,148	0.001	0.0023	73
12	40,960	4,196	0.001	0.0043	67
13	81,920	8,292	0.001	0.0084	62
14	163,840	16,484	0.001	0.0165	56

obtain the overall system dynamic range. Consequently in the worst case on the highest gain level (when the seismic input signal has fallen below 61 microvolts), the system dynamic range is 140 db.

The dynamic range at the digitizer, calculated from noise levels, is from 4 to 28 db less than the digital resolution expressed in decibels. Each 6 db of dynamic range below the resolution represents the loss of one bit of resolution. For example, on gain level 0 (gain of 10), the last bit of the fifteen bits is below the rms noise level. At gain level 12, the last three bits are lost; and at gain level 14, more than four bits are below the rms noise level.

In most applications, digitizing below the system noise level would be of little value. In the seismic application, however, the additional resolution capability is valuable. The reason is that computer procedures such as filtering, cross-correlation, and convolution can retrieve data from noise. Stacking procedures, too, can attenuate the noise in relation to the wanted signal. There are reports of data being extracted from noise as much as 35 db greater than the data. In order for noise removal procedures to function effectively, the digital resolution capability must extend below the noise level. As computer procedures are improved and become more widely used, 14-bit-plus-sign resolution will become more and more useful.

Automatic Gain Selection and Recording

The selection of one of the 15 gain levels is entirely automatic, except for the early gain setting which will be discussed in the next section. The Model 72 amplifier optimizes gain solely on the basis of signal amplitude, thereby eliminating operator judgment in this matter.

The output of the AGR amplifier is ordinarily held between one-quarter and one-half of digitizer full scale. The upper setpoint was selected so that a seismic signal could double and still remain within the digitizer scale. Thus, a burst-out increasing at the rate of 6 db/ms can be digitized and recorded. Yet, as the signal peaks gradually fall below quarter scale (as the seismic signal declines), these small signals can be very precisely digitized, as 12 out of the 14 magnitude bits are still in use at these levels. In effect, the selection of the setpoints strikes a tradeoff between the ability to record burst-outs and the ability to resolve signals below the lower setpoint.

The selection of the appropriate gain level is the function of the gain control unit. This unit consists essentially of logic elements which compare the digital output of the digitizer with the upper and lower set points and a 4-bit up/down counter which stores the 4-bit binary gain code currently in use. As the seismic signal decreases and falls below one-quarter scale, the counter is incremented up one gain level. If the signal increases and exceeds half scale, the counter is decremented by one. The output of the counter is decoded to control the two post-amplifiers, the amplifier output selector, and the buffer amplifier--all the switchable elements of the automatic gain-ranging amplifier. The counter output is also recorded on the magnetic tape periodically.

To accommodate variations in field conditions, the user may specify the number of gain control units per system. If one unit is used, it is responsive to all seismic inputs, and the signal with the highest input amplitude dictates the gain of all channels. This is called "ganged gain" control.

If a gain control unit is connected to a group of inputs, say four, then each independently controls the gain of its group. Again, the signal with the highest input amplitude sets the gain of all channels within the group. This is called "group gain" control. If a unit is connected to each channel, it is responsive only to the amplitude of that channel. This is called "individual gain" control. With this arrangement, the gain of the one channel is optimal at all times.

Generally, where prospecting will be confined to shallow spreads, inter-channel amplitude variations with

respect to time will be small and "ganged gain" is practical. Where spreads extend over large distances and inter-channel amplitude variations are large (many times in excess of 20 to 30 db) with respect to time, it is best to use "individual gain."

The 4-bit gain code (the output of the up/down gain control counter) is recorded on the magnetic tape in digital form once each scan, in the case of "ganged gain," and once each sample, in the case of group or individual gain.

Early Gain

The early gain selector switch permits the operator to set the initial gain at a low value and hold it there in spite of the fact that, with no signal coming in, the gain levels would automatically cycle up to a high value. The amplifier holds this early gain value until first break exceeds the trip sensitivity--also set by the operator--and releases full automatic gain control. The early gain switches have 12 positions ranging from 0 to -84 db (referred to full scale of 1 volt, in steps of 6 to 12 db). The early gain settings also provide a means of setting the AGR amplifier on 12 gain levels for test purposes.

Release Rate

In the case of a varying data signal which is crossing zero many times per second, it is apparent that some of the sample values of the signal would fall below the one-quarter scale set point which triggers the gain increase. Still, the signal peaks would be above the trigger level, and the existing gain level should be continued. A means is needed to delay the gain increase until all samples fall below the trigger level.

In this system, this end is accomplished by examining all samples of all channels (in a gain group) for a time period which is set by a release-rate switch. One of three maximum release rates, fast, medium, and slow, may be selected by the operator. The release rate is an expression of the speed, in decibels per second, at which an amplifier is capable of increasing gain to follow a declining seismic signal. The release rates are specified by the customer.

As soon as all samples are below the lower set point for an examination period, the gain is increased by 6 db at the next scan. Thus, with a 30-millisecond examination period, for example, the gain could be increased 6 db every 30 milliseconds or at a rate of 200 db/sec. This examination period is an asynchronous "sliding window" that finds the earliest possible time that the conditions for a gain increase are satisfied. Provision of three release rates permits the operator to select the one best suited to the data being received.

Attack Rate

The system is capable of reducing gain at a very rapid "attack" rate, 6000 db/sec. If any sample of any channel exceeds the upper (one-half) scale set point, the gain is reduced by one step immediately--that is, at the next scan. Thus, gain reduction can occur at a maximum rate of 6 db each millisecond (length of one scan) or 6000 db/sec.

As already pointed out in the discussion of quarter- and half-scale set points, an increasing signal, such as a burst-out, has 6 db of digitizer scale available before it would go off the top of the digitizer scale. Now, it may be noted, the digitizer scale may, in effect, be doubled (by halving the gain) in only a single scan of one millisecond. Thus, the system is capable of reducing gain at a dynamic rate of 6000 db/sec--fast enough to keep up with nearly any signal.

Gain Control Operation

An example of how gain control operates during a seismic run will make clear the relationships between early gain, trip sensitivity, gain levels, release rate, and attack rate. Figure 2 shows a plot of the envelope of a seismic-signal peak level, the level leaving the amplifier, and gain level--all plotted against the same

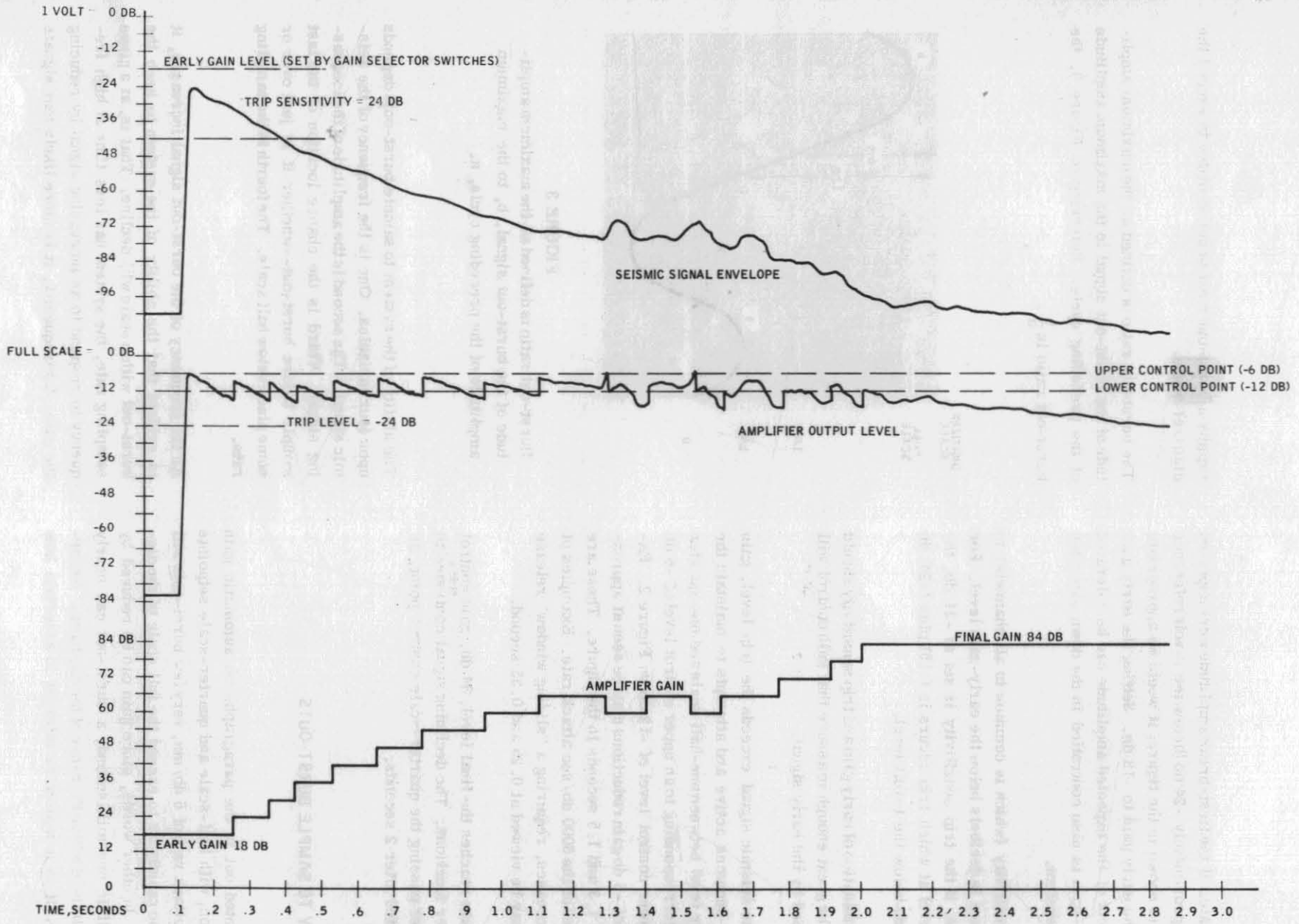

FIGURE 2

How the automatic gain-ranging amplifier works may be visualized by comparing the top curve (envelope of seismic-signal peak levels) with the middle curve (the level entering the digitizer) and the bottom curve (gain levels).

time scale. If the first-break amplitude were expected to be approximately -24 db (below the 1-volt reference level), as shown in the figure, it would be appropriate to set the early gain to -18 db. Setting the early gain 6 db short of the expected amplitude can be tolerated because gain is also controlled in the down direction in this system.

Trip sensitivity (which is common to all channels) is expressed in decibels below the early-gain level. For example, if the trip sensitivity is set at -24 db, the input level at which trip occurs is (-18) plus (-24) db or -42 db below the 1-volt level.

The combination of early gain and trip sensitivity should always be great enough to assure that gain control will be tripped by the early signal.

After the seismic signal exceeds the trip level, gain control becomes active and attempts to maintain the digitizer level between one-half scale and one-quarter scale, corresponding to an upper control level of -6 db and a lower control level of -12 db on Figure 2. Examples of -6 db gain reductions may be seen at approximately 1.3 and 1.5 seconds in the figure. These are examples of the 6000 db/sec attack rate. Examples of gain increases, requiring a "sliding window" release rate, may be viewed at 0.25 and 0.35 second.

When gain reaches the final level, 84 db, gain control no longer functions. The declining signal continues to fall after passing the quarter-scale control point, as illustrated after 2 seconds.

ABILITY TO SAMPLE BURST-OUTS

As pointed out in the paragraphs on automatic gain selection, with half-scale and quarter-scale setpoints and an attack rate of 6 db/ms, very few burst-outs will occur so rapidly as to exceed the full scale of the digitizer. In other words, since gain can be reduced by one-half in one millisecond, a burst-out can nearly always be held within the range of the digitizer. Nevertheless, it is a matter of interest to ascertain how rapidly a burst-out must occur in order to exceed the digitizer scale.

The burst-out ratio is defined as the maximum amplitude of the burst-out signal to the maximum amplitude of the preceding cycle. Referring to Figure 3, the burst-out ratio is $\frac{b}{a}$.

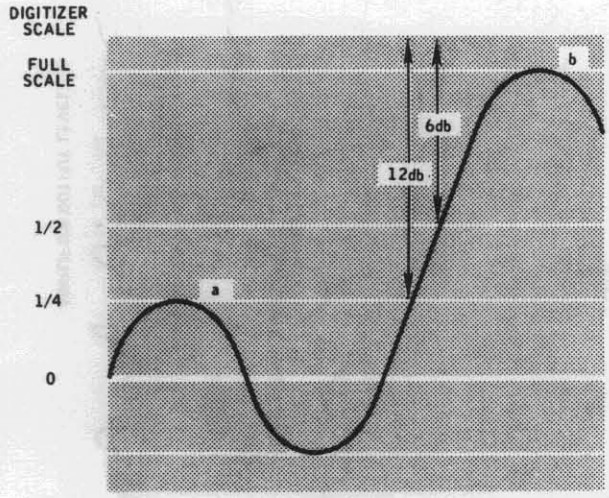

FIGURE 3

Burst-out ratio is defined as the maximum amplitude of the burst-out signal, b, to the maximum amplitude of the preceding cycle, a.

The ability of the system to sample burst-outs depends upon four variables. One is the frequency of the seismic signal. The second is the amplitude of the increasing signal. Third is the chance location of the last sample before burst-out--whether it is just over or some place below half scale. The fourth is the sampling rate.

As the frequency of the burst-out signal increases, it is evident that the ability of the system to keep the burst-out within scale will decline. That is, at a given sampling rate, the system has less time at high frequency to respond to an increasing signal by reducing the gain. Consequently, it is more likely that signals

of a given burst-out ratio will be overscale. Similarly, at low frequencies there will be more time available to reduce gain, and higher burst-out ratios can be accommodated within scale.

As amplitude (the second variable) increases, the ability of the system to record each sample at true amplitude decreases. (All samples are recorded--overscale samples are recorded as full scale of the gain range in use.)

Where a given sample falls is a matter of chance. Yet, this sample location affects the ability of the system to accommodate the succeeding sample. A sample just under half scale, for example, requires the system to wait another sample interval before changing gain range. On the other hand, if the sample is just over half scale, gain range is shifted at once--substantially improving the chance of being able to accommodate the next sample.

A generalized mathematical analysis of the effect of these variables follows.

First, the line between complete recording and the possibility of one overscale will be analyzed. This case occurs (on the channel controlling the gain) when the last sample digitized is a very small interval below half scale, as diagrammed in Figure 4. The burst-out ratio (that will not exceed full scale) is $\frac{b}{1/2Y}$.

Given:

Y = Digitizer Full Scale

b = Burst-Out Amplitude

t_1 = Time of first sample considered

t_2 = Time of second sample considered

ω = Burst-out fundamental frequency

From the equation of a sine wave,

$$y = b \sin\omega t$$

$$Y = b \sin\omega t_2$$

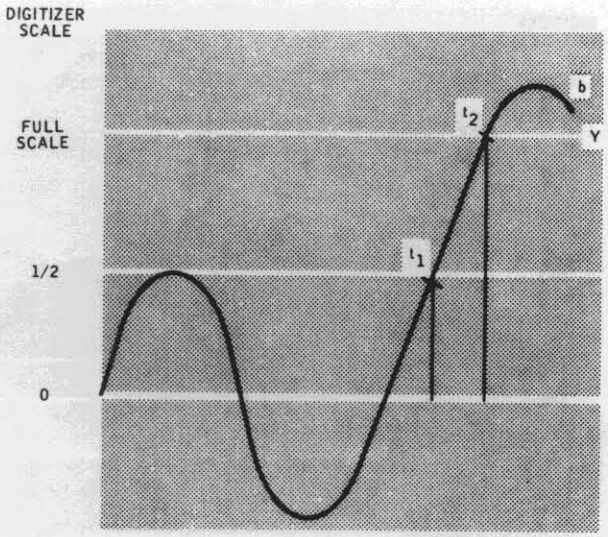

FIGURE 4

This diagram illustrates the case which occurs when the last sample digitized is just below half scale.

Transposing terms,

$$\frac{b}{1/2Y} = \frac{1}{1/2 \sin\omega t_2}$$

This equation may be reduced to the following, expressed in terms of frequency:

$$\frac{b}{1/2Y} = \frac{\sqrt{5-4\cos\omega \times 10^{-3}}}{\sin\omega \times 10^{-3}}$$

Next, the line between a possible overscale and a certain overscale will be analyzed. This case occurs (on the channel controlling the gain) when the last sample digitized is a very small interval above half scale, as diagrammed in Figure 5. Since the sample is above half scale, the amplifier down-ranges before the next sample is taken, as represented by the solid line in the diagram. The dotted line represents what would have been the path of the burst-out on the original gain range. The burst-out ratio, consequently, is $\frac{2b}{1/4Y}$.

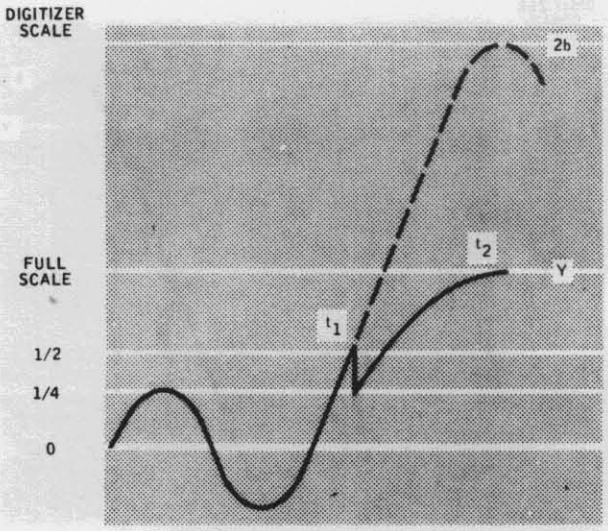

FIGURE 5

When the last sample digitized is just above half scale, the amplifier reduces gain immediately, and quarter scale becomes half scale on the lower gain level, as demonstrated by the solid line.

Starting with,

$$Y = b \sin\omega t_2$$

Transposing terms,

$$\frac{2b}{1/4Y} = \frac{2}{1/4 \sin\omega t_2}$$

This equation may be reduced to the following, expressed in terms of frequency:

$$\frac{2b}{1/4Y} = \frac{\sqrt{65-16\cos\omega \times 10^{-3}}}{\sin\omega \times 10^{-3}} \qquad (2)$$

The two equations of burst-out ratio are plotted against frequency in Figure 6.

The lower curve, plotted from equation (1), extends from a burst-out ratio of 24 db at 10 cps to 6 db at 200 cps. The upper curve, plotted from equation (2), runs from nearly 42 db at 10 cps to 18 db at 200 cps. Between the two curves, probability increases from 0 to 1 that one overscale will occur on the controlling channel.

When the signal is within the digitizer range (that is, when the burst-out is within the limits diagrammed), amplification is accomplished within the specified distortion of 0.1%. The burst-out sample is digitized and recorded to the same high standard of accuracy and precision as other signals running along at a relatively constant amplitude. In contrast, when conventional analog amplifiers are used, distortion increases rapidly as the amplifier attempts to follow a burst-out. Harmonic distortion goes from perhaps 0.5% to more than 2% as burst-out ratio increases.

If a burst-out occurs so rapidly that a sample exceeds full scale of the digitizer, that sample is still recorded as a full-scale number, as shown in Figure 7. The area of contribution to distortion is cross-hatched. This graphic burst-out analysis is based on the worst case for a 5-to-1 burst-out at 50 cycles. To make this example worst case, it was assumed that the peak value of the previous cycle was just short of half scale--thus holding the amplifier on the current gain level. Furthermore, data sample 1 on the burst-out is assumed to be just below half scale so that, once more, the current gain level continues. By time t_2, the burst-out exceeds full scale on gain n which is equal to ordinate 2. Data sample 2, therefore, is recorded as full scale on gain n. Since this sample is in excess of half scale on gain n, gain is shifted to n/2 by the next sample time, t_3. Full scale on gain n/2 is now equal to ordinate 4, and data sample 3 is within this scale. This data sample exceeds half scale, however, so gain is shifted to n/4 by the time of the next sample at t_4.

As indicated on the plot of burst-out ratio vs. frequency (Figure 6), the probability of one overscale occurring

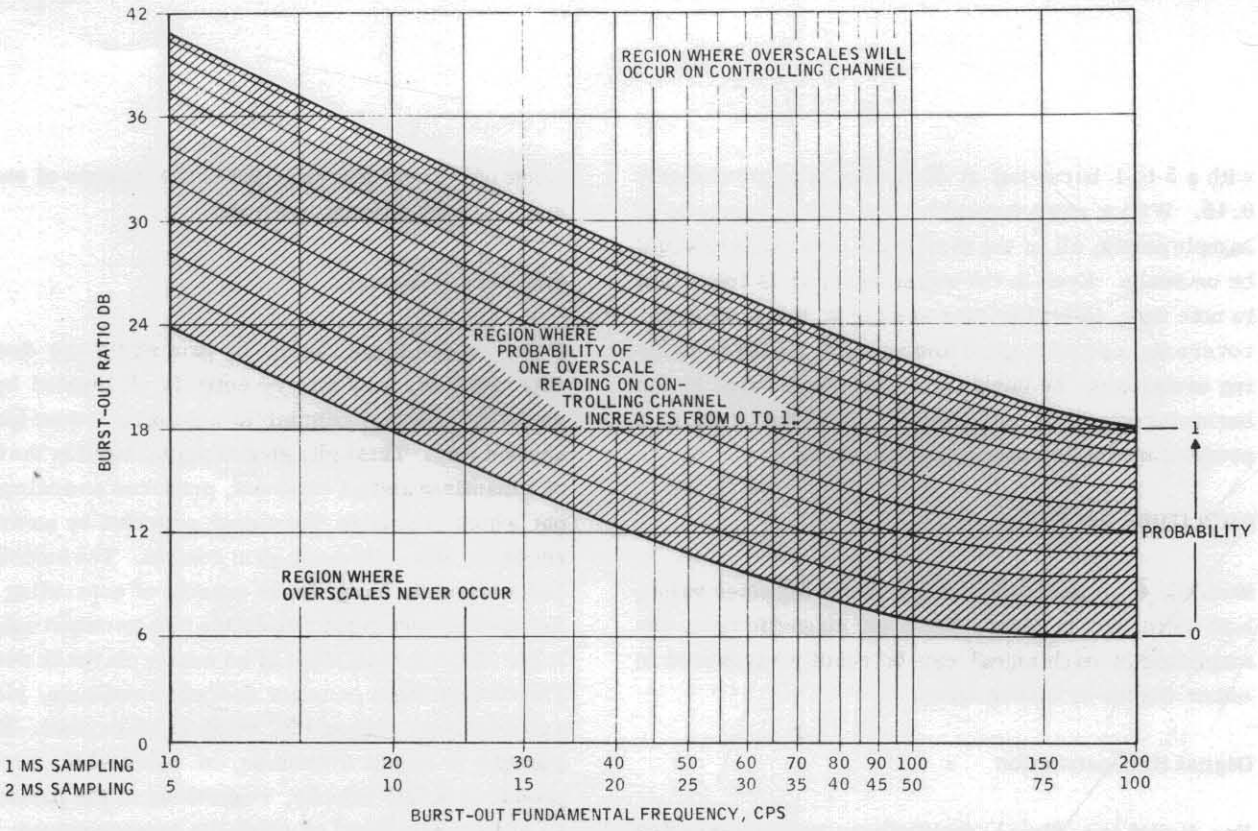

FIGURE 6

Burst-out fundamental frequency is plotted against burst-out ratio to show regions of no overscales, a possibility of one overscale, and certain overscales.

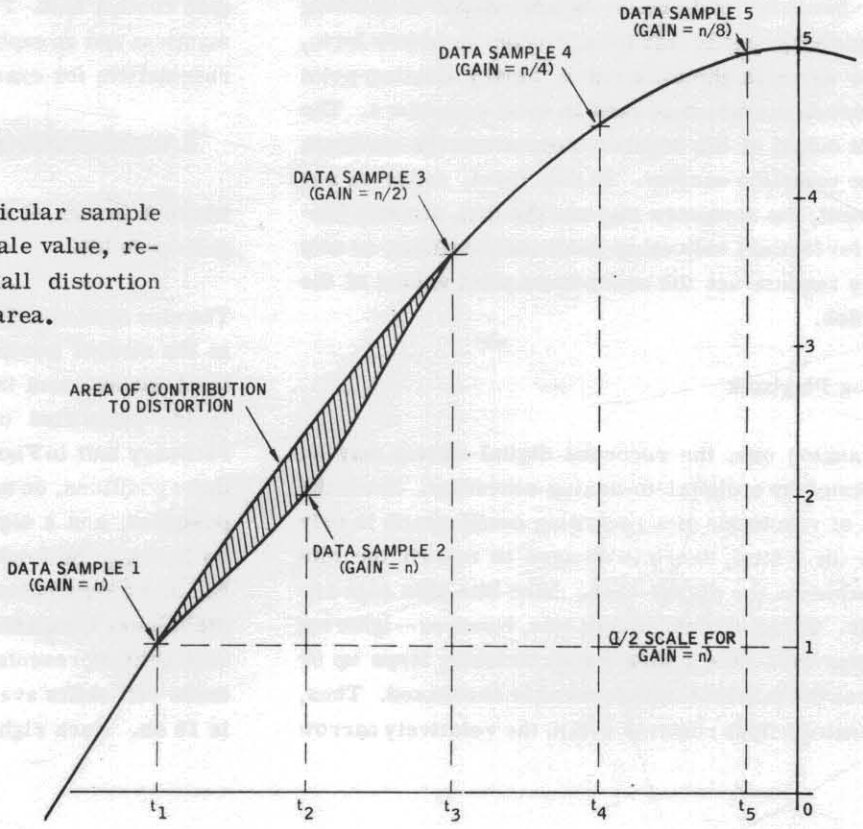

FIGURE 7

If an overscale occurs, the particular sample involved is recorded as a full-scale value, resulting in the comparatively small distortion represented by the crosshatched area.

with a 5-to-1 burst-out at 50 cycles is approximately 0.15. With a more favorable "chance" occurrence of sample points, all of the samples in this example would be on scale. Even in the worst case, it is important to note that, following data sample 2, the system recovers (by reducing gain) and records all the remaining samples of the burst-out. The peak value of the burst-out signal is not clipped, as might occur in a programmed gain control configuration.

AMPLITUDE RECOVERY

With the 4-bit gain code and the 15-bit digitizer value, both recorded in binary form on magnetic tape, the amplitude of each signal can be readily recovered in either digital or analog form.

Digital Reconstruction

For digital use, signal amplitude can be reconstructed by a computer to a degree of precision unprecedented in seismic recording experience, as already discussed in the section on dynamic range. It may be noted further, however, that one of the advantages of doubling the gain each step is that the gain code, in binary form, is the same as the exponent in binary floating-point representation which is used in most computers. The 15-bit output of the digitizer represents the mantissa of the complete number. In this form, mantissa and exponent, the computer may use the data directly (except for format) in floating-point computations, or may easily reconstruct the exact-fixed point values of the samples.

Analog Playback

For analog use, the recorded digital values may be converted by a digital-to-analog converter. Since the limit of resolution of a recording oscillograph is only 0.5% (or 8 bits), there is no need to use all the bits available on the digital tape. Nine bits plus sign are ample. Using only these data bits, however--ignoring the gain code--the analog output suddenly steps up or down as the gain level is increased or decreased. Thus, the analog output remains within the relatively narrow range of the oscillograph--but at the expense of sudden steps at each gain change point.

Smoothed Recovery

If the sudden steps caused by gain shifts are deemed objectionable, they may be entirely eliminated by the smoothed-recovery digital-to-analog converter (patent applied for). This unit, given a digital input in the form of a mantissa and an exponent, produces an analog output which simulates the signal provided by an analog recorder with automatic gain control. The smoothed-recovery unit, however, is capable of converting digital data of very great resolution into an output adapted to the limited resolution of an analog playback device. This output has a constant average amplitude, just as a conventional analog AGC seismic trace does. Rapid changes in output amplitude, or burst-outs, are reproduced in full fidelity, regardless of the particular amplifier-gain-level on which the event occurred. The digital input consists of two parts: One part is the 15 binary bits from the system analog-to-digital converter, and the other part is the 4 binary bits from the gain control unit. These two parts are equivalent to a mantissa and an exponent in binary floating-point representation; for example:

$$S.QQQQQQQQQQQQQQ \times 2^{-GGGG}$$

where S is sign, Q represents a mantissa bit and G, a gain-code bit.

The nine most significant bits of the mantissa are placed in the central positions of the mantissa register and the 4-bit exponent in the exponent register, as shown in the simplified block diagram of the smoothed-recovery unit in Figure 8. The mantissa register has three positions, on both the left and right of the central positions, and a sign position, making 16 bits in all. By shifting the 9-bit mantissa to the left, burst-outs can be accommodated. Since each left shift doubles the value of the mantissa (in the binary number system), each shift represents a 6-db burst-out capability. With three left shifts available, total burst-out capability is 18 db. Each right shift, on the other hand, halves

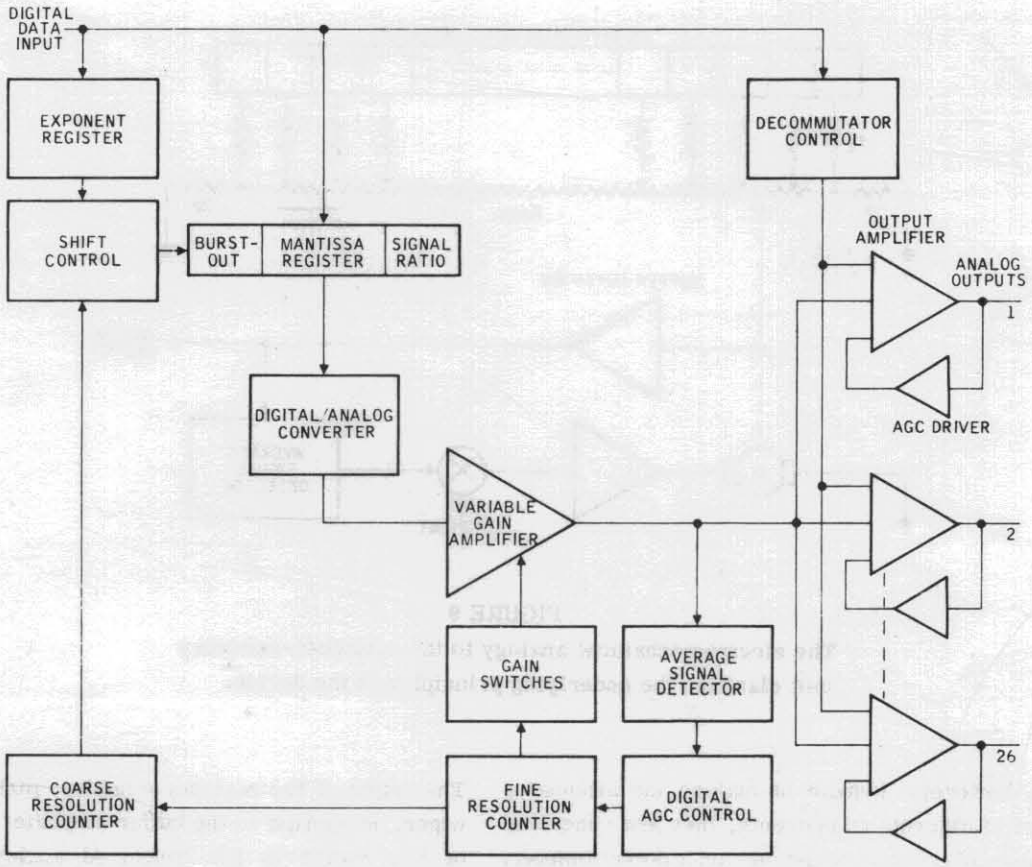

FIGURE 8
Simplified diagram shows major components of the smoothed-recovery digital-to-analog converter.

the value of the mantissa, permitting the D/A converter to accommodate deviations in the below-average direction.

Once positioned in the register, the mantissa bits are converted to the analog equivalent by a conventional resistance ladder. The summed analog signal is applied to the variable gain amplifier and then to each of the channel output amplifiers in sequence. The selection of the output amplifier is made by the decommutation control so that the channel, currently contained in the digital input registers, corresponds to the channel number of the output amplifier selected.

The feedback path from the variable-gain-amplifier output performs two functions, both by digital means: one is the variation of the amplifier gain; and the other, in conjunction with the exponent register, is the shifting of the mantissa. Before describing how these functions are accomplished digitally, the explanation of an electromechanical analogy will serve to clarify the underlying principles.

This electromechanical counterpart, diagrammed in Figure 9, consists of a 29-bit digital input register (necessary to contain the mantissa and exponent in fixed-point representation), a 29-bit resistance ladder for D/A conversion, a buffer amplifier, an average signal detector, and a servo system. The resistance ladder consists of binary "weighing" resistors of value 2R and attenuator resistors (between bits) of value R. This resistance network differs from the conventional

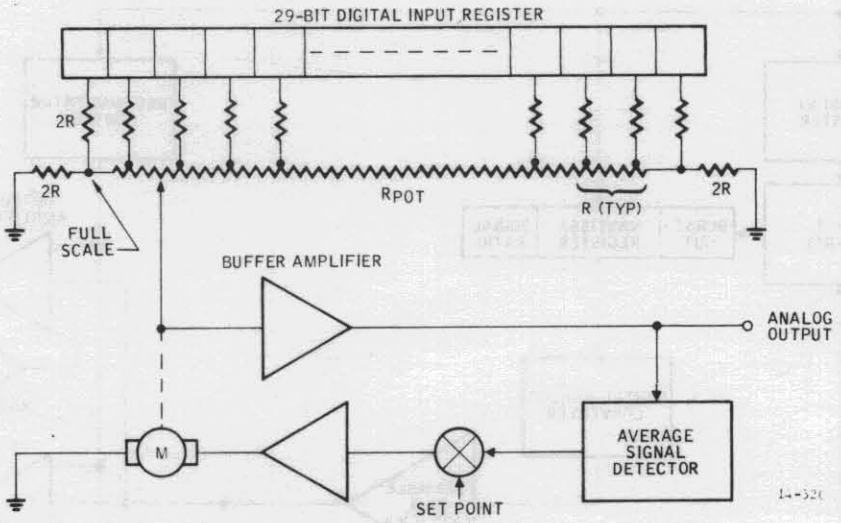

FIGURE 9

The electromechanical analogy to the smoothed-recovery unit clarifies the underlying principles of the device.

version, however. Instead of making the attenuator resistors of discrete components, they are conceived of as points of constant resistance on a potentiometer.

Now, if the 15 bits of mantissa, S and Q, are placed in the left-most positions of the digital input register (corresponding to an exponent value of 0), full-scale output appears at the left end of the potentiometer. If the Q-bits are shifted 5 positions to the right, corresponding to an exponent value of -5, full-scale output now appears 5 constant-resistance points to the right of the original point. Thus, at whatever exponent value the Q-bits are positioned, the potentiometer wiper may be located at a corresponding full-scale point.

Furthermore, it is possible to attenuate a full-scale output by moving the wiper to the left of whatever full-scale point is currently in use. Moving the wiper in this manner results in a rate of decrease of signal of 6 db/resistance point. Actually, the movement of the wiper produces a continuous decrease in signal, since the wiper contact is not limited to the constant-resistance points.

The output of the resistance ladder, picked up by the wiper, is applied to the buffer amplifier. The output of this buffer is the converted analog signal. In order to keep the average output constant, the buffer-amplifier output is also fed back, through a servo path, to vary the position of the wiper on the potentiometer. The first step on the feedback path is the average signal detector. This unit produces an output proportional to the average peak value of the reproduced seismic signal. This output is subtracted from a setpoint signal, and the difference is used to drive the wiper motor. The wiper motor drives the wiper to a position which provides a smoothed output at a constant average level. This level is proportional to the set point of the servo system.

Returning to the digital approach shown in Figure 8, the wiper analogy is replaced by a combination of the position of the Q-bits in the mantissa register and the gain of the variable-gain amplifier. Mantissa position is shifted, left or right by shift control, on the basis of data received from the exponent register and the coarse-resolution counter. Gain is varied in proportion to the count in the fine-resolution counter.

The average signal detector produces an output proportional to the average of the peak values of the maximum channel. Depending on whether this signal is above or below a set-point level, the fine-resolution counter is caused to count down or up. The bits in this counter then cause a number of parallel resistance paths to be either closed or open, depending on whether the bit value is 1 or 0. The parallel sum of the closed resistance paths then varies the feedback in the variable-gain amplifier, thus changing the gain.

With 8 bits in the fine-resolution counter, each controlling a resistor, 256 resistance combinations are available. Gain is caused to vary, in 256 increments, over a 2:1 range (equivalent to 6 db) with a resolution of 0.2%.

When the fine-resolution counter reaches full count, a bit is carried over to (or borrowed from) the coarse-resolution counter. This count--in the form of 4 bits--is compared with the value in the exponent register, also containing 4 bits. When the two values are equal, the mantissa remains in the central positions in the mantissa register. When the exponent exceeds the coarse count, the mantissa is shifted to the right. When the exponent is less than the coarse count, the mantissa is shifted to the left.

By analogy, the exponent controls the position of the mantissa in the register, and the coarse count controls the position of the wiper on the constant-resistance points of the potentiometer. In the digital approach, the difference between these two counts is used solely to shift the mantissa. Thus, the use of a smaller digital register (15 bits, instead of 29) becomes feasible and, of course, the resistance ladder is reduced accordingly.

Again, by analogy, the fine-resolution count corresponds to the position of the wiper between constant-resistance points on the potentiometer. The 8-bit counter with 256 counts is, for practical purposes, the equivalent of the infinite resolution of a wiper.

The general effect of the smoothed-recovery unit may be understood by reference to Figure 10 where signal diagrams are shown in relation to the principal elements of the block diagram. The first diagram, at the input to the digital-to-analog converter, is a visualization of the envelope of the digital output of the system A/D converter. The envelope curves represent both the mantissa and the exponent for the maximum and minimum channels. The difference between channel amplitudes is limited to 30 db. The envelopes have been drawn to converge toward the end of the record, just as typical seismic signals do.

The envelope of the analog output of the D/A converter is shown in the second diagram. Since the average signal detector is averaging the peak, or envelope, values of the maximum channel, the playback envelope of this controlling channel remains approximately constant. This envelope is servo-controlled to a nominal level of 1/4 volt. This level is labeled "0 db" for the purpose of this diagram. The envelope of the minimum channel may be as much as 30 db below the maximum channel, at first. The minimum envelope gradually approaches the constant envelope as the maximum and minimum signals draw together toward the end of the record. The dashed line across the top of this diagram represents the +18-db burst-out capability, provided by the 3 left-hand bits of the digital input register of the D/A converter.

To bring the playback envelopes of all channels to the same constant level, AGC drivers in a feedback configuration (as diagrammed in Figure 8) are used with each output sample-and-hold amplifier. The third diagram shows the envelope of the maximum, or controlling, channel after output amplification to a nominal level of 1 volt. Since this channel already has a constant envelope, as a result of servo control in the D/A converter, AGC action need not be in operation on this channel. The gain diagram, therefore, shows no AGC action. Full scale of the output amplifiers is 10 volts, accommodating burst-outs of as much as 20 db above the average envelope level of 1 volt. A burst-out of a given db ratio has the same amplitude at any point along the time scale. Therefore, burst-outs are easy to see on the camera record.

On the minimum channel, illustrated in the fourth diagram (Figure 10), initial AGC action as high as 30 db

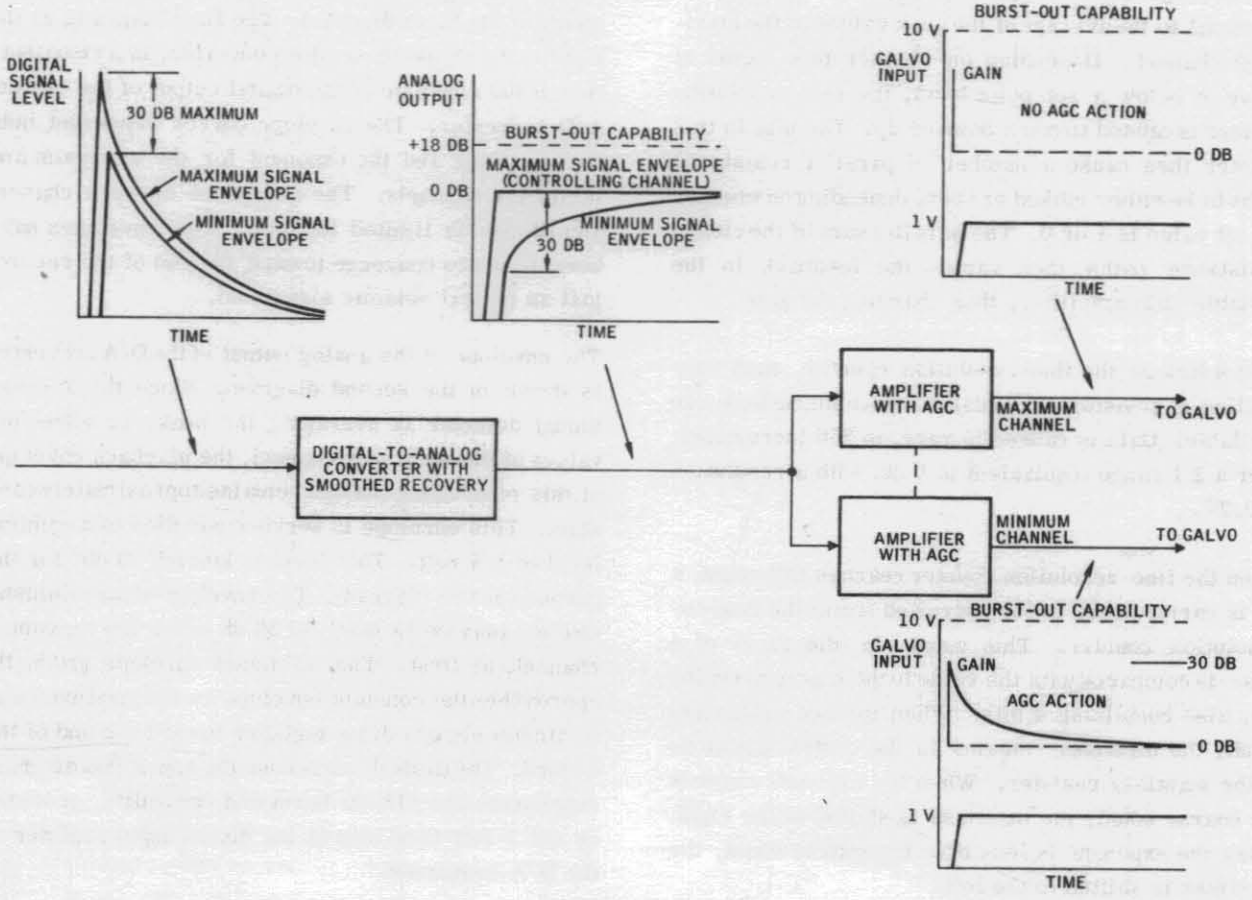

FIGURE 10

Signal diagrams demonstrate the general effect of the smoothed-recovery unit from the entering digital values to the smoothed, constant-level, analog outputs.

may be necessary, as shown on the gain sketch in this diagram. Gain drops off to zero as the seismic signals converge. Thus, using varying amounts of automatically-controlled gain, the peak values of the galvanometer inputs for all channels are averaged out at 1 volt. Burst-outs occur on a faster time scale than the AGC action. Consequently, burst-outs are recorded at amplitude values between 1 and 10 volts.

TIME CORRELATION

The time relationship between events on different seismic traces is an important part of the information to be analyzed. In digital recording, it is customary to record a time code on the magnetic tape once each scan. In this system, a 15-bit binary time code with a resolution of one millisecond is recorded either at the beginning or the end of each scan. In addition, the sampling intervals within a scan are maintained to electronic-clock standards of accuracy, making it possible to determine the time of a digital sample within less than a millisecond of uncertainty.

HARMONIC DISTORTION

Harmonic distortion causes the output of an amplifier to contain frequency components not present in the input.

As a result, the output is not an exact amplified replica of the input. The distortion is present primarily as second and third harmonics of the principal input frequencies. For instance, the third harmonic of a 10-cps input signal would appear as a 30-cps output. With 1% harmonic distortion, the 30-cps output would have a magnitude of 1% of the 10-cps output. Thus, a severe 10-cps ground roll, 40 db above the amplitude of the reflection signals, would produce an erroneous 30-cps signal of the same amplitude as the reaction signals at 30-cps.

This example indicates how important it is that the seismic amplifier not introduce harmonic distortions which fall within the frequency range of the seismic signals. The frequencies which carry the information of greatest value in seismic work generally lie between 10 cps and 250 cps. To assure that this range of frequencies is passed without distortion through the pre-amplifiers, post-amplifiers, and buffer amplifier, the pre-amplifier was designed to have a passband of 5 to 2000 cps, and the overall response was designed to pass 5 to 1000 cps (down 3 db).

Two types of amplifiers could handle this range of frequencies: a-c amplifiers and chopper-stabilized d-c amplifiers. The last named was selected because the first has drawbacks in this application.

One difficulty in using an a-c amplifier in this application is that harmonic distortion increases at low frequencies. The general technique for reducing distortion is to increase amplifier feedback loop gain. If distortion through the amplifier were 100%--a worst-case assumption for design purposes--it could be reduced to 0.1% by designing loop gain to be 1000. Since distortion is probably much better than 100%, it is reduced to less than 0.1% by loop gain of 1000. To maintain this low level of distortion at low frequencies, such as 10 cps, loop gain has to be maintained down to d-c. In an a-c amplifier, however, loop gain declines at these low frequencies, resulting in increased distortion.

Furthermore, if an a-c signal is being passed through an amplifier and the gain is suddenly changed, a d-c component is introduced. The magnitude of this component depends on the point in the waveform at which the gain switching occurs. At the peak of a sine wave, for instance, this d-c offset equals one-half the integral of one-half cycle. In an a-c coupled amplifier, it decays at a rate determined by the time constant of the lower cutoff frequency of the amplifier.

The chopper-stabilized d-c amplifier avoids these difficulties because it can pass both d-c and a-c components. Consequently, loop gain can be maintained well over 1000 from d-c to beyond 1000 cps, reducing harmonic distortion to less than 0.1%.

The d-c component introduced by gain switching does not appear as a decaying error because of the presence of the d-c channel; but it is present as an offset. These offsets can be held to a fraction of a millivolt by careful design but, at higher gains, even this fraction becomes appreciable. In cascaded amplifiers, too, a small offset may be emphasized by succeeding amplifiers to become significant.

These errors are not large enough, generally, to be evident on an oscillograph record, since they are below the resolution of a galvanometer. In a high-resolution digital system, however, they become significant, and several design measures have been devised to overcome them.

First, the preamplifier is operated at a single fixed gain, x10. Any inaccuracies at this stage would be particularly important since the error would be amplified in the post-amplifiers and the buffer amplifier. By operating the preamplifier at a single gain, switching transients and d-c offsets are entirely avoided at this point.

Second, the gain of the two parallel post-amplifiers is always switched when the amplifier-being-switched is off line. Since these two amplifiers also operate at relatively low signal levels, followed by gain in the buffer amplifier, offset errors could be important. In order to be able to switch gain off line, these amplifiers are selectable. While one is carrying the signal at a

given gain level, the other one is gain-switched. After time for the gain change to settle, the second amplifier may be selected by the selector switch, and so on, alternately.

The gain table, Table 2, indicates how the post-amplifiers are gain-switched off line, whether gain is being increased or decreased. When gain is increasing, the off-line amplifier is switched at least one gain step before it will be brought on line. Since gain can be increased only following an examination period of at least 30 ms, the post-amplifier has more than 30 ms to rise to the new level. When gain is decreasing, the off-line amplifier is switched three gain steps before it will be called on. Since gain can drop at 1-ms intervals, a minimum of 3 ms is always provided for the signal to stabilize at a lower level.

It may be noted that, although offsets and switching transients are largely avoided by the choice of chopper-stabilized d-c amplifiers, there is no serial amplification of whatever small offsets or transients there may be.

Furthermore, the use of digital gain control prevents low-frequency distortion which may amount to 2 or 3% at 5 or 10 cps, even in a good AGC amplifier.

Through the measures described, plus careful attention to every detail of design and fabrication, harmonic distortion in the automatic gain-ranging amplifier is specified at 0.1%--an order of magnitude better than most seismic amplifiers.

NOISE REDUCTION

Noise is any unwanted signal which interferes with the measurement of the wanted signal. In the present instance, some of it originates within the amplifier and some outside. Part of the outside noise, caused by sources of a seismic nature, is actually wanted signal so far as the amplifier is concerned. The seismic signal should be separated into wanted and unwanted components at a later stage, computer processing.

The undesired outside noise, then, may include radio-frequency interference, 60-cycle pickup, and common-mode voltage. As an experienced manufacturer of low-level data acquisition systems, the techniques for reducing these signals to insignificant proportions are well known to SDS Data Systems and have been fully utilized in the design of this system.

Noise within the amplifier originates largely from the thermal motion of electrons, although there may be pickup from one component to an adjoining one. Pick-up may be reduced to an insignificant level, however, by good design. Good design involves the proper mounting of components, location of elements, and shielding. For example, twisted-pair, shielded wiring is used in interconnecting cables and some elements are completely protected with electromagnetic shields. A certain minimum of thermal noise is inescapable, however; this minimum is inherent in the principles of physics.

Thermal noise is proportional to temperature, source resistance, and bandwidth. Temperature and source resistance, of course, are fixed by the nature of the application. The effect of bandwidth on noise can be reduced by limiting the bandwidth and, in seismic applications, low-cut and high-cut filters do limit the bandwidth. Nevertheless, under values of these three factors met in seismic work, theoretically minimum thermal noise will be about 0.05 microvolt, referred to input.

Active components introduce some additional noise. The noise contribution of the transistors, however, has been substantially reduced by the use of silicon planar passivated units. The latest available, this type has a noise figure on the order of 1.5 db, less than half the noise figure of the transistors in use as recently as a year ago.

Thus, by careful attention to design factors, the total noise specification has been held, typically, to 0.1 microvolt rms, referred to input. Under certain circumstances, noise may be as much as 0.2 microvolt rms, referred to input.

TABLE 2

The combination of gains provided by the two post-amplifiers and the buffer amplifier results in 15 levels of gain. Note that the post-amplifiers, when gain is increasing, are gain-switched one step before the output is selected; when decreasing, three steps.

Gain Level	Post-Amplifiers		Multiplexer Selection	Buffer Amplifier	Gain	Decibels
	Upper	Lower				
0	1	16	Upper	1	1	0
1	1	16	Upper	2	2	6
2	1	16	Upper	4	4	12
3	1	16	Upper	8	8	18
4	1	16	Lower	1	16	24
5	1	16	Lower	2	32	30
6	1	16	Lower	4	64	36
7	256	16	Lower	8	128	42
8	256	16	Upper	1	256	48
9	256	16	Upper	2	512	54
10	256	16	Upper	4	1024	60
11	256	4096	Upper	8	2048	66
12	256	4096	Lower	1	4096	72
13	256	4096	Lower	2	8192	78
14	256	4096	Lower	4	16384	84
15	Invalid code					

OPERATOR ADJUSTMENTS

Earlier methods of gain control have imposed time-consuming tasks on the operator. Most AGC circuits utilize a bridge arrangement which must be balanced frequently if amplifier instability, d-c shift, and distortion are to be held to acceptable values. Programmed gain control requires one or more test shots to establish the program times and gain values.

The digital gain control technique requires no attention at all from the operator. Gain change, both up and down, is entirely automatic, dependent solely on signal amplitude.

Other automatic features include a file counter, which automatically records a file number with each file, and a time code, which is automatically recorded with each scan. Gain code, of course, is also recorded in digital form with the sample values to which it is relevant.

TEST CAPABILITY

A test unit is provided by means of which the gain, frequency response, phase delay, and step response of the AGR amplifier may be determined. Test equipment includes an oscillator, attenuator, phase shifter, null detector, and a self-contained ohmmeter.

A two-position switching device permits the geophone inputs to be disconnected and the amplifier inputs placed in parallel and connected to the attenuator. The oscillator provides excitation to the attenuator, both sine wave and step. The phase shifter provides an adjustable phase shift to offset the phase shift through the amplifier.

To determine gain accuracy and phase shift, the sinusoidal output of the oscillator is applied to the attenuator and phase shifter. The attenuator has four positions of gain--all less than one. Thus, when the reciprocal of the attenuator gain equals the amplifier gain, a null is possible; providing the phase shift through the amplifier is equal to that through the phase shifted. Ordinarily, gain will be approximately correct, and the operator will adjust the phase shifter to obtain a null. Since the phase shifter is calibrated, the operator may then observe the phase shift at that frequency. To adjust the gain correctly, the operator must then adjust the fixed gain control in the pre-amplifier of the AGR amplifier for minimum null. If a minimum reading cannot be obtained, it is possible by logical analysis to determine the particular amplifier unit which is at fault.

To observe step response, the step output of the oscillator is applied to the amplifier input.

Shunt resistance of the lines (indicating an open geophone) and leakage resistance to ground (indicating leakage or short which could cause a-c noise) may be checked with the self-contained ohmmeter which has two ranges.

DISTINCTIVE FEATURES

The outstanding merits of the field recording system can be brought to a conclusion by a simple listing of the major features:

a. Dynamic range covers 168 db.

b. Gain selection and recording is entirely automatic.

c. Early gain and trip sensitivity are set by operator.

d. Fast, automatic attack and release rates enable gain to follow signal.

e. Ability to sample burst-outs without overscales ranges from an average of 12 db at 200 cps to 32 db at 10 cps (with 1-ms sampling rate).

f. Precisely recovered amplitude permits new kinds of analysis.

g. Time is correlated with signals to nearest millisecond, or better.

h. Advanced design reduces harmonic distortion below 0.1%.

i. Gain accuracy is 0.02% between steps (on single channel); 0.1% between channels.

j. Thorough attention to detail holds noise to 0.1 microvolt rms, typical.

k. Digital gain control minimizes operator's responsibilities during run.

l. Gain, frequency-response, phase-delay, step-response, shunt-resistance, and resistance-to-ground tests are provided.

074096

SALES OFFICES

Paragon Systems, Inc.
2803 Buffalo Speedway
Houston, Texas 77006
Phone: 713–621–7250

Scientific Resources Corporation,
Southwest Operations
2200 South Post Oak
424 Post Oak Bank Building
Houston, Texas 77027
Phone: 713–621–7590

Scientific Resources Corporation
Two Penn Plaza
New York City, New York 10001
Phone: 212–695–8770

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SECTION VI B
074097

FINAL REPORT

OFFSHORE NAVIGATION, INC.

PROJECT 361

TELEDYNE EXPLORATION COMPANY

for

MAGELLAN OIL COMPANY

N.S.W., VICTORIA, TASMANIA

AUGUST/SEPTEMBER 1969

074098

A B S T R A C T

Project 361 was an XR Shoran Controlled Marine Seismic Survey for potential mineral deposits off the east coast of New South Wales and in the Bass Strait area of Australia.

The Principal involved was MAGELLAN OIL COMPANY.

TELEDYNE EXPLORATION COMPANY (TELEDYNE) was the Prime Contractor and Operator.

OFFSHORE NAVIGATION, INC. (ONI) provided horizontal control for the survey.

074099

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BRIEF DESCRIPTION

OF
SHORAN

RADIOPOSITIONING SYSTEM

I. THE SHORAN RADIOPOSITIONING SYSTEM

The Shoran system is a radar transponder type of radiopositioning system. The Shoran mobile station equipment measures the distance from its location to those of two fixed ground beacon stations. The position of the mobile unit is thus fixed at the intersection of the two circular distance or range arcs so determined. The position of the ground beacon stations or base stations is normally accurately known, so that the corresponding position of the mobile station can be accurately computed or determined by graphical methods. Should the position coordinates of the base stations not be accurately known, the mobile station may still be positioned relative to the baseline determined by the base station locations.

The Shoran mobile unit measures the distances of the two base stations by measuring the time required for pulses of radio signals to travel from the mobile station to each base station and return. The time intervals so measured are related to the corresponding distances by using the highly constant velocity characteristic of radio waves in air through the simple relationship.

Total distance covered = Elapsed time x velocity.

Because of this relationship, it is possible to graduate the indicating dials in the mobile unit in terms of dis-

I. THE SHORAN RADIOPOSITIONING SYSTEM (continued)

tance rather than elapsed time. For example, using radio waves which have a velocity of approximately 186,000 miles per second, the scale of the time-interval measuring system is graduated so that, when the time interval required for a round trip of the signal is 1/1000 second, the scale reads 93 miles. (The total distance traveled by the radio signals in 1/1000 second is 186 miles. Since this is round trip distance, it must be halved to obtain the distance between mobile and base stations.) The Shoran dials are graduated in terms of statute miles rather than nautical miles.

The basic equipment units used to create the round-trip signal paths originating and terminating at the mobile station are shown in figure 1. This equipment consists of a signal source (labeled pulse generator in figure 1), a transmitter, receiver and indicator unit comprising the mobile station, and a receiver coupled to a transmitter at each base station.

Pulse signals originating at the mobile station are radiated from the mobile transmitter and received by one of the base stations. At this base station, the pulse is sent from the output of the receiver to the input of the transmitter, and is then retransmitted back to the mobile

I. THE SHORAN RADIOPOSITIONING SYSTEM (continued)

station. After passing through the mobile receiver, the pulse is routed to an indicating circuit where its time lag, or lapse, with respect to the original outgoing pulse is determined, and indicated in terms of distance rather than units of time.

Other pulses are transmitted to the second base station, using a different radio frequency to permit their discrimination from those intended for the first base station. These pulses are received and retransmitted by the second base station, and on their return to the mobile station are similarly sent through the indicating circuits for measurement of the time required for their round trip and the indication of corresponding distance. Thus the equipment provides continuous, essentially simultaneous, indications of the distances to both base stations.

The Shoran system operates in the VHF/UHF portion of the radio spectrum. Normally, three separate frequencies are used. Two of these are transmitted alternately by the mobile station to interrogate each base station in turn, as previously described. The third frequency is utilized by the base stations to retransmit the received pulses back to the mobile station. Both base stations transmit on the single frequency in order to utilize a single receiver at the mobile station.

I. THE SHORAN RADIOPOSITIONING SYSTEM (continued)

The propagation characteristics of VHF/UHF radio signals is such that they tend to travel in straight lines. While they are refracted in the atmosphere to some small extent, they do not tend to follow the earth's curvature as do radio signals of considerable lower frequency. They lack the ability to "see" beyond the radio horizon. Thus the Shoran system is essentially a "line of sight" system, with the maximum range being limited, to a large extent, by the heights of the mobile and base station antennas.

The range of the system under particular conditions may be estimated from the relationship

$$d = k\left(\sqrt{h_1} + \sqrt{h_2}\right)$$

where,

d = estimated maximum range, in miles
h_1 = height of mobile station antenna, in feet, above sea level
h_2 = height of base station antenna, in feet, above sea level
k = empirical range factor

The factor, k, above depends upon several factors among which are included antenna gain, receiver sensitivity, transmitted power and atmospheric refractive index. It will vary in value from 1.5 to 2.5, under normally encountered conditions.

The range formula, above, presumes no obstructions between mobile and base stations. The presence of intervening hills or other obstructions can reduce the otherwise obtainable range.

I. THE SHORAN RADIOPOSITIONING SYSTEM (continued)

Under certain conditions, abnormally long Shoran ranges can be obtained by exploiting the existence of an atmospheric phenomenon known as a temperature inversion layer. This is a layer of high refractive index occurring within the first few thousand feet of the atmosphere. It has the effect of confining the radio waves near the earth's surface, and acts as a duct to bend radio waves around the curvature of the earth. Under these conditions the factor, k, above may be several times greater than normal. In some marine areas of the world, this phenomenon occurs quite regularly during certain seasons.

The instrumental accuracy of the Shoran equipment, when properly calibrated, is $\pm$ 50-75 feet on a single range. The overall position accuracy is related to the range accuracy by the angle of intersection, at the mobile station, between the two Shoran range circles. This is illustrated in Figure 2. In normal geophysical operations, this angle of intersection is held between 30 and 150 degrees. Refer to Appendix A for examples of areas of coverage for different angles of intersection of the Shoran range circles.

The range accuracy of the Shoran system can be improved, possible by a factor of 2, by correcting the propagation velocity slightly under varying meterological conditions, and by the

I. THE SHORAN RADIOPOSITIONING SYSTEM (continued)

application of more rigid calibration and operating specifications. For most operations, this additional accuracy cannot be economically justified.

In computing (or determining graphically) the position from a pair of Shoran ranges, cognizance must be maintained that a position ambiguity may exist. Each pair of ranges (one to each base station) actually determines two independent positions, one on each side of the Shoran baseline, as illustrated in Figure 3. One position is the "mirror image", so to speak, of the other. Further, the Shoran mileage dials repeat every 100 miles of range. To eliminate this ambiguity one must know, from other means, the correct side of the baseline and the distance to each base station within the proper multiple of 100 miles.

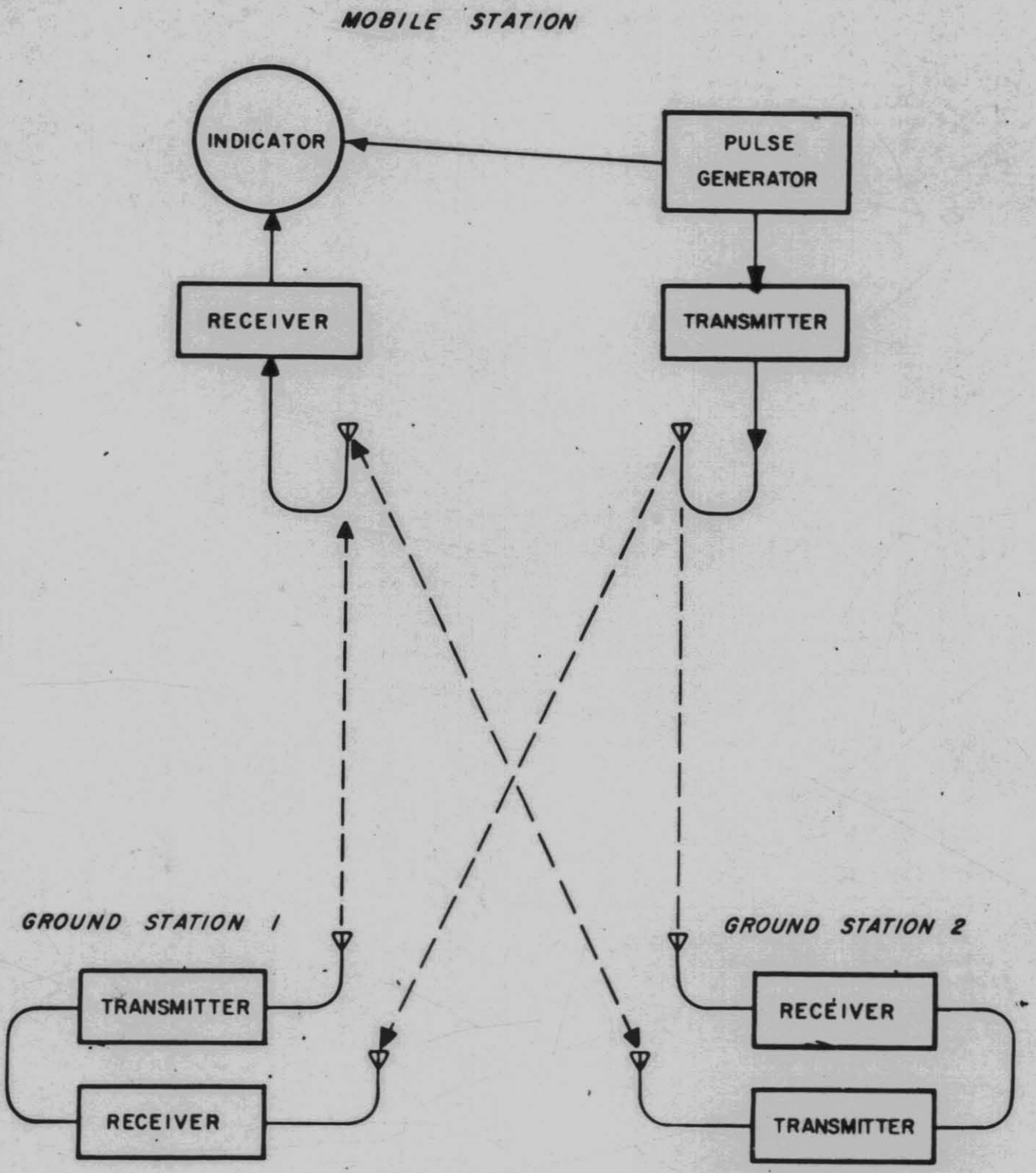
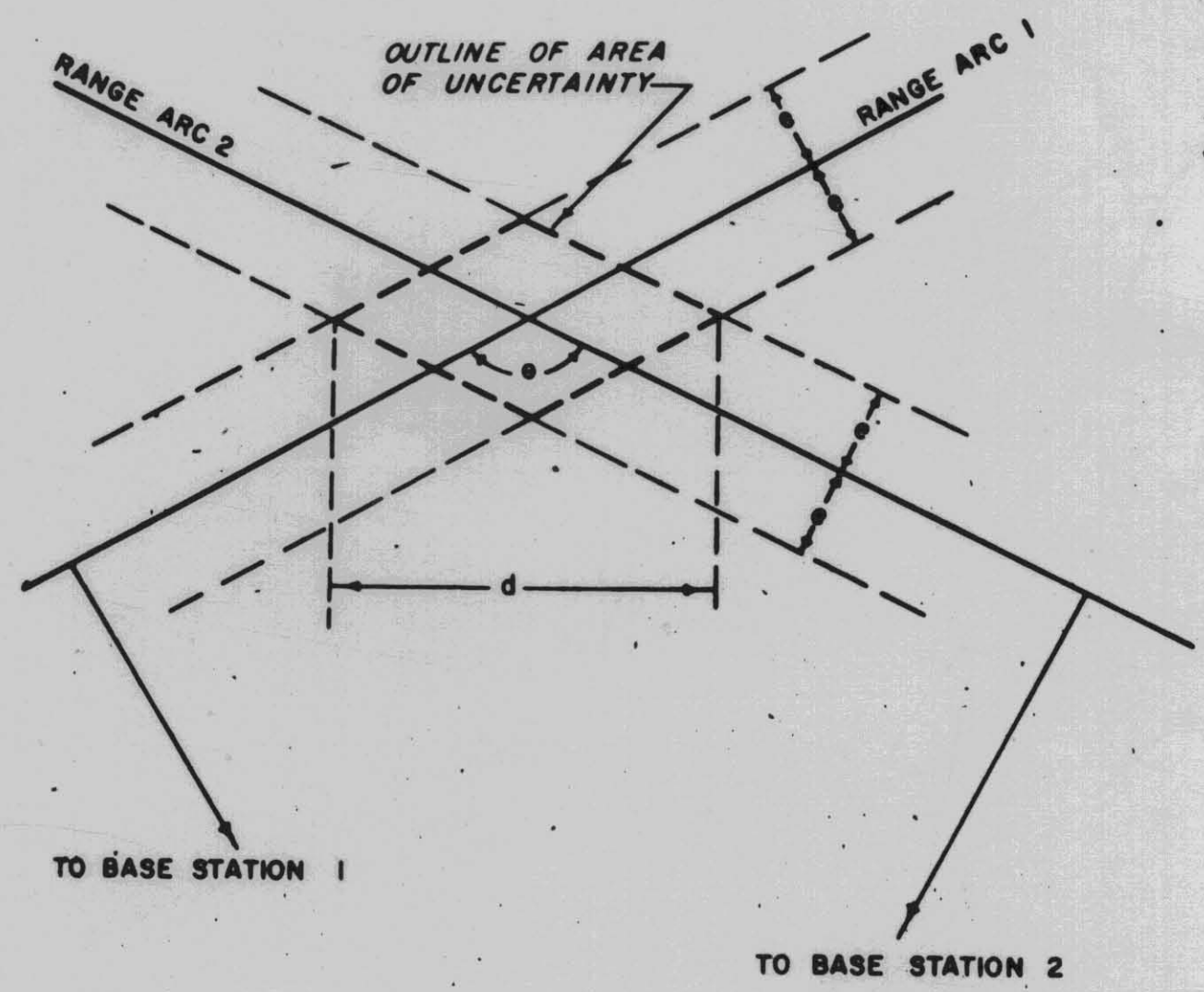


FIGURE 1

SIMPLIFIED BLOCK DIAGRAM OF BASIC RADIO EQUIPMENT OF A SHORAN SYSTEM



$$\phi = \frac{2\epsilon}{\sin \frac{\theta}{2}}$$

ϵ = RANGE ERROR

θ = ANGLE OF INTERSECTION OF RANGE CIRCLES

5 cm

FIGURE 2

AREA OF UNCERTAINTY OF POSITION DUE TO ERROR IN RANGE MEASUREMENT

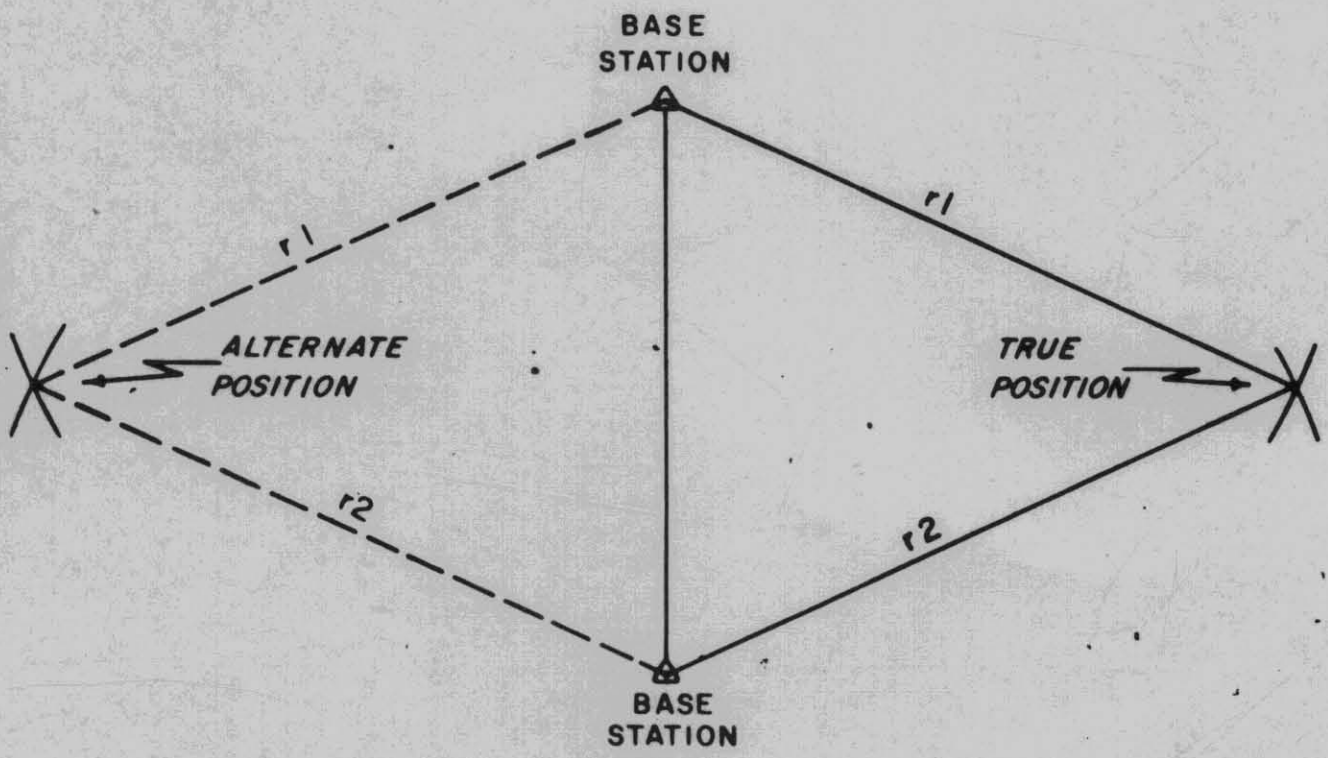
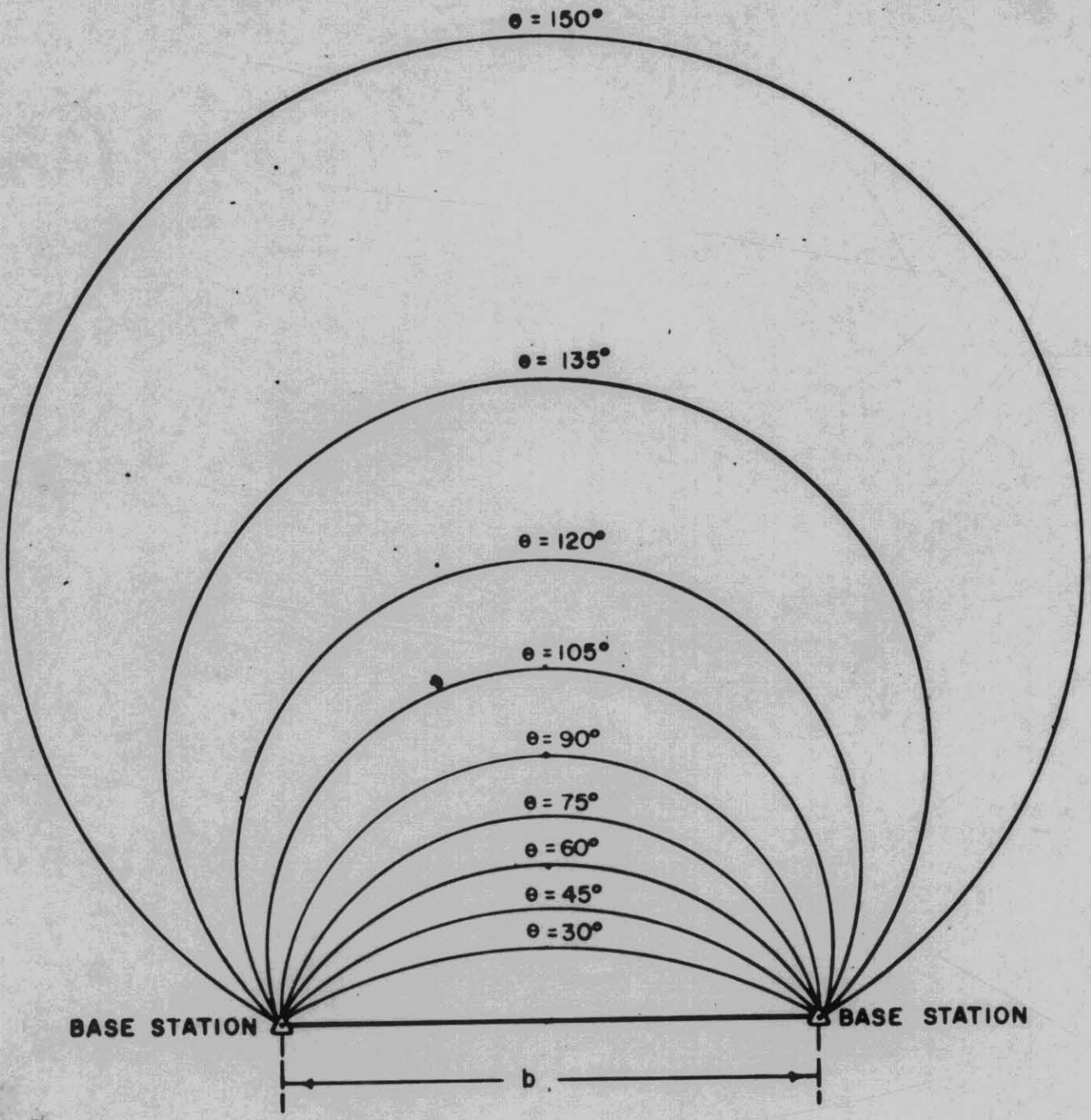


FIGURE 3

POSITION AMBIGUITY IN CIRCULAR RANGE SYSTEM



ALL ARCS ARE PORTIONS OF CIRCLES THROUGH BASE STATION POSITIONS OF RADIUS GIVEN BY:-

$$r = \frac{b}{2 \sin \theta}$$

WHERE θ IS ANGLE OF INTERSECTION BETWEEN RANGE CIRCLES

5 cm

APPENDIX A

RELATIVE AREA OF COVERAGE, CIRCULAR RANGING SYSTEM

II. AREA OF OPERATIONS

The work area was extensive and was actually in the waters of three states in Australia. It extended from Jervis Bay in New South Wales to Eden in the same state, along the east coast. From Eden the work area extended southwest across Bass Strait to the northeast tip of Tasmania. The last phase of the program again crossed the Bass Strait from the northwest tip of Tasmania to just south of the Victorian coastline.

Because of the extent and rapid progress of the program CNI's base of operations changed several times. It was located at:

Narooma, N.S.W.	13 August to 18 August
Eden, N.S.W.	18 August to 23 August
Yarram, Victoria	23 August to 5 Sept.
Beech Forrest, Victoria	6 Sept. to 10 Sept.
Portland, Victoria	10 Sept. to 14 Sept.
Melbourne, Victoria	14 Sept. to 18 Sept.

From these locations activities of the field crew were directed and radiotelephone communications maintained.

III. FIELD OPERATIONS RECAP

The vessel utilized during the survey was the M/V TELEDEX IV. Shoran indicating equipment was already installed from a previous operation.

Initial base station installation began on August 13 and was completed on August 15, 1969.

III. FIELD OPERATIONS RECAP (Continued)

Actual seismic operations began on August 17, 1969 when the vessel occupied the first line and commenced "sparker" operations. Final Shoran readings for the client were observed on September 14, 1969 when the program was completed.

Dismantling of the base stations was completed on September 14 and the equipment was packed for shipment to and storage in Sydney by September 18.

All ONI Personnel, except the Party Chief, were released on September 16, 1969. The Party Chief organized the shipment of the base station equipment back to Sydney and closed the base of operations on September 18.

IV. GENERAL INFORMATION

A. Radiotelephone communications were maintained between Shoran installations on 3216 Kilocycles. Difficulties caused by interferance from P.M.G. radiotelephone link on this or a closely adjacent frequency were experienced between 1700 and 0800 Hours.

B. Peripheral equipment was furnished by ONI for this project. On the first day of operation a power surge in the ship's A.C. supply caused a burn-out of the printer. Time did not allow a replacement to be sent from Nola before the end of the project.

IV. GENERAL INFORMATION (Continued)

The Track Plotter was used successfully between August 29 and September 2. Prior to, and after these dates, the method of line changes used with sparker did not allow the operator to feed the plotter sheets in time. Extreme weather conditions and P.M.G. interference at King Island base station during the last week of operations combined to make use of the plotter impossible during the last few days of the operation.

C. The Shoran field survey notes were mailed to Sydney after completion of each trip and were eventually forwarded on to Mr. A. Sabitay of MAGELLAN OIL COMPANY.

V. COMPUTING AND BASIC CONTROL

Prior to the start of Field Operations ONI in New Orleans pre-determined the Shoran ranges and grid co-ordinates for each recording boat location to be occupied during the course of the survey. These preplots were prepared in accordance with the program assignment chart furnished to ONI. Due to changes made in the initial program by MAGELLAN additional preplots were prepared in Sydney.

Co-ordinates of the base stations used to provide control for the survey were furnished by the Australian National Mapping Service and the New South Wales Department of Lands and Surveys. The co-ordinates appearing on the descriptions and plats are referred to the Australian Transverse Mercator Projection, Clark 1858 Spheroid, Belts 6, 7 and 8.

VI. PERSONNEL

Petterson, D.	Party Chief
Wooddy, D.	Mobile Operator
Carney, P.	Mobile Operator
Barrett, P.	Base Operator
Warmke, P.	Base Operator
Godman, S.	Base Operator
Mills, P.	Base Operator
Burgess, A.	Base Operator
Naylor, G.	Base Operator
Studer, P.	Base Operator
Mitchell, J.	Draftsman

VII. DISTRIBUTION

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DOUBLE BAY. NSW 2028. AUSTRALIA — 1 Copy

STATION: FITE (DROMEDARY)

LONGITUDE:	150°	01'	44".65	X	304632
LATITUDE:	36°	18'	35".33	Y	519277

ELEVATION: 820 YARDS (Approximately)

The position of this station was derived by offsetting the nearby "Dromedary" Trig. Station. The station is marked by a large round rock on a small clearing adjacent to the road and is approximately 210 yards south of Dromedary Trig. The station is located approximately ten miles west of the "Dromedary Trail" sign post marking the intersection about seven miles north of Central Tilba.

In August 1969 the last three miles of the road to the site was in very poor condition and if further deterioration occurs the road will be impassable to four wheel drive vehicles. The road is not maintained and before a decision is made to use this site again it would be advisable to check with Mr. & Mrs. Travis, General Store, Narooma. Good local information is also available from Mr. D. Rose, Narooma, who was most helpful in setting up the station and also has several four wheel drive vehicles he would make available. Any deterioration in the road condition could mean it would take at least three days to set up a station at this site.

Peter Baxter, Wagona Street, Narooma, has visited the site and could be useful as a camp helper.

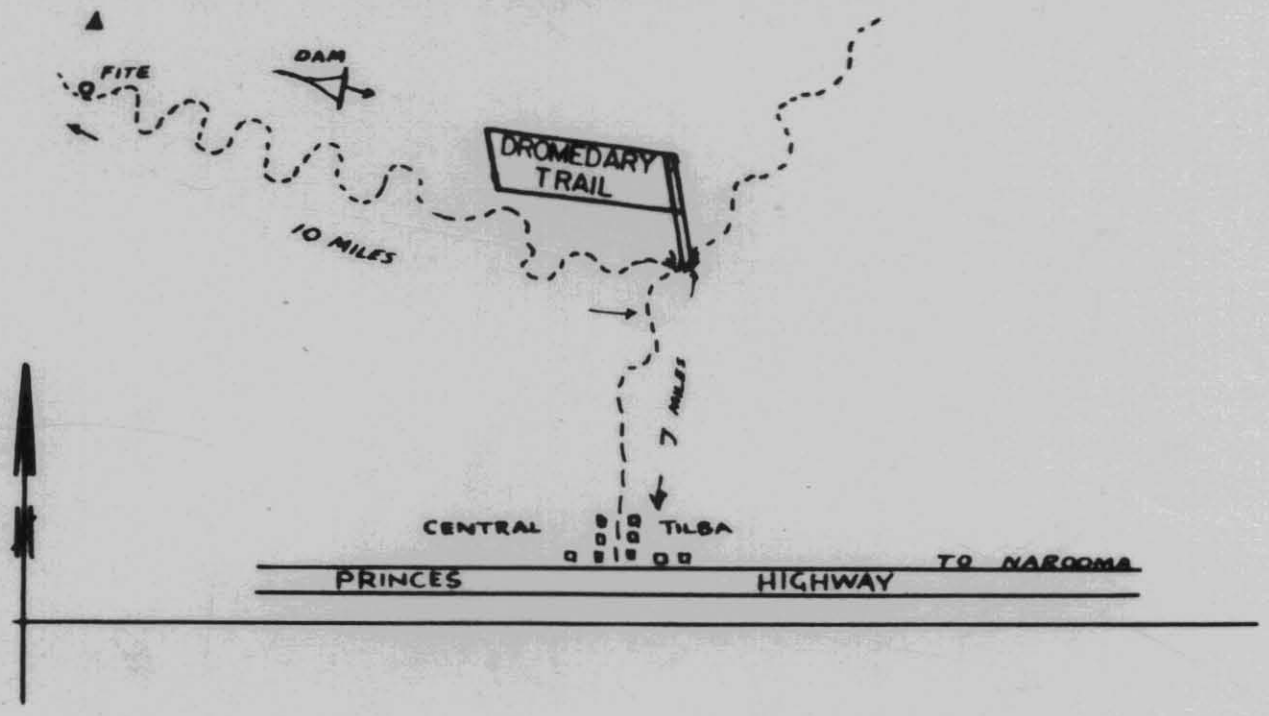
FITE (DROMEDARY) — AUSTRALIA

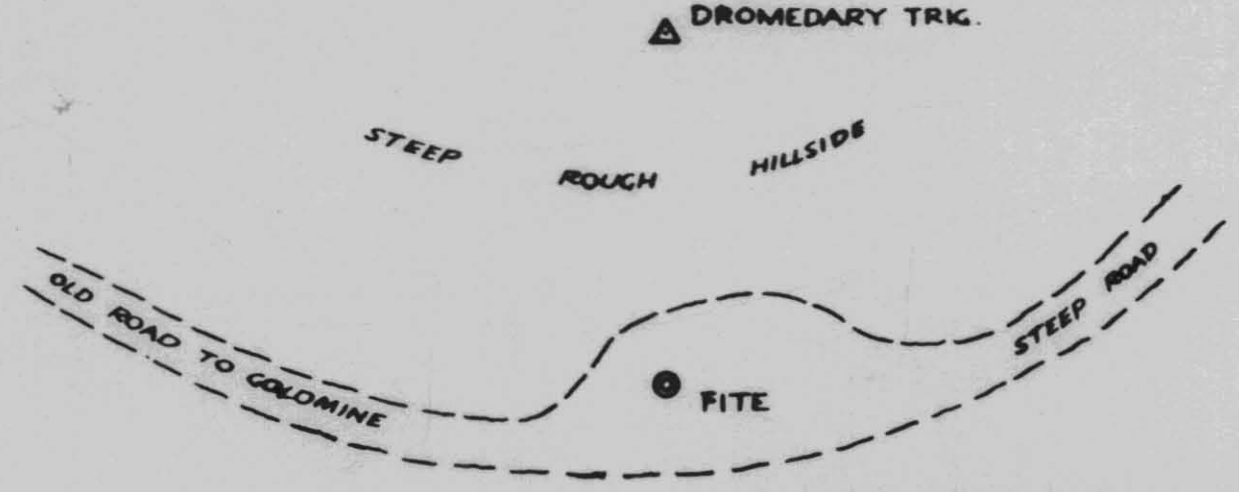
LONG.	150° 01' 44"·65	E	304 632 yds.
LAT.	36° 18' 35"·33	N	519 277 yds.

ELEVATION 820 yds. approx.

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION CLARK 1858 SPHEROID

ZONE 8 TRUE ORIGIN 34° S, 151° E FALSE ORIGIN 800000 yds. S, 400000 yds W





DIAGRAMS NOT TO SCALE

OFFSHORE NAVIGATION INC.
NEW ORLEANS, LA.

STATION: BIMMIL

LONGITUDE: 149° 53' 23".758 X 291952 YARDS
LATITUDE: 37° 00' 46".208 Y 433808 YARDS

ELEVATION: 344 YARDS

The antenna was erected beside the stone cairn station marker.

The station is located approximately 1½ miles west along the road joining Princes Highway at the water reservoir about three miles north of Eden township.

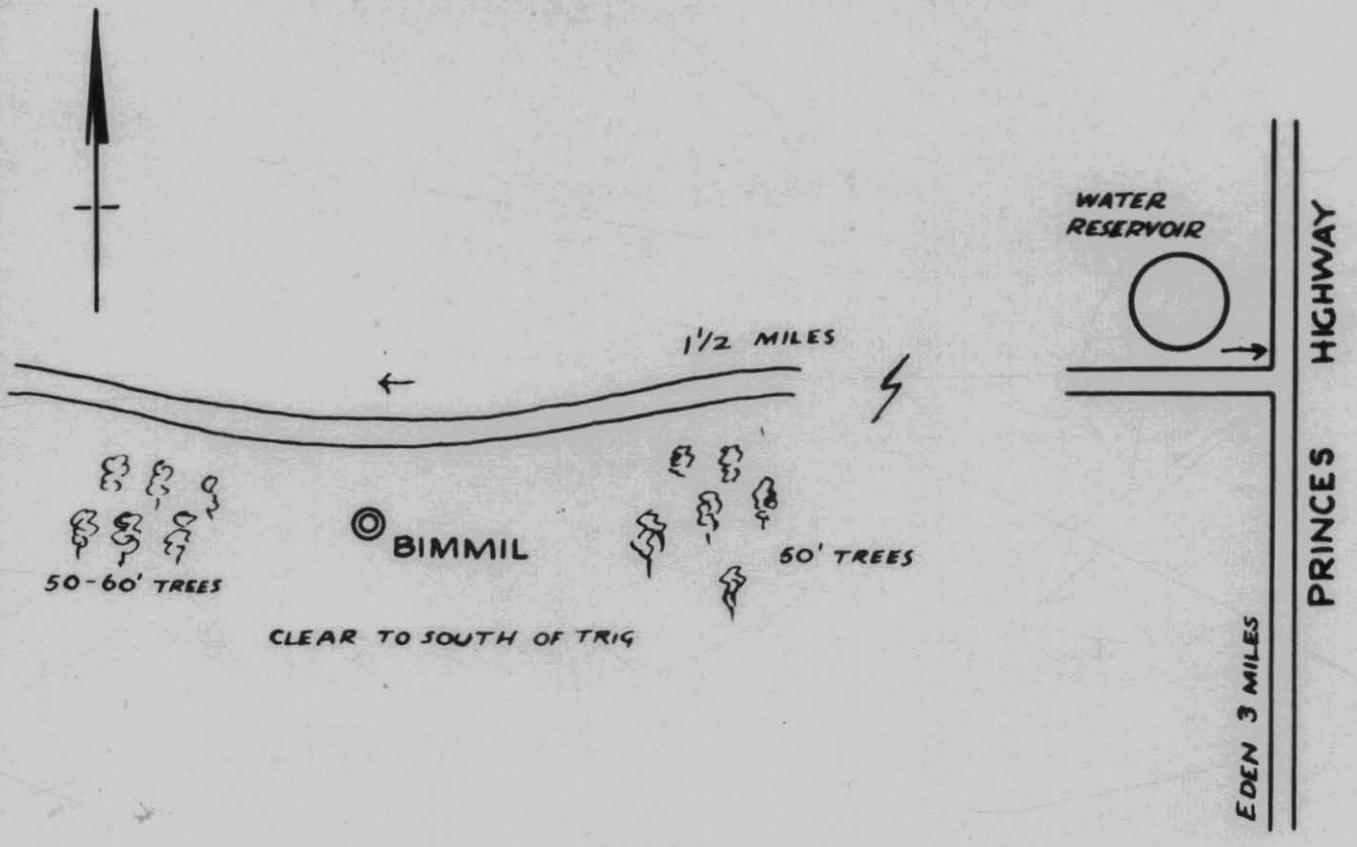
BIMMIL —— AUSTRALIA

LAT	37° 00' 46".208	N	433 808 yards
LONG.	149° 53' 23".758	E	291 952 yards

ELEVATION 344 yards

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION CLARK 1858 SPHEROID

ZONE 8 TRUE ORIGIN 34° S and 151° E FALSE ORIGIN 800000yds S and 400000 yds W.



NOT TO SCALE.

OFFSHORE NAVIGATION INC.
NEW ORLEANS, LA.

STATION: JERRAWANGALA

LONGITUDE:	150°	24'	31".09	X	341034 YARDS
LATITUDE:	35°	06'	17".42	Y	665791 YARDS

ELEVATION: 442 YARDS

The antenna was erected adjacent to the stone cairn marking the Trig. Station.

To reach the station proceed west and south along Turpentine Road from the Tomerong store and service station on Princes Highway for a distance of sixteen miles. Turn left and proceed along a formed track for 1.2 miles. The station is located in a cleared area near the edge of a steep cliff and approximately 85 feet south west of a small house.

JERRAWANGALA — AUSTRALIA

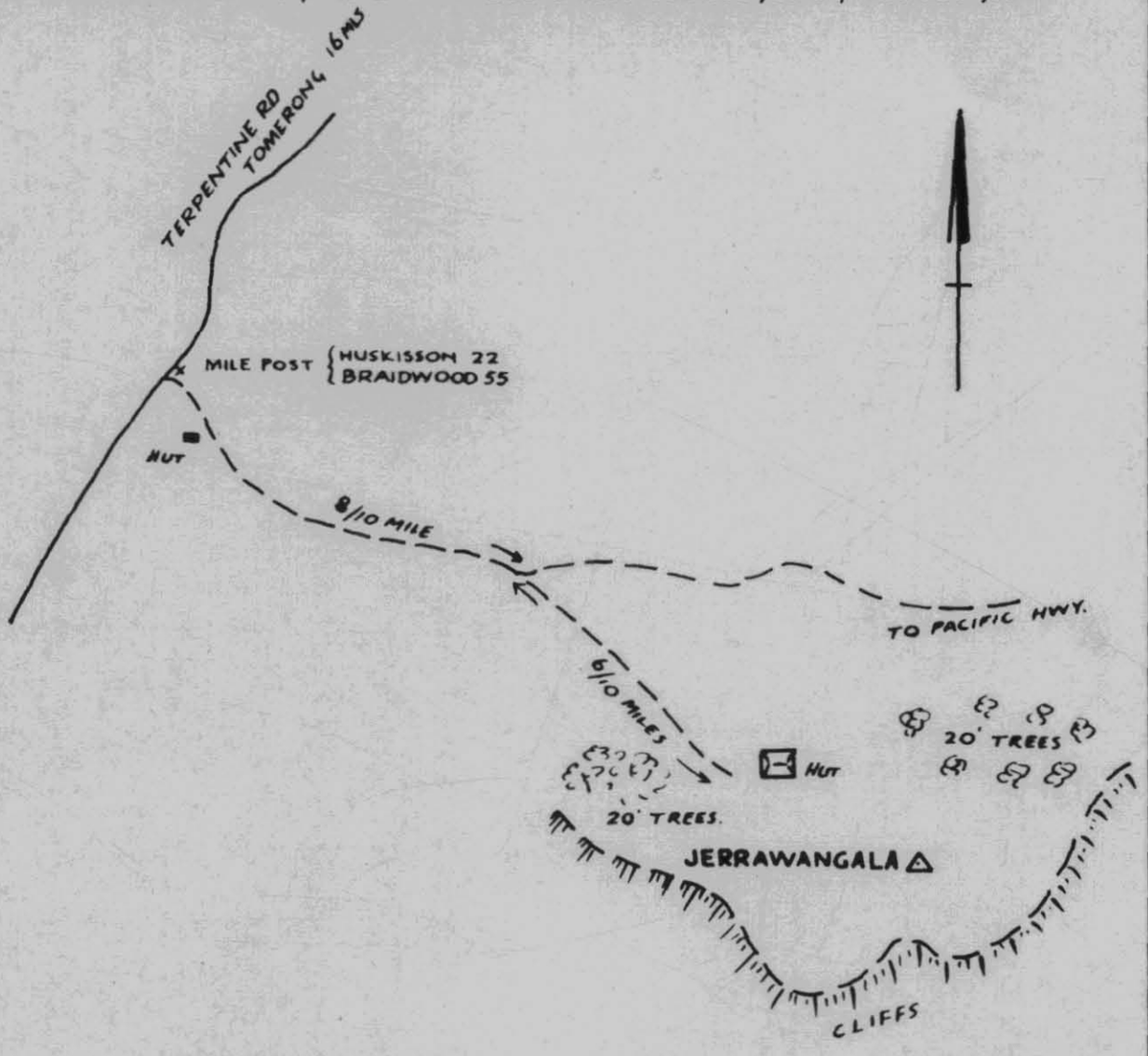
LONG 150° 24' 31".09 E 341 034 yds.

LAT. 35° 06' 17".42 N 665 791 yds

ELEVATION 442 yds.

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION CLARK 1858 SPHEROID

ZONE 8 TRUE ORIGIN 34° S, 151° E FALSE ORIGIN 800000 yds S, 400000 yds W



5 cm

OFFSHORE NAVIGATION INC.
NEW ORLEANS, LA.

STATION: MT. CHAPPLE (740)

LOCATED: About 30 miles south of Colac, Victoria in village of Lavers Hill.

ACCESS: Proceed on road south from Colac through Barongarook, Gellibrand to Lavers Hill. Is accessible by motor vehicle.

MARKER: Shoran station was located on a reference marker which was offset 93.54 feet at an azimuth of 103° from Tri-station Mt. Chapple, and approximately 200 feet west of the Lavers Hill, Victoria, Post Office. The reference marker is a one-half inch copper tube set in a cement block.

The tri-station plaque is set in a cement block with two one-inch galvanized pipes driven into the ground on the east and west sides of the cement block.

GENERAL: Supplies and water can be obtained in the area.

ELEVATION: 602 Yards

SKETCH: See next page.

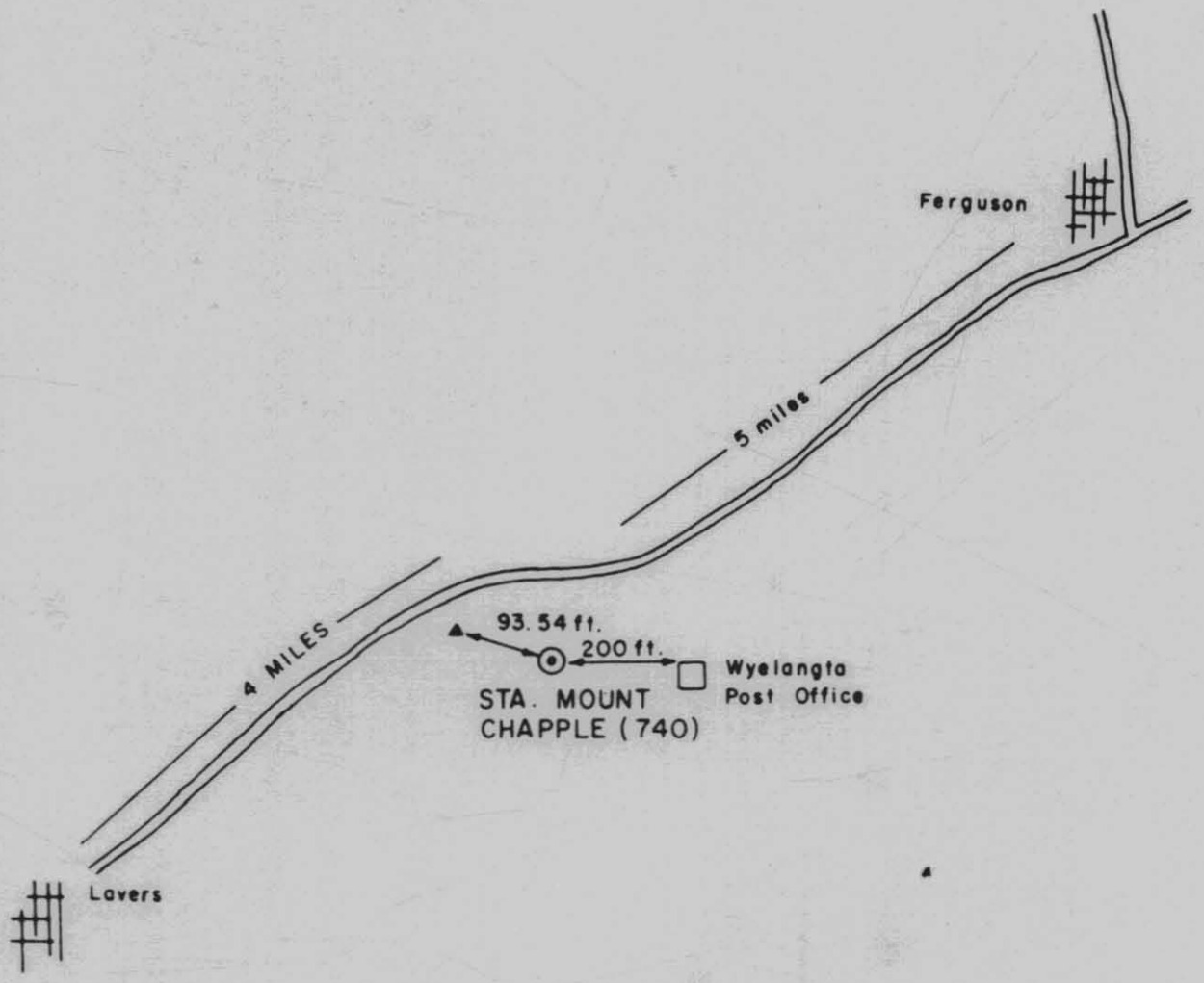
STA. MOUNT CHAPPLE (740)—AUSTRALIA

LAT. 38°39'51".15 S
LONG. 143°27'09".00 E
ELEV. 602 yards

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID

BELT 6, C.M. 141° E
N = 1,230,867 yards
E = 633,462 yards

BELT 7, C.M. 146° E
N = 1,230,618 yards
E = 157,494 yards



5 cm

OFFSHORE NAVIGATION, INC.
NEW ORLEANS, LA.

STATION: MT. CANN (720)

LATITUDE:	37°	38'	55".34 S	N = 1,352,691 YARDS
LONGITUDE:	148°	58'	45".80 E	E = 687,592 YARDS

ELEVATION: 585 YARDS

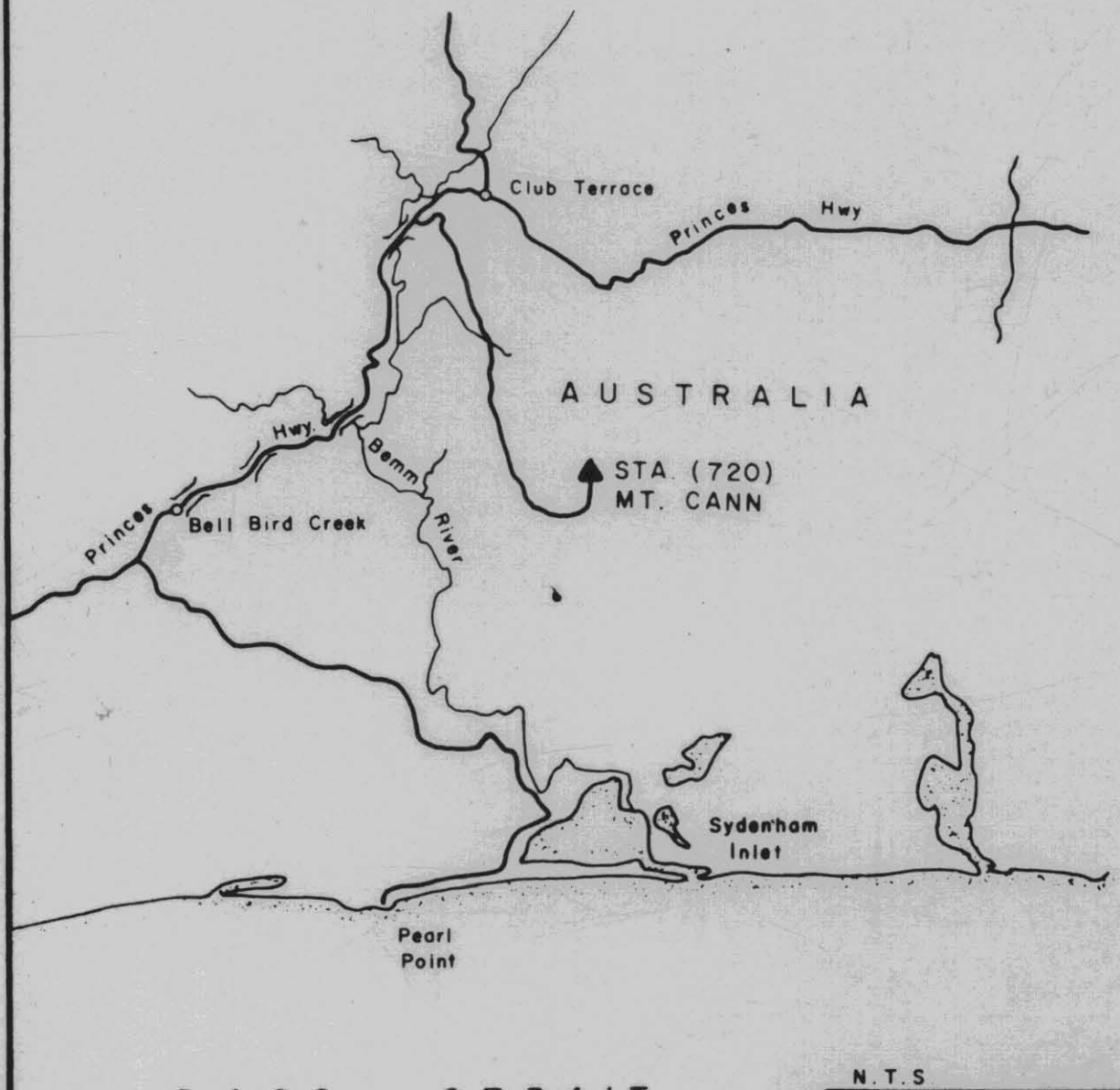
Follow the Princes Highway for approximately 35 miles east of the town of Orbost. Take the first road to the right after crossing the Bemm River bridge. It goes to the mountain.

A four-wheel drive vehicle is needed in wet weather. This is a drive-on site. A hut is located at the site. Permission to occupy it should be obtained from the Forestry office at Cann River.

STA. (720) MT. CANN — AUSTRALIA

LAT. 37° 38' 55".34 S N 1,352,691 yards
LONG. 148° 58' 45".80 E E 687,592 yards
ELEV. 585 yards

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID,
BELT 7, C.M. 146° E; F.N. = 1,000,000 YARDS



N.T.S

OFFSHORE NAVIGATION, INC.
NEW ORLEANS, LA.

STATION: KING ISLAND (712)

LOCATED: On the southern end of King Island, Tasmania.

ACCESS: Equipment can be flown in to the airport or landed by boat at Naracoopa. A local trucking contractor, Mr. Reg. Philpot, can be hired to transport equipment to the station which is 15 miles south of Curry and 3 miles north of Grassy on property belonging to Mr. John Lindsay, telephone Lymwood 212.

MARKER: A 12 foot steel structure.

GENERAL: Mr. Lindsay can be relied on to carry equipment from his house to station site with his tractor. Water can be obtained at the farmhouse, and foodstuffs are readily obtainable from Curry.

ELEVATION: 233 yards.

SKETCH: See next page.

GEOGRAPHICAL COORDINATES		ATM PROJ., CLARKE 1858 SPHEROID Belt 7, C.M. 146°	
Latitude	Longitude	East	North
40°02'10".35 S	144°01'07".04 E	215,045 yards	1,065,350 yards

STA. (712) KING ISLAND — TASMANIA

LAT.	40° 02' 10".35 S	N	1,065,350 yards
LONG.	144° 01' 07".04 E	E	215,045 yards
ELEV	233 yards		

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID
BELT 7, C.M. 146° E; F.N. = 1,000,000 YARDS



SCALE 1:250,000

5 cm

OFFSHORE NAVIGATION, INC
NEW ORLEANS, LA

STATION: Walkers Lookout

LOCATED: In the central region of Flinders Island in the Bass Strait.

ACCESS: Equipment must be flown to Whitemark Airport from Victoria or Tasmania. Follow road from airport to Whitemark until Memana turnoff is reached. Follow the turnoff until a dirt road is seen on the right about two miles from turnoff. Follow this road to the top of the hill and trig. point, a distance of three miles.

MARKER: A wooden post with a four-gallon drum on top. There are two T.V. towers beside the trig. marker.

GENERAL: Mr. Walker, a contractor in Whitemark, is available to transport equipment. Water and supplies must be carried from Whitemark.

ELEVATION: 500 yards.

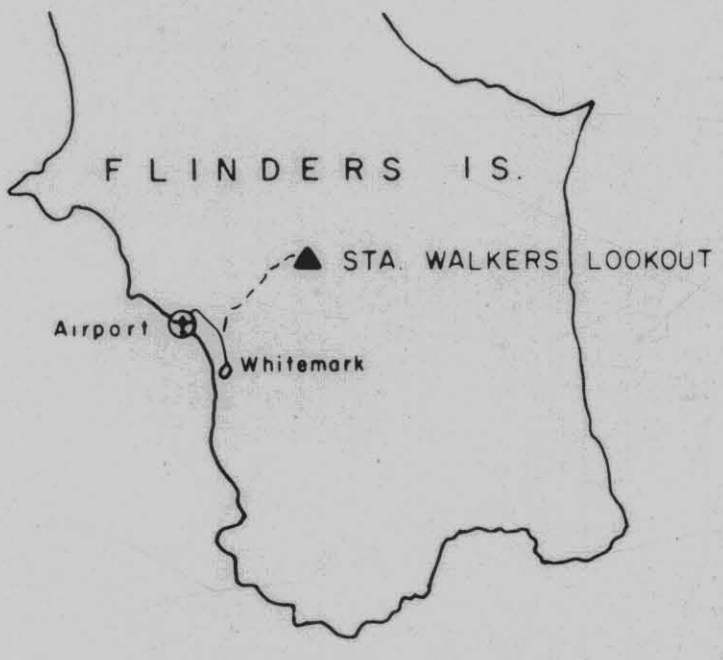
SKETCH: See next page.

GEOGRAPHICAL COORDINATES		ATM PROJ., CLARKE 1858 SPHEROID BELT 7, C.M. = 146° E.	
Latitude	Longitude	North	East
40°03'27"53 S	148°04'46"40 E	1,062,537 yards	594,059 yards

STA. WALKERS LOOKOUT — TASMANIA

LAT. 40° 03' 27"53 S N 1,062,537 yards
LONG. 148° 04' 46".40 E E 594,059 yards
ELEV. 500 yards

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID
BELT 7, C.M 146° E, F.N = 1,000,000 YARDS



BASS STRAIT

5 cm

OFFSHORE NAVIGATION, INC.
NEW ORLEANS, LA

STATION: Deal Island

LOCATED: On the southwest end of Deal Island.

ACCESS: Equipment and supplies must be carried from Port Albert, Victoria. This can be arranged by contacting Mr. Frank Gould at Port Albert, telephone 832343. Mr. Gould has a boat in which he makes regular supply runs to Bass Strait lighthouses. Equipment will be unloaded at Jetty which is 2 miles from the site. The Lightkeeper has a Land Rover which is available to transport equipment to within 125 yards of the site. From this point it must be packed up a bush track to the site. Water is available at the Lighthouse.

MARKER: A metal plate on highest point of hill between two large rocks.

GENERAL: To occupy site permission must be obtained from The Regional Lighthouse Engineer, Shipping and Transport Department, 497 Collins St., Melbourne. Phone 620151.

ELEVATION: 333 yards.

SKETCH: See next page.

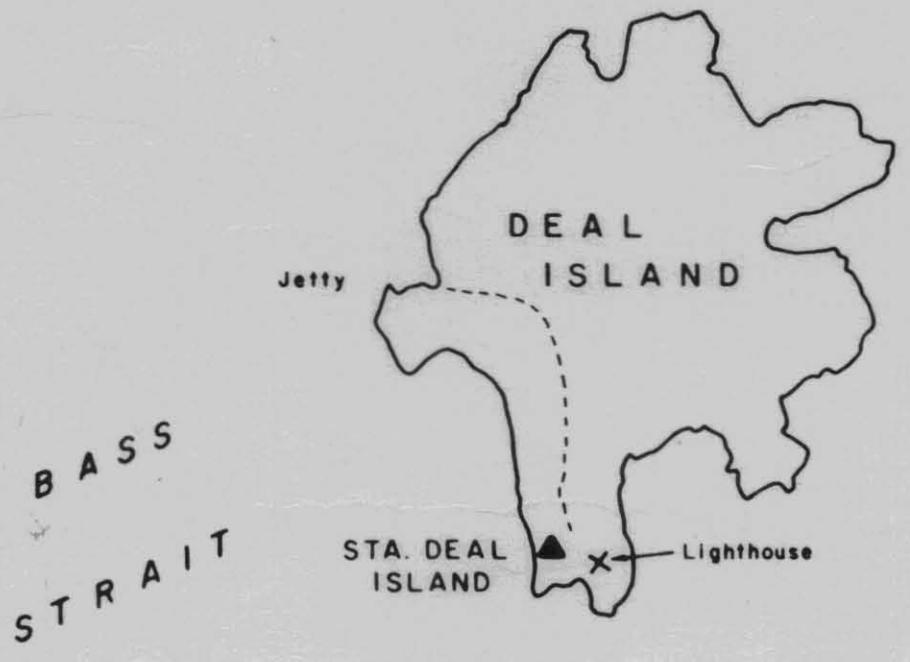
GEOGRAPHICAL COORDINATES		ATM PROJ., CLARKE 1858 SPHEROID BELT 7, C.M. = 146° E.	
Latitude	Longitude	North	East
39°29'41".36 S	147°19'09".23 E	1,132,236 yards	524,112 yards

074131

STATION DEAL ISLAND — TASMANIA

LAT.	39° 29' 41."36 S	N	1,132,236 yards
LONG.	147° 19' 09."23 E	E	524,112 yards
ELEV.	333 yards		

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID
BELT 7, C.M. 146° E; F.N. = 1,000,000 YARDS



N

NTS

OFFSHORE NAVIGATION, INC.
NEW ORLEANS, LA.

STATION: Mt. William

LOCATED: On the most prominent hill in the extreme northeast corner of Tasmania on land owned by the British Tobacco Company.

ACCESS: Take the road east from Launceston to Derby, then another six miles to the Gladstone turn-off on the left. Follow this all the way into Gladstone and take the Ansons Bay road to the right. Follow this for about five miles until the Mussel Roe Bay road is seen on the left. This leads to the farmhouse where the manager of the British Tobacco Company lives. His house is about three miles west of the site. The tower and equipment was taken by crawler tractor and trailer to within 200 yards of the trig. site and handcarried the rest of the way.

ELEVATION: 236 yards.

SKETCH: See next page.

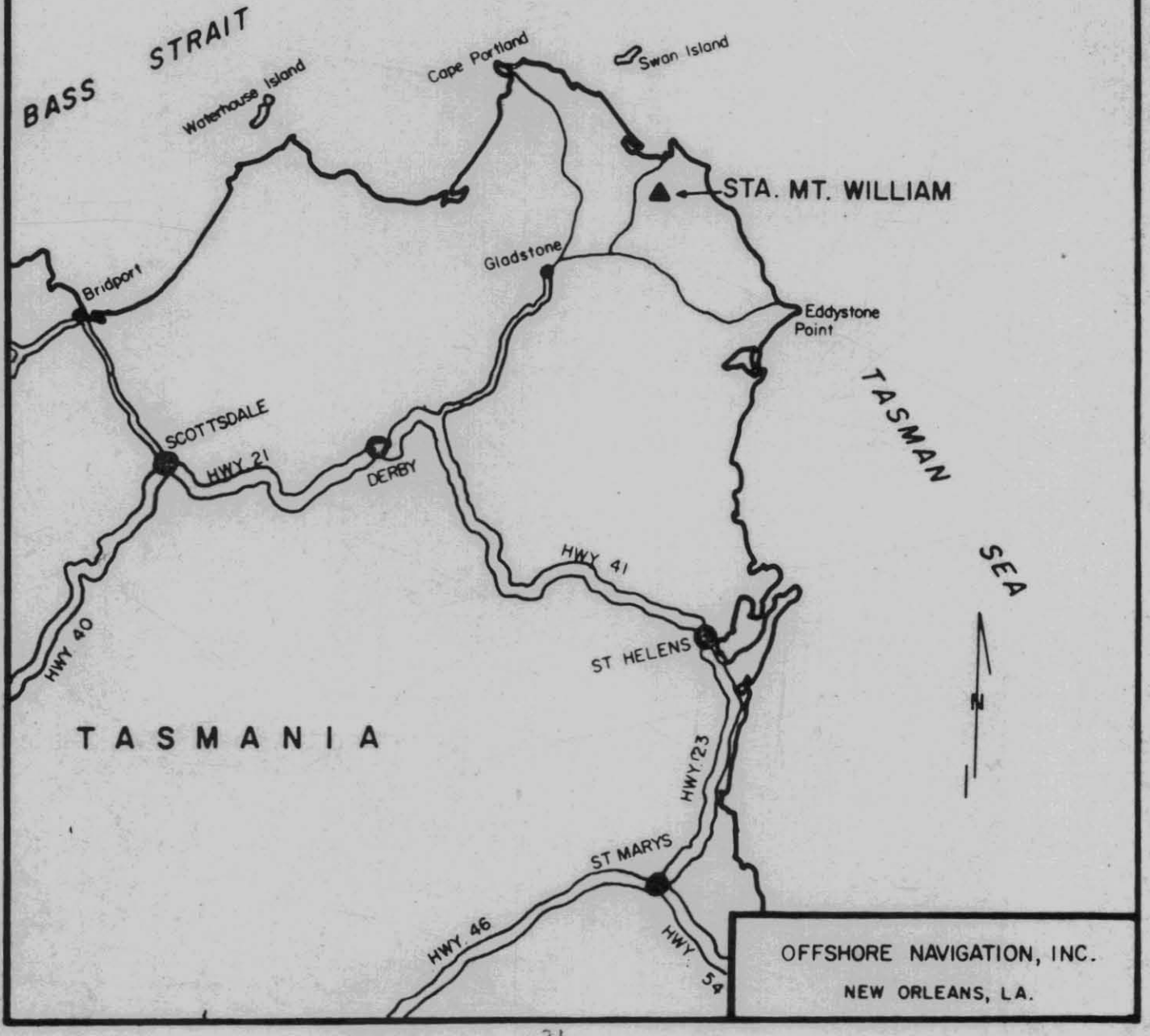
GEOGRAPHICAL COORDINATES		ATM PROJ., CLARKE 1858 SPHEROID BELT 7, C.M. = 146° E.	
Latitude	Longitude	North	East
40°54'34"90 S	148°11'13"55 E	958,813 yards	601,530 yards

STA. MT. WILLIAM—AUSTRALIA

LAT	40° 54' 34"90 S	N	958,813	yards
LONG	148° 11' 13"55 E	E	601,530	yards
ELEV	236 yards			

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID
BELT 7, C M 146° E, F N = 1,000,000 YARDS

5 cm



OFFSHORE NAVIGATION, INC.
NEW ORLEANS, LA.

STATION: Southdown

LOCATED: On west coast of Tasmania.

ACCESS: A drive-on site. Take the highway west from Devonport to Marrawah which is on the west coast. From Marrawah, take the road south toward Temma for five miles. At this point the trig. marker can be seen on the right about 10 yards off the road.

ELEVATION: 30 yards.

SKETCH: See next page.

GEOGRAPHICAL COORDINATES		A.T.M. PROJ., CLARKE 1858 SPHEROID BELT 7, C.M. 146° E.	
Latitude	Longitude	North *	East
40°57'54".73 S	144°39'58".33 E	953,654 yards	277,203 yards

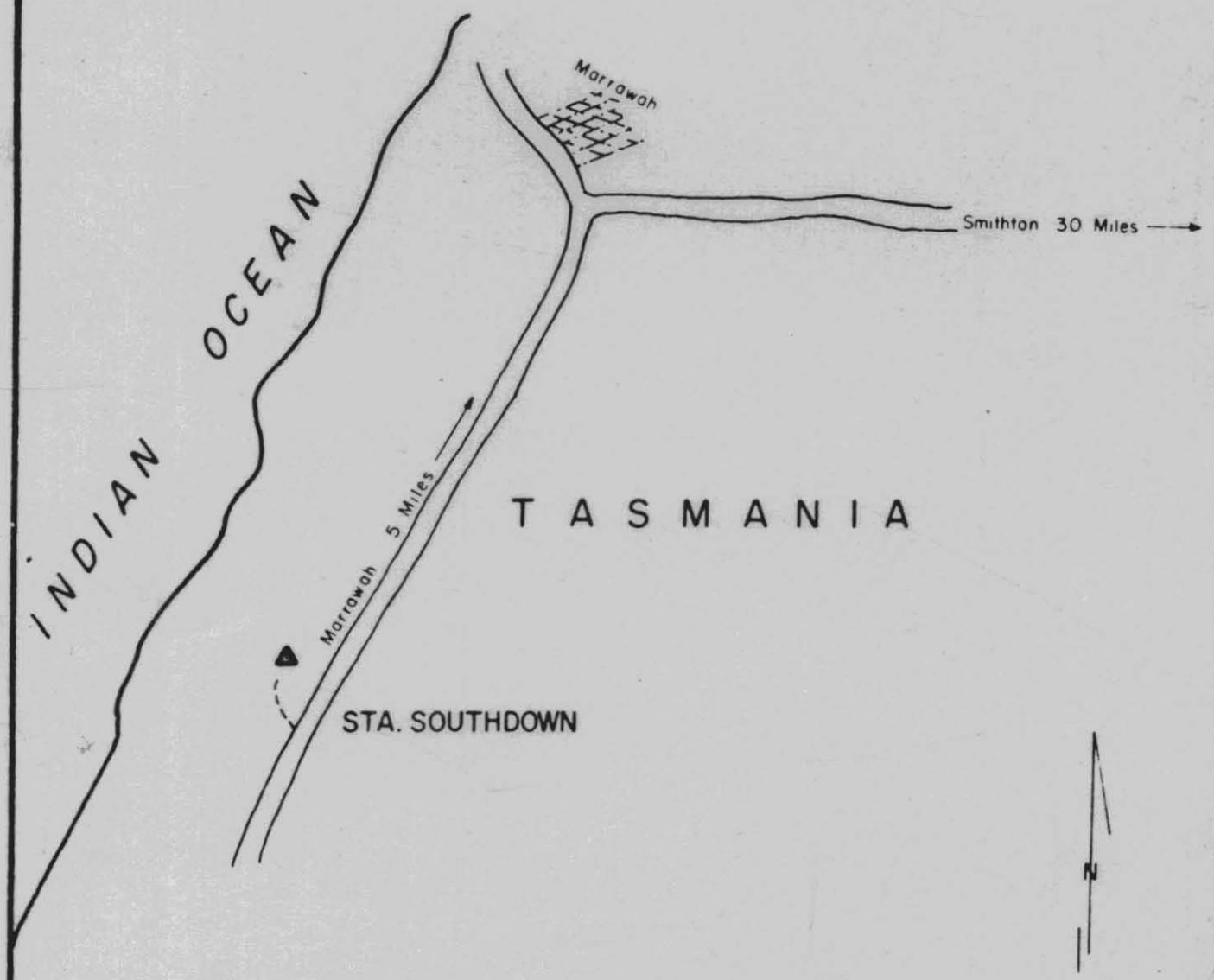
*False Northing = 1,000,000 yards

074135

STA. SOUTHDOWN——TASMANIA

LAT	40° 57' 54"73 S	N	953,654 yards
LONG	144° 39' 58"33 E	E	277,203 yards
ELEV	30 yards		

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID
BELT 7, C. M 146°E, F.N. = 1,000,000 YARDS



5 cm

OFFSHORE NAVIGATION, INC.
NEW ORLEANS, LA.

STATION: GENOA PEAK

LATITUDE:	37° 31' 54".39	N 370,485
LONGITUDE:	149° 37' 38".81	E 267,316
ELEVATION:	536 YARDS	

ACCESS: Follow the main highway through the town of Genoa towards Melbourne approximately one mile. The turnoff to Genoa Trail is plainly marked and travelling towards Melbourne it will be on the left. Follow this trail (road), which is plainly marked along its entire length, to the base of Genoa Peak. The station is on top of the peak which is a heap of huge boulders. A "Flying Fox" must be used to take equipment to the top of the peak. The distance from base to the top is about one half to three quarters of a mile. The Trig. Site and tower location are on a boulder about the size of a dining table. The camp site is about seventy feet away on top of another rock which is slightly larger.

Four days with a five or six man working party should be allowed to set this station and a similar time to take it down.

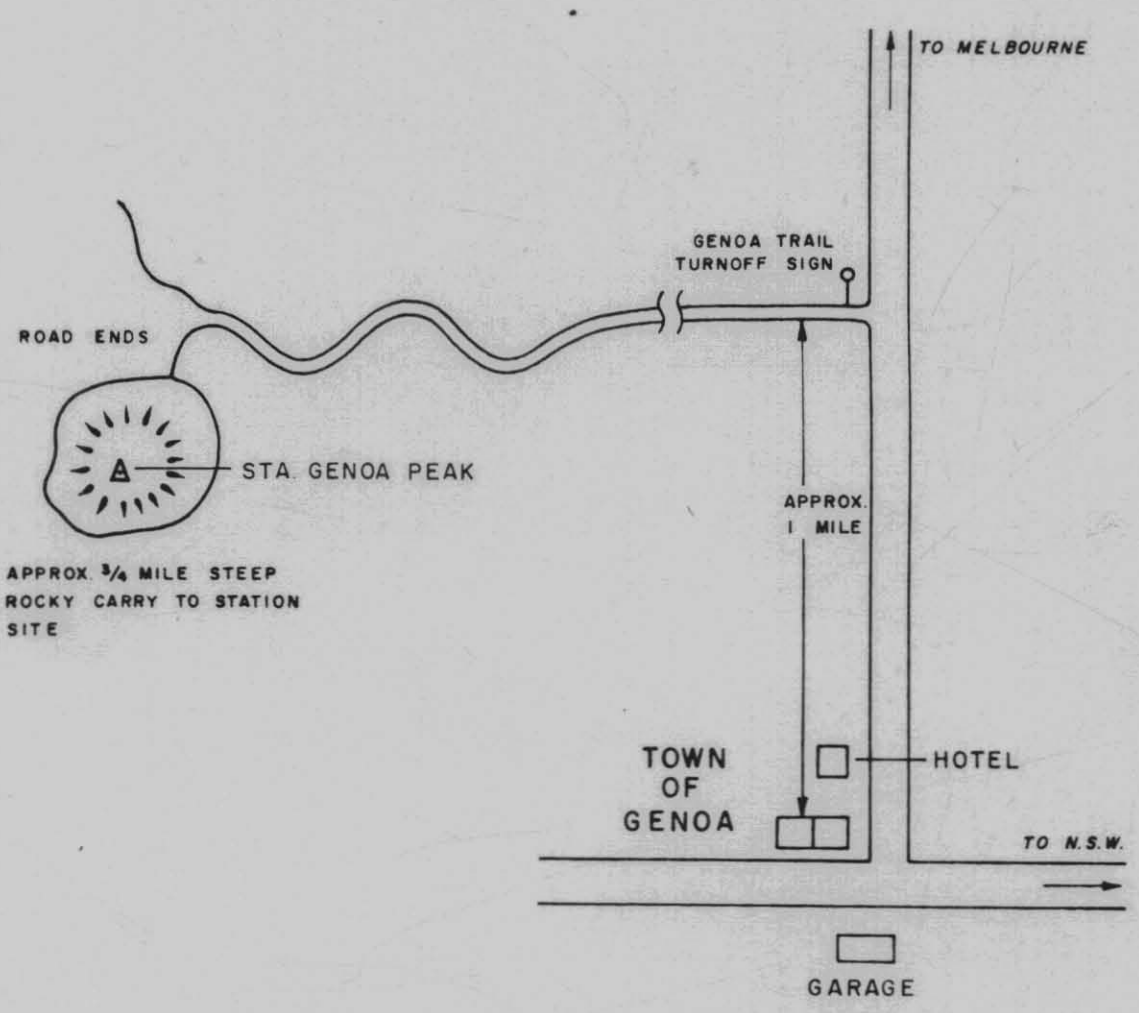
STA. GENOA PEAK – AUSTRALIA

LAT. 37° 31' 54".39 N. 370,485

LONG. 149° 37' 38".81 E. 267,316

ELEV. 536 yards

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION, CLARKE 1858 SPHEROID
BELT 8, C.M. 151° E



5 cm

OFFSHORE NAVIGATION, INC.
NEW ORLEANS, L.A.

074138

SECTION VII
A.

DIGITAL PROCESSING REPORT

OF

EAST GIPPSLAND DATA

FOR

MAGELLAN PETROLEUM AUSTRALIA, LTD.

BY

WESTERN GEOPHYSICAL COMPANY

Shreveport Digital Center - September, 1969

INTRODUCTION

The digital processing of the Magellan Petroleum East Gippsland Data was performed in the Shreveport Digital Center of Western Geophysical Company during the month of September, 1969. This data was recorded using a continuous tow cable with a group interval of 330 feet and a lead-in of 837 feet. Thirty channel Binary Gain Amplifiers were used for recording at a two millisecond sample rate. Recordings were made at an average of sixty-four times per mile.

As per instructions from Magellan Petroleum, the data was processed 2400% with deconvolution before stacking. The procedures used and the programs utilized in processing this data will be described below in the order in which they were applied to the data.

EDIT-SUM

This program is divided into three phases and combines editing, summing and gain application into one operation. The edit phase includes the demultiplexing of the data into a serial by trace format and an analysis of the binary gain information. In the summing phase, the traces are restored to geophone amplitude by applying the inverse of the gain changes. Each trace is then binary point normalized and the requested number are then summed together. In the gain application portion of this program, a theoretical decay function is computed from each geophone amplitude, summed trace, and the inverse of this curve is then applied to the data to produce a balanced output trace. In addition the data was subsampled at this stage so that the processing would be at a sample rate of 4 ms.

The input parameters to this program are determined by running test edits of the data at selected locations over the area. The results are quality checked by the visual inspection of the output at specified intervals along each line.

DECONVOLUTION

An iterative time variant deconvolution was performed on the data after editing. This deconvolution utilized operators of between 30 and 128 ms in length. Each operator was used only

over that portion of trace for which it was designed and new operators were designed and used down the trace. The operators were designed from autocorrelations of one and two seconds in length. Autocorrelations of the data were taken before deconvolution to assist in the choosing of parameters. Auto-correlations of the same points were taken after deconvolution to check the results of the program.

AUTO-CORRELATION PROGRAM

In the processing of this data two types of autocorrelations were made, both before and after deconvolution, and prints of these autocorrelations were sent with the data. In one type of autocorrelation made, one section of trace was used. This section of trace was 2400 ms. long and the correlations started about 150 ms. below the first arrival energy. In the second type of autocorrelation, two separate zones of trace, each 1000 ms. long, were used. The start of correlation in these zones was two seconds and three seconds respectively. The scale of the autocorrelograms sent is 200 ms. per inch.

VELOCITY ANALYSIS AND DETERMINATION

Preliminary velocities were determined by means of the Velan (Velocity Analysis) Program. In this program, vertical velocities are automatically determined from the crosscorrelation

of members of the same CDP family. Each member of each family is NMO corrected for each velocity used in the determination. All possible crosscorrelations among the members of each family are then made for each velocity. The velocities used were started at 4,500 feet/second and increased in increments of 200 feet/second. Six CDP families were used in these analyses. This procedure involved using data from fourteen adjacent shotpoints. These fourteen shotpoints include the one whose number appears on the analysis and the thirteen shotpoints immediately following it. The shotpoint number of the analyses is the same as the input point which contributed the short traces to the analysis. This point is also the center point of the stack and the monitor point on the 100% section. The length of each correlation zone used in the analysis was 24 milliseconds.

The results of these correlations for each velocity at each time zone are then plotted on graph paper by a drum-type mechanical plotter. This graph illustrates the average correlation for the six families used in the analysis at each velocity. A vertical mix or average of three time zones was also utilized in plotting the results. Thus, each horizontal line on the plot would represent the average measurements over a zone of 72 milliseconds with the time on the left of the plot as the mid-point of that zone.

Curves of average velocity verses reflection time are then designed by the velocity analyst from these graphs. This family of velocity functions is used to produce 100% NMO corrected sections for each line. These sections are then examined and residual NMO corrections are calculated to produce corrected or revised velocity functions.

NORMAL MOVEOUT APPLICATION

The normal moveout corrections for the final sections were computed from the revised velocity functions for each line. The calculations were performed independently for each trace using a straight-ray computational method. A limiting factor on the moveout change was imposed. This factor limited the amount of moveout change per 100 ms. of trace time to 50 ms. In addition, muting or the controlled suppression of first arrivals and early refracted energy was applied at this time. Copies of the final velocity functions used showing the average velocity used and the moveout removed on selected groups were sent along with the final sections.

2400% CDP STACKING

The moveout corrected data was then input to the stacking program to produce a 2400% CDP stacked output. A moving gain and trace balancing application was also applied to the data at this point.

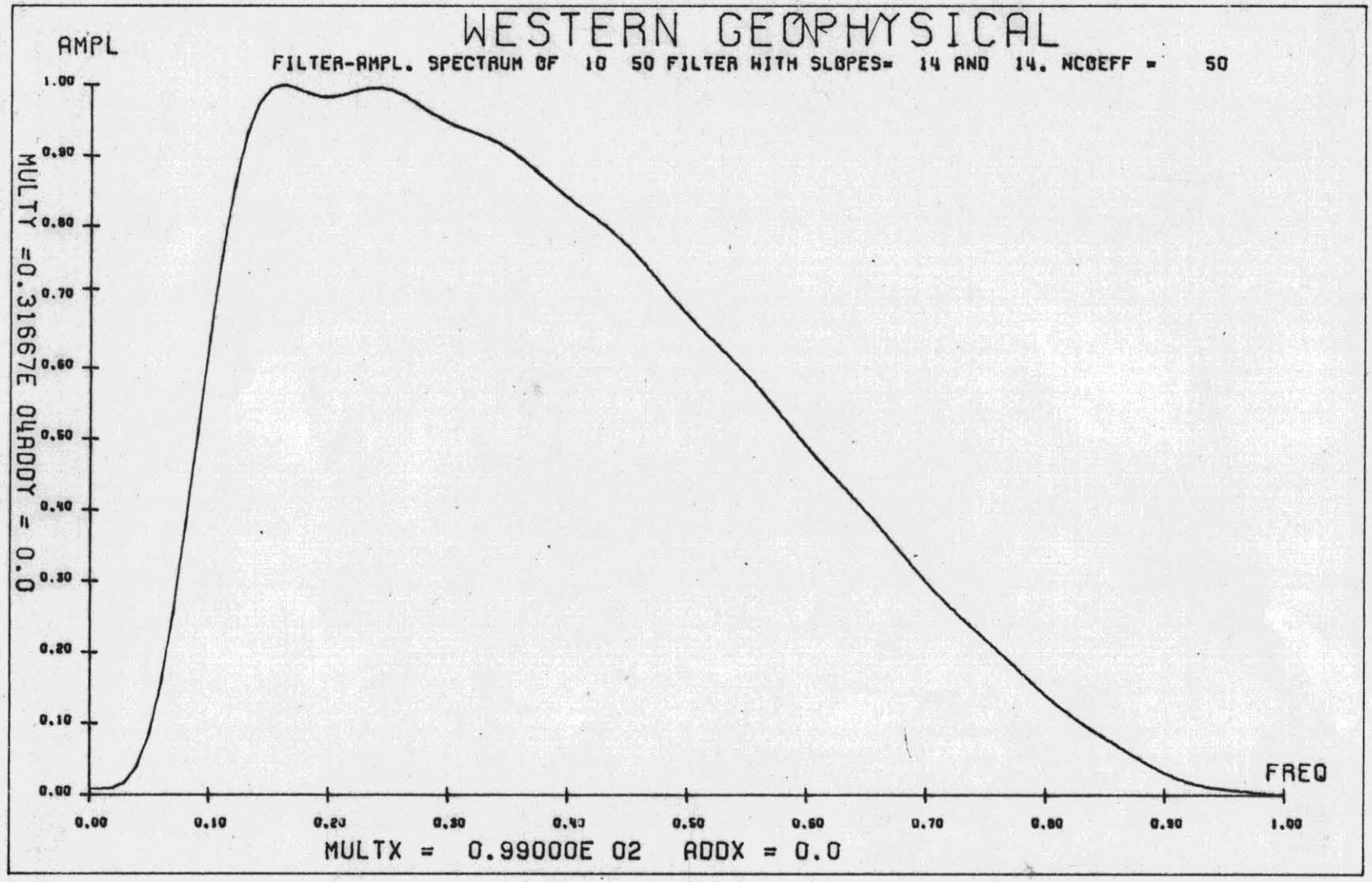
FILTERING

Zero-phase time variant digital filtering was then applied to the data to produce the final sections. The filters used were determined from a set of filter comparisons run on the data to determine the best filters for each time zone. The filters used were designed to have 14 db slopes on both the low and high side and the operators were of 50 points in length. A taper or transition zone of 400 ms. was employed at each filter change.

As a result of the filter comparisons, the filters used on the final sections were as follows:

Time	Band Pass (70% points)
0 - 1.2 seconds	10 - 50 cps
1.2 - 5.0 seconds	9 - 45 cps

Plots of the amplitude spectrum of these filters are included with this report.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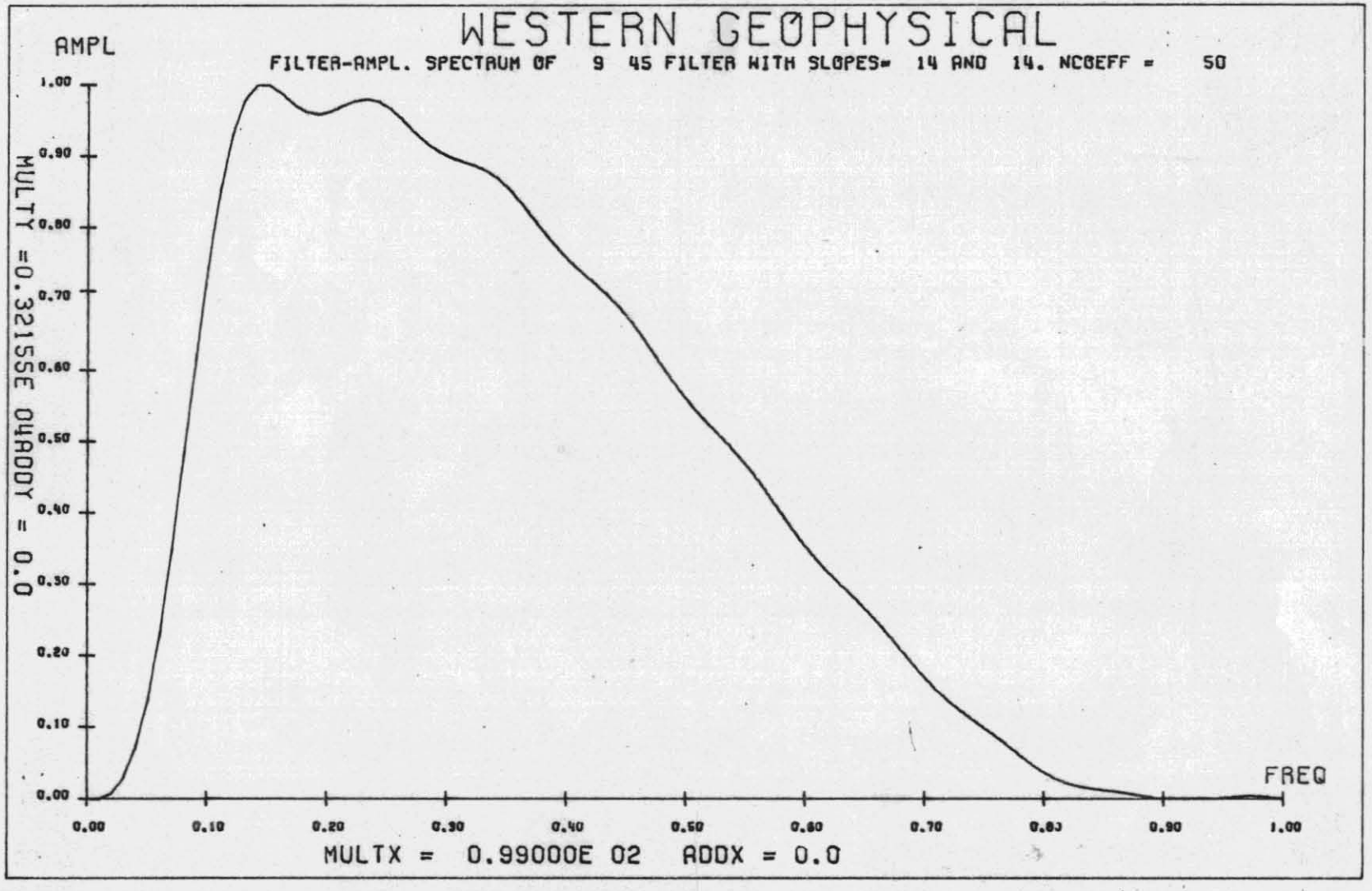
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
FREQ
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
MULTX = 0.99000E 02 ADDX = 0.0

5 cm


WESTERN GEOPHYSICAL
FILTER-AMPL. SPECTRUM OF 9 45 FILTER WITH SLOPES= 14 AND 14. NCOEFF = 50
AMPL
MULTY= 0.32152E 00ADDY = 0.0
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0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
FREQ
MULTX = 0.99000E 02 ADDX = 0.0

5 cm

RED

ID = 3 DISTANCE = 7800

074147

INTERVAL VELOCITY	RMS VELOCITY	AVERAGE VELOCITY	CENTER TIME	RECORD TIME	DELTA-T
5000	5000	5000	100	1563	1463
5180	5100	5090	200	1542	1342
6600	5650	5593	300	1413	1113
7440	6150	6055	400	1330	930
7740	6500	6392	500	1300	800
8120	6800	6680	600	1294	694
9240	7200	7045	700	1290	590
9940	7600	7407	800	1301	501
11320	8100	7842	900	1318	418
12200	8600	8278	1000	1350	350
15950	10200	9556	1200	1423	223
18720	11800	10865	1400	1548	148
19420	13000	11935	1600	1709	109
23240	14500	13191	1800	1879	79
28810	16500	14753	2000	2055	55
29000	18000	16048	2200	2242	42
25140	19000	17139	2500	2533	33
28441	23000	21377	4000	4014	14

SECTION VII

SECTION VII

074148

TELEDYNE EXPLORATION COMPANY
P.O. BOX 36269
5825 CHIMNEY ROCK ROAD
HOUSTON, TEXAS 77036
713 666-2561

October 15, 1969

Magellan Petroleum Australia Limited
G. P. O. Box 455
Brisbane, Australia, 4001

Re: Data Processing Report
New South Wales Permit EPP (NSW) 1
Line M32S, Shot Points 1-535

Gentlemen:

The SDS 1010 digitally recorded field data were shipped by air freight to Teledyne Exploration Company at Houston, Texas, for complete processing thereof. An IBM 360 Model 44 was used in the data reduction, with field recording at 2 ms. and processing at 4 ms. sampling rates respectively.

Diagnostic edits were made of all field reels upon receipt. The program is a multi function package which includes routines for parity dropout and skew error recovery, as well as a listing of file numbers, constants, length of recordings, etc. This information was used as a check against the field operator's report of reel data content and in programming the data for demultiplexing. A 4 over 0 vertical composite, full dynamic range signal recovery and amplitude normalization were accomplished during the subsequent demult operation.

Autovels spaced at three mile intervals, constant velocity stacks, 100% continuous coverage profiles, and other available velocity control were all utilized in evaluating the applied velocities for proper normal moveout and stacking effects. A copy of the velocities used on the final presentation is attached to this report, however, the curve below the shallow reflector is considered speculative due to possible lack of section and/or no data. A study at SP486 suggests the refraction velocity of the shallow marker at that particular location to approximate 16,600'/sec. In addition, experimental curves were tabulated in which, with a fix on the early event,

074149

reflection velocities at a two-way time of 1.6 were varied from 9,000'/sec. to 15,000'/sec. in 1,000'/sec. increments. None of these runs afforded reliable or superior results over the velocity curve so submitted. A constant velocity test of 7,000'/sec. tended to enhance apparent multiple energy.

No static corrections were applied in processing the data.

The stacking program calculated reference coordinates for each geophone group and stacked all subsurface depth points falling within a selected coordinate span of 150'.

All data were deconvolved before NMO and stack using minimum phase inverse 100 point operators, individually designed from each trace and individually applied to that trace. Autocorrelation windows of 1.0 to 3.0 seconds and band limits of 14 - 36 were used in the deconvolution operator design.

The final stack and 100% sections were time-variant digitally filtered as follows: band pass 20 - 42 with a low-high slope of 12 and 36 db/octave respectively from 0 - 1.3 seconds and 14 - 34, sloped 12 and 36 db/octave, from .8 - 4.0 seconds. Analog filters of out - 1/100, to reduce sampling rate chatter, were used in plotting all presentations.

Respectfully submitted,

TELEDYNE EXPLORATION

R. B. Burckert

RBB/slr

SECTION VII B.

074150

FINAL REPORT
EAST GIPPSLAND BASIN AREA
TASMAN-BASS STRAIT MARINE
SEISMIC SURVEY
PERMITS: VIC/P4 and T/1P

for

MAGELLAN PETROLEUM SOUTHERN PTY. LTD.
7th FLOOR - ALEXANDRA CHAMBERS
201 WICKHAM TERRACE
BRISBANE, QUEENSLAND

by

GEOPHYSICAL SERVICE INTERNATIONAL
Party 852
120 Christie Street
St. Leonards, New South Wales

Assistant Party Chief : J. Gillard

November, 1969

GSI-709

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II	INTRODUCTION	2
III	SUMMARY AND CONCLUSIONS	3
IV	PROCESSING METHODS	4
V	MISCELLANEOUS	23

LIST OF PLATES

Plate	Description
1	FLOW DIAGRAM - PRELIMINARY 100% PROCESSING
2	FLOW DIAGRAM - FINAL 2400% PROCESSING
3	LOCATION MAP

I.

ABSTRACT

A detailed marine seismic survey was conducted in the East Gippsland Basin Area to delineate structural leads obtained from a previous survey.

The final processed record sections show good quality reflection data which ties satisfactorily to previous work.

II.

INTRODUCTION

A marine seismic survey of 106 line miles was conducted in the East Gippsland Basin Area (See Plate 3) by Teledyne Exploration Company for Magellan Petroleum Southern Pty. Limited, during the period 30th August, 1969 through 2nd September, 1969.

The area of investigation is situated within permits VIC P/4 and T/1P. This survey was designed to delineate structural leads obtained from previous survey work in the area.

The data processing were carried out by Geophysical Service International during the period October to November 1969.

The transcription of field data to TIAC format, vertical stack processing and record section displays were carried out on a Texas Instruments Seismic Digital Filtering and Display System Model 870.

All the other processing was carried out on a Texas Instruments Automatic Computer (TIAC) Model 827.

Key G.S.I. processing personnel were:

J. Gillard - Assistant Party Chief
B. Supangkat - Geophysical Engineer

Client Supervision was provided by Mr. A. Sabitay, of Magellan Petroleum Southern Pty. Limited.

III.

SUMMARY AND CONCLUSIONS

The reliability and quality of the processed records is generally good. The data ties satisfactorily with the previous seismic work in the area. Water depths are generally consistent but there are a few water-depth misties. These are due to the highly irregular water bottom, particularly in deep water, and its effect on recording a true vertical depth.

IV.

PROCESSING METHODS

A. Processing Sequence

Complete flow diagrams for preliminary (100%) and final (2400%) processing are shown on Plates 1 and 2.

B. Translation and Vertical Stack

The initial phase of processing accomplished the following:-

1. Transcribed the data to TIAC format.
2. Performed a vertical stack of two input records, thus reducing the 48-fold data to 24-fold vertically stacked data for all lines except Line M60T. Line M60T was vertically stacked using four input records, thus being reduced to 12-fold vertically stacked data.

All lines were transcribed and vertically stacked to a record time of 4.254 seconds at a sample rate of two milliseconds.

The resultant vertically stacked data in TIAC format was used as input data for all subsequent processing.

C. Edit - True Amplitude Recovery - TIAC Normal Moveout Correction

The vertical stack records were closely examined and all reversed or faulty traces were edited during the preliminary stages of the Normal Moveout routines. True amplitude recovery (TAR) was applied to all lines except Line M57T.

Loss of energy due to spherical divergence is a function of average velocity and time. A constant average velocity of 5000 feet per second was used to compute TAR functions for this area.

An initial gain of -14 db and a rate of 4 db per second from time 0 to 4.0 seconds were used to compute the exponential function for correction of inelastic attenuation losses. This exponential function determines the modulation level of the output data. The modulation level of data at any given time may be increased or decreased before output depending on the modulation level on tape when compared with the exponential function. The final result is data which is evenly modulated from start-of-record time to end-of-record time.

D. Velocity Analysis

Velocity control was obtained by using:

1. Single Fold (100%) processed records.

   From the velocity information used for previous processing in the area, a composite trial velocity was computed and applied for the single fold processing.

2. Moveout Scans

   A Moveout Scan is the application of negative time shifts approximating a normal moveout (NMO) correction curve to traces for one to 24/N consecutive common depth points and stacking of the traces. N is multiplicity of subsurface coverage. In the routine, 96 scans for 96 different NMO correction curves are performed for each group of common-depth-point (CDP) input traces, therefore outputting 96 stacked traces. Correlative reflections with NMO time equal to absolute values of time shifts for a scan are aligned, and the stacked reflection will be a maximum relative to corresponding stacked reflections on adjacent traces.

For each set of 96 scans, the following processes were performed:

a. Gathered a set of 24 CDP traces from input records.

b. Performed time-variant deconvolution on CDP traces.

c. Applied time-variant zero-phase filtering to CDP traces.

d. Computed shot-to-group distances.

e. Zeroed early parts of CDP traces.

f. Output the processed CDP traces on output tape.

g. Applied time shifts for 96 different Moveout Scans to CDP traces and summed the CDP traces after each application.

h. Picked reflection maxima on stacked traces for the set of Moveout Scans and computed implied RMS velocities from time shifts corresponding to reflection maxima.

Moveout Scans were processed at the following selected locations:

Line #	Shotpoints	
M52B	2	72
	21	86
	36	96
M53B	69	28
	60	12
	51	4
	43	
M54B	05	53
	11	70
	26	85
	41	
M60T	17	130
	39	162
	75	192
	110	

Evaluation of the single-fold processed records, in conjunction with the Moveout Scans yielded the final velocity functions.

The velocity functions used for 100% and 2400% processing are:

VELOCITY FUNCTION MA

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line	Sp to Sp	2400% processing Line	Sp to Sp
0	6690	M55T	all	M55T	1-94
1.000	8430	M56T	all	M56T	all
1.500	9110	M57T	all	M59T	36-64
2.000	9770	M58T	all		
4.254	12900	M59T	all		

VELOCITY FUNCTION MB

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	2400% processing Line Sp to Sp
0	6700		M55T 95-132
1.300	9400		M59T 19-35
1.950	10057		
4.254	12900		

VELOCITY FUNCTION MC

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	2400% processing Line Sp to Sp
0	6700		M59T IS8-18
1.200	9772		
1.950	10057		
4.254	12950		

VELOCITY FUNCTION MD

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	2400% processing Line Sp to Sp
0	6000		M52B 09-26
1.300	8795		M53B 63-IS8
1.900	9581		M54B 58-96
2.700	10877		
4.254	12600		

VELOCITY FUNCTION ME

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	2400% processing Line Sp to Sp
0	6000		M52B 27-44
1.250	8900		M53B 49-62
4.254	12800		M54B 44-57

VELOCITY FUNCTION MF

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	2400% processing Line Sp to Sp
0	6500		M52B 45-105
1.000	8867		M53B 07-48
1.500	9800		M54B 014-43
2.500	11300		
4.254	13000		

VELOCITY FUNCTION MG

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	5000		M60T 1-13
1.150	8600		
1.550	9160		
4.254	13000		

VELOCITY FUNCTION MH

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	5500		M60T 14-55
1.180	9600		M60T 92-145
1.725	10200		
4.254	13000		

VELOCITY FUNCTION MI

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	6800		M60T 56-91
1.100	9792		M60T 146-181
1.650	10000		
4.254	13000		

VELOCITY FUNCTION MJ

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	6500		M60T 181-216
.600	8600		
.900	10300		
1.100	10923		
1.750	11027		
4.254	13500		

VELOCITY FUNCTION MK

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	2400% processing Line Sp to Sp
0	7000	M52B all	
1.500	9800	M53B all	
2.500	11300	M54B all	
4.254	13000		

VELOCITY FUNCTION ML

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	6400	M60T 1-55	
1.000	9760		
1.500	9925		
4.254	13368		

VELOCITY FUNCTION MM

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	7600	M60T 56-120	
.700	9980		
1.350	10052		
1.600	10509		
4.254	14039		

VELOCITY FUNCTION MN

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	6800	M60T 121-185	
1.100	9792		
1.650	10000		
4.254	13438		

VELOCITY FUNCTION MO

Time in seconds	Average Velocity in Ft. per sec.	100% processing Line Sp to Sp	1200% processing Line Sp to Sp
0	7100	M60T 186-216	
.800	10044		
1.100	10923		
1.750	11027		
4.254	13781		

E. Frequency Analysis

Two filter analyses were made on Line M57T, from shotpoints 07-11 and 36-47. Frequency bands used in the analysis were 5-15, 10-20, 20-40 and 30-60 cps. Final time-varying filters were determined and applied according to the following schedule :

Line No.	S.P to S.P	20-60cps	10-50cps	10-50cps	8-40cps
M52B	09-105	1.100	1.300	1.900	2.100
M53B	76-46	1.048	1.148	1.600	1.800
	47-IS8	1.148	1.348	1.800	2.000
M54B	014-08	1.300	1.400	2.000	2.100
	07-47	1.200	1.300	1.800	2.000
	48-96	1.000	1.148	1.700	1.800
M55T	All	.400	.900	1.800	2.000
M56T	All	.400	.800	1.800	2.000
M57T	All	.400	.700	1.500	1.700
M58T	All	.400	1.000	1.600	1.800
M59T	64-10	.500	1.000	2.000	2.300
	9-IS8	.500	1.200	2.000	2.300
M60T	All	.700	.800	1.900	2.000

The general procedure when determining the above times was to apply the 20-60 cps filter from 0 time to a point immediately above the zone of interest. A 10-50 cps filter was then applied to a point immediately below the zone of interest. An 8-40 cps filter was then applied to end-of-record time.

F. Experimental Processing

1. Line M57T was processed in two ways. Firstly, by applying time-varying deconvolution filters before stacking, and secondly, applying the TVD filters after stacking. On the basis of this comparison, it was decided that data quality was enhanced to a greater extent by application of the TVD filters before stack. TVD was done before stack in production processing of all lines, excepting Line M60T. Line M60T was processed by applying TVD filters after stack.

2. Line M55T was reprocessed and displayed using a "mix". The mixing is done separately for each set of 24 stacked traces (1 stack record) and is accomplished as follows:

Mixed trace 1 = 150% of unmixed trace 1
Mixed trace 2 = unmixed trace 2 + 50% of unmixed trace 1
Mixed trace 3 = unmixed trace 3 + 50% of unmixed trace 2
Traces 4 through 12 follow similarly
Mixed trace 13 = unmixed trace 13 + 50% of unmixed trace 14
Traces 14 through 23 follow similarly
Mixed trace 24 = 150% of unmixed trace 24

No appreciable difference could be seen when comparing the record section with mix and the record section without mix.

G. Deconvolution

The gates used for the computation of time-varying deconvolution filters were selected so as to exclude excessively noisy portions of traces (front-end noise) and dead portions of traces.

The TVD parameters listed below are applicable to trace 1 of each processed record. Parameters used for trace 1 are applied to trace 2 after having been shifted in time by the amount of the data shift. Parameters for all other traces of a given record follow similarly. All times shown are in seconds.

Line M52T

	S.P to S.P 09-105
Number of filter points	34
Length of operator	.140
First gate start time	1.900
Second gate start time	2.600
First gate end time	3.300
Second gate end time	4.000
Data shift	-.052

Line M53T

	S.P to S.P 76-49	S.P to S.P 48-28	S.P to S.P 27-IS8
Number of filter points	34	34	34
Length of operator	.140	.140	.140
First gate start time	1.900	1.900	1.900
Second gate start time	2.600	2.600	2.600
First gate end time	3.300	3.300	3.300
Second gate end time	4.000	4.000	4.000
Data shift	-.060	-.048	-.039

LINE M54T

	S.P to S.P 014-18	S.P to S.P 19-43	S.P to S.P 44-96
Number of filter points	38	32	36
Length of operator	.153	.133	.146
First gate start time	1.700	1.000	1.800
Second gate start time	2.467	2.667	2.534
First gate end time	3.233	3.333	3.266
Second gate end time	4.000	4.000	4.000
Data shift	-.030	-.052	-.056

LINES M55T, M56T, M57T, M58T, M59T (used for all the above lines)

Number of filter points	36
Length of operator	.146
First gate start time	1.800
Second gate start time	2.534
First gate end time	3.266
Second gate end time	4.000
Data shift	-.050

LINE M60T

	S.P to S.P 1 - 216
Number of filter points	52
Length of operator	.206
First gate start time	.900
Second gate start time	1.934
First gate end time	2.966
Second gate end time	4.000
Data shift	0

H. Horizontal Stack

All lines excepting Line M60T were stacked 24-fold. Line M60T was stacked 12-fold. The following tabulations show first break suppression times for each trace. The first time given (in seconds) is the time at which trace 24 began to taper on for contribution purposes. 100% contribution of trace 24 was reached after 128 milliseconds. Each successive trace begins contribution at the given time and tapers on similarly.

Lines M52B, M53B, M54B

Times
.050
.050
.200
.484
.628
.772
.916
1.060
1.204
1.348
1.396
1.444
1.492
1.540
1.584
1.628
1.676
1.720
1.764

Lines M52B, M53B, M54 (cont.)

Times
1.808
1.856
1.904
1.952
2.000

Lines M55T, M56T, M58T,
and Line M59T (Sp's 61-10 only)

Times
.100
.190
.280
.370
.460
.550
.640
.730
.820
.910
1.000
1.090
1.180
1.270
1.360
1.450
1.540
1.630
1.720

Lines M55T, M56T, M58T, and Line M59T (Sp's 61-10 only) (cont.)

Times
1.810
1.900
1.990
2.080
2.170

Line M59T (Sp's 9-06 only)

Times
.200
.290
.380
.470
.560
.650
.740
.830
.920
1.010
1.100
1.190
1.280
1.370
1.460
1.550
1.640
1.730
1.820

Line M59T (Sp's 9-06 only)

(cont.)

Times
1.910
2.000
2.090
2.180
2.270

Line M60T

Times
.050
.050
.200
.484
.628
.772
.916
1.060
1.204
1.348
1.396
1.444
1.492
1.540
1.584
1.628
1.676
1.720
1.764
1.808
1.856
1.904
1.952
2.000

First break suppression times shown below for Line M57T differ in application from that applied to the other lines. Application of these suppression times is as follows:

> The first time shown is the time at which traces 24 and 23 of the input records begin contributing to the stack. The second time is the time at which traces 24 and 23 are contributing fully and is also the time at which traces 22 and 21 begin contributing. The third through twelfth times listed follow similarly for each set of two traces.

Line M57T

Times
.050
.200
.800
.930
1.060
1.190
1.320
1.450
1.580
1.710
1.840
1.970
2.100

I. Display of processed records

The final unfiltered stack records were displayed on paper using a constant gain factor. The finally filtered stack records were displayed on film using time-variant gain. The

time-variant gain applied is commonly referred to within G.S.I. as medium digital AGC. The display program applies medium digital AGC to a record by first amplifying the entire record to a chosen average level within a specified gate. The entire record is then divided into 300 millisecond gates. Amplitude within these gates are attenuated if they exceed the average amplitude within the originally specified gate. All data was displayed at a speed of 3.75 inches per second, - variable area - wiggly traces format, and zero bias. Gain was computed on one record of a line and applied to all records of that line.

Display parameters are as follows:

Line No.	Gain Gate	Gain in db applied
M52B	.800-2.000	31
M53B	.800-2.000	29
M54B	.800-2.000	31
M55T	.800-2.000	26
M56T	.800-2.000	24
M57T	.800-2.000	23
M58T	.800-2.000	23
M59T	.800-2.000	25
M60T	1.000-2.000	27

V.

MISCELLANEOUS

A. Water Depth and Water Replacement Static Corrections

Water depths ranged from 220 feet to 3350 feet. Field recorded fathograms were available for water depths up to 1800 feet. A correction of 9 feet was added to all water depths (obtained from fathograms) to correct for the depth of the transducer. Where water depths exceeded 1800 feet, the water depth values were computed from the water botton reflection time on trace 24 of each vertically stacked record by applying the following formulae:

$$Tx = \frac{Tw}{2}$$

$$T = \sqrt{Tx^2 - Ty^2}$$

$$Wd = Vw \sqrt{Tx^2 - Ty^2}$$

$$C = T - \frac{Wd}{Vr}$$

where:

Tw = Two-way water bottom reflection time read from trace 24 of vertical stack records.

Tx = One-way time to water bottom

Ty = One-way horizontal travel time from energy source to a point mid-way between energy source and group 24.

T = One-way vertical time to water bottom.

Vw = Water velocity = 4850 feet per second.

Wd = Water depth.

Vr = Water replacement velocity = 7000 feet per second.

C = One-way static correction for replacement of water layer.

Travel times through water were computed from known water depths (fathograms) and compared with travel times obtained from vertically stacked records. Times obtained each way at corresponding locations tied satisfactorily.

The total water replacement static correction applied to a given data trace is the C computed for the shot location plus the C computed for the receiver location. In addition, static corrections are also applied to each trace to adjust for the depth of the energy source and the depth of the geophones.

B. Static Correction for Start-of-Scan

Production transcription was commenced at start-of-scan. Experimental comparison of records transcribed with Time 0 at start-of-scan and records transcribed with Time 0 at time break showed that the time break lagged start-of-scan by 108 milliseconds.

This 108 milliseconds static correction was applied during the production vertical-stack process.

C. Trace Equalization

The following tabulation shows the time gates (in seconds) used for computing trace equalization scalers:

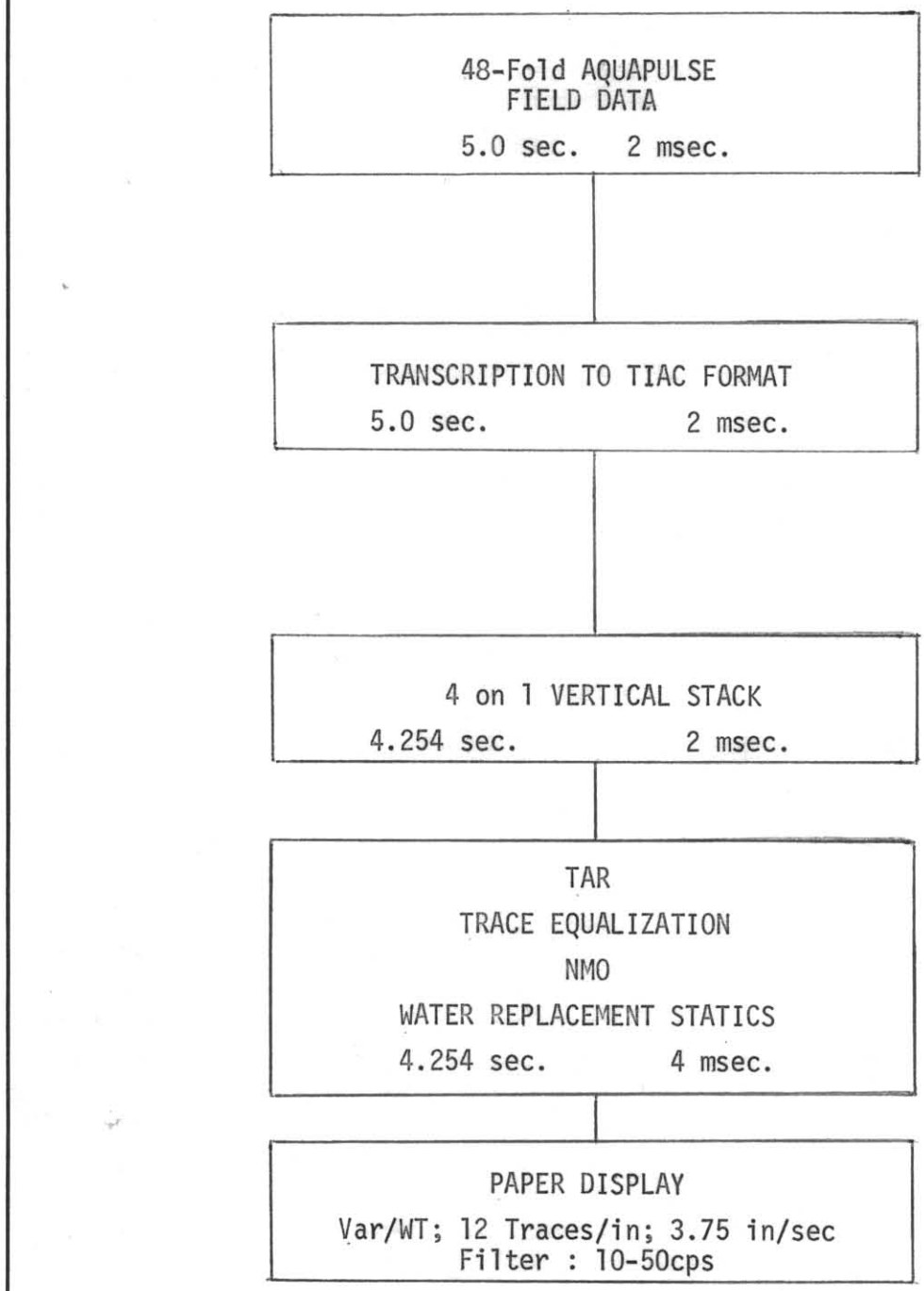
Line No.	Time	Sp to Sp
M52B	2.000-3.000	all
M53B	2.100-3.200	all
M54B	1.700-3.200	014-18
	2.000-3.200	19-43
	1.800-3.000	44-96
M55T	1.500-2.500	all
M56T	1.500-2.500	all
M57T	1.600-2.600	all
M58T	1.500-2.500	all
M59T	1.800-2.800	all
M60T	1.800-3.000	all

Respectfully Submitted,
GEOPHYSICAL SERVICE INTERNATIONAL

J. GILLARD,
Assistant Party Chief.

Approved

K. GRAYBILL,
Party Chief.



MAGELLAN PETROLEUM SOUTHERN PTY. LTD.

FLOW DIAGRAM

PRELIMINARY 100% PROCESSING

GEOPHYSICAL SERVICE INTERNATIONAL
PARTY 852

PLATE 1

GSI-709



48-Fold AQUAPULSE
FIELD DATA
5.0 sec. 2 msec.

TRANSCRIPTION TO TIAC FORMAT
5.0 sec 2 msec.

4 on 1 VERTICAL STACK
4.254 sec. 2 msec.

TAR
TRACE EQUALIZATION
NMO
WATER REPLACEMENT STATICS
4.254 sec. 4 msec.

DECONVOLUTION
4.254 sec. 4 msec.

FIRST BREAK SUPPRESSION
24-Fold STACK
TIME VARYING FILTERING
4.254 sec. 4 msec.

FILM DISPLAY
Var/WT; 12 Traces/in; 3.75 in/sec.
Time-Variant Gain

PAPER DISPLAY
Var/WT; 12 Traces/in; 3.75 in/sec.
FILTER : OUT-OUT

MAGELLAN PETROLEUM SOUTHERN PTY. LTD.

FLOW DIAGRAM

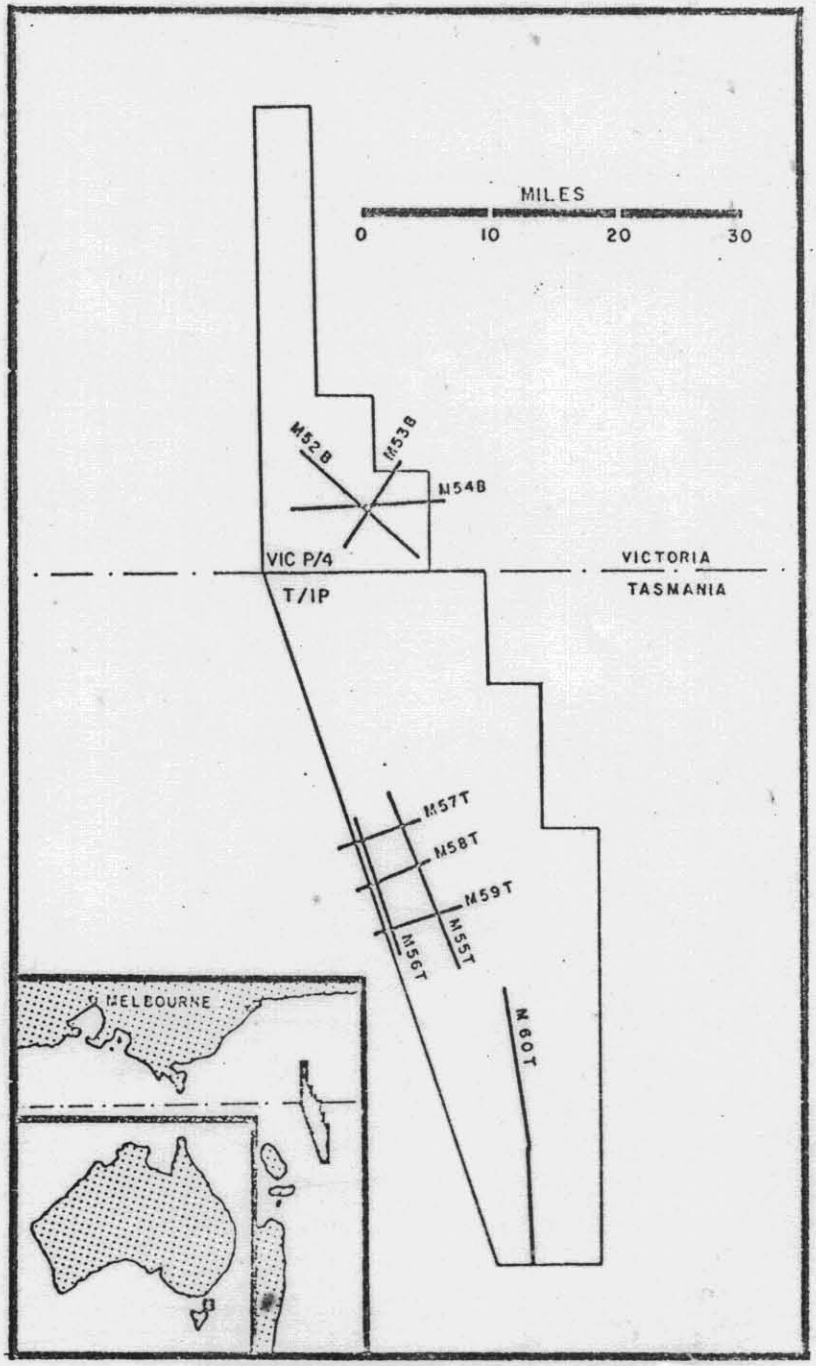
FINAL 2400% PROCESSING

GEOPHYSICAL SERVICE INTERNATIONAL PARTY 852

PLATE 2

GSI-709

074180



MARINE SEISMIC SURVEY

TASMAN-BASS STRAIT

CDP PROCESSED LINES

NOVEMBER 1969

PLATE 3

5 cm

SECTION VIII
~~GS-M-05-3~~
~~PART 6~~

074181

ADDENDUM TO FINAL REPORT

TASMAN - BASS STRAIT MARINE SEISMIC PROFILER AND MAGNETIC SURVEY

MAGELLAN PETROLEUM AUSTRALIA LIMITED

May, 1970

A. Sabitay

TABLE OF CONTENTS

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SECTION I

SUMMARY AND CONCLUSIONS

Thirty five miles of common depth point (CDP) detail reflection recordings and 108 miles of reconnaissance single channel data were obtained within the non-subsidy area of the Gippsland Basin during the Tasman - Bass Strait Marine Profiler and Magnetic Survey. These data were recorded on August 29th and 30th, 1969 by Teledyne Exploration Company under contract to Magellan Petroleum Australia Limited. The CDP data were digitally processed by Geophysical Service International and all of the data interpreted by Magellan's geophysical staff.

The purpose of the work was to define a structural lead mapped in the East Gippsland Seismic Survey, June, 1969, and to extend knowledge of section thickness and basin configuration at the eastern boundary of the Gippsland Basin. The first objective was to be accomplished by shooting and processing three detail air-gun lines and the second by several reconnaissance sparker profiles.

Definition of the structural lead (Feature IV) was accomplished although the sought closed anticline could not be confirmed. Instead a possible faulted nose having about 100 feet of closure over an area of three square miles was delineated on the "Top of the Latrobe Complex" mapping horizon.

Another possible structure was defined about five miles northeast of the southwest corner of Permit Vic/P4 with 100 feet of vertical closure over about four square miles. An absent or at best thin sequence of Latrobe rocks are postulated on the anticline.

The reconnaissance work confirmed a previously mapped small structure in Vic/P3. Continuance of sedimentary section seaward of Vic/P3 and Vic/P4 was found but no further knowledge was gained concerning the Gippsland Basin's eastern boundary.

These remarks apply solely to that area within a radius of fifty miles from Kingfish A-1 and Halibut A-1 referred to as the "non-subsidy" part of the Tasman - Bass Strait Seismic Survey.

SECTION II

INTRODUCTION

A. Report Composition

This addendum to the Final Report of the "Tasman - Bass Strait Seismic Profiler and Magnetic Survey, February, 1970" describes the interpretation of data collected within the non-subsidy area of the Gippsland Basin. The reference final report was produced in two versions, one for the Bureau of Mineral Resources and one for all other recipients. The BMR version had all references to the non-subsidy data extracted whereas the "other" version described collection and computer processing of both subsidy and non-subsidy data.

As in the final report, the results of the "sparker" (reconnaissance) and "air-gun" (detail) work are separately reported herein. Reconnaissance results are illustrated on three 1:250,000 scale maps of the East Gippsland Basin Area (Plates 6,7 and 8 of the Tasman - Bass Strait report). The maps submitted with this addendum replace Plates 6,7 and 8 of the subsidy report. Three structure contour maps and an isopach on a scale of 1:50,000 are submitted to illustrate the results of the detail work done in the non-subsidy area. These have Plate No.'s 17,18 and 19.

B. Objectives

In addition to the pertinent objectives described in the final report, the detail work done in the non-subsidy area was designed to confirm a speculative structure (Feature IV) defined in the East Gippsland Marine Seismic Survey, July, 1969. The reconnaissance work was programmed to add to Magellan's knowledge of Gippsland Basin regional geology

through definition of section thickness, depth to magnetic basement and general geologic attitudes of reflecting horizons.

C. Non-Subsidy Data

The field data included in this addendum consists of 108 miles of "sparker" reconnaissance profiling and 35 miles of "air-gun" detail CDP lines. These lines were obtained in Permits Vic/P3 and Vic/P4 within a 50 mile radius of Kingfish A-1 and Halibut A-1 wells in the Gippsland Basin. Shooting dates were August 29th and 30th, 1969.

SECTION III

INTERPRETATION

A. Reconnaissance Data

The data interpreted in this sub-section includes Lines M49A, M50B, and M51B. Little additional information was gained from these lines on the section thickness and structural attitudes of the reflection section in the non-subsidy area.

In Permit Vic/P3 multiples obscured the sought after basement reflector. However, a previously defined structural high was clearly seen near SP115, Line M49A2.

The water depths between Vic/P3 and Vic/P4 were too deep to permit recording of a basement reflector with the time scale used. On Line M50B3 a possible basement reflector may be present from 2.4 seconds at the northwest end and deepening southeastward. The additional data in Vic/P4 (M51B) confirmed general northeast dip and only gradually thinning section in this direction.

Examination of the magnetic data for the reconnaissance lines revealed generally deep magnetic basement. One speculative depth determination was available near SP65, Line M50B2 of 9,600 feet depth below sea level.

The foregoing results are illustrated by:

Plate 6 - Water Depths: 1:250,000

Plate 7 - Reflection Time to Basement: 1:250,000

Plate 8 - Time Interval (Water Bottom to Basement): 1:250,000

B. Detail Data

1) General

Lines M52B, M53B and M54B were integrated with previous CDP lines in Vic/P4 near the Tasmanian boundary for the following discussion. Three depth maps were compiled illustrating:

Plate 17 - Structure Contours, Horizon "B" (near Top Latrobe Complex); 1:50,000

Plate 18 - Structure Contours, Horizon "C" (near Base Latrobe Complex); 1:50,000

Plate 19 - Isopachous Contours, Horizons "B" to "C"; 1:50,000

Depth conversions to derive these maps were made as described in the final report for the East Gippsland Seismic Survey, June, 1969 (Page 42).

2) Record Quality

The data, when compared with the previous East Gippsland work, is reliable. Fair to good reflections were obtained to 1.5 seconds and fair to poor events can be discontinuously followed to 2.0 seconds. The southeastern five miles of Line M29B were repeated on the northwestern end of Line M52B. These results are nearly identical. Several faults are thought to cross the new lines and their effects (discontinuous reflections, diffractions, and spurious events) cause the main quality problems on the processed time sections.

3) Structure and Stratigraphy

Line M52B confirmed the speculative turnover mapped as Feature IV in the East Gippsland report. The crest has

been interpreted at SP42 on Plate 17, Latrobe Map. Southwest dip on the feature, necessary to complete anticlinal closure, was not found on Line M53B. Consequently, Feature IV at Top Latrobe level is downgraded to a possible faulted nose with about 100 feet of closure against the fault involving an area of about three square miles.

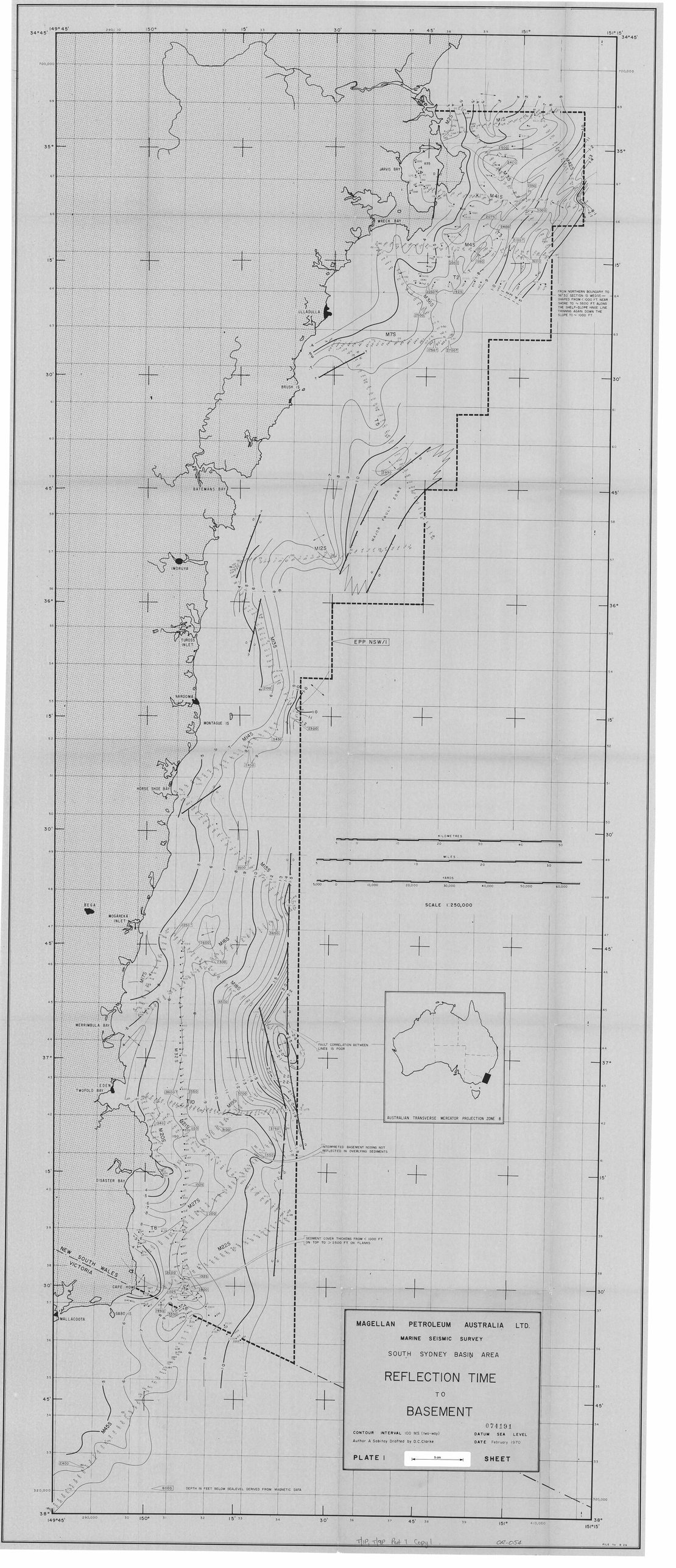
A possible closed anticline has been mapped just south of the west end of Line M54B about five miles northeast of the southwest corner of Permit Vic/P4. This feature, at Top Latrobe level, may have 100 feet of closure in an area of about four square miles. The isopach shows less than 400 feet of Latrobe Complex section and there is the possibility that the Latrobe sediments are absent in the area.

The southeast - northwest fault system in the vicinity of Line M30B remains poorly defined. Several fault crossings were located on the new work but their correlation with old work fault crossings is not clear.

Basement (?) (or Base of the Latrobe Complex) is shown to be a rough surface on Plate 18. This map is dominated by the ridge generally paralleling Line M31B and having five or more culminations. On the north flank of the ridge the poorly defined southeast - northwest fault system is shown with throws down to the northeast. Further northeastward a very rough area is mapped dominated by highs in the southeast and a large syncline in the northwest. The contouring, north of and within the fault system, is highly speculative.

The rough surface of the Basement (?) controls the Isopach of the Latrobe Complex shown in Plate 19. Thin or absent Latrobe is seen on the previously mentioned central ridge. North of the fault system thin section is found on basement highs and thick section in lows, as expected.

During work on this part of Vic/P4 an impression was gained that channel scouring, localized by the northwest - southeast fault system, may have been active north of the basement ridge. This possibility deserves further study because the presence of pre-Miocene channels or submarine canyons would create erosional structure possibilities. An area defined by Lines M8B, M9B and M28B and M29B would become a prospective lead if a channel is confirmed where indicated.



T/P, T/9P Part 1 Copy 1

OR-054

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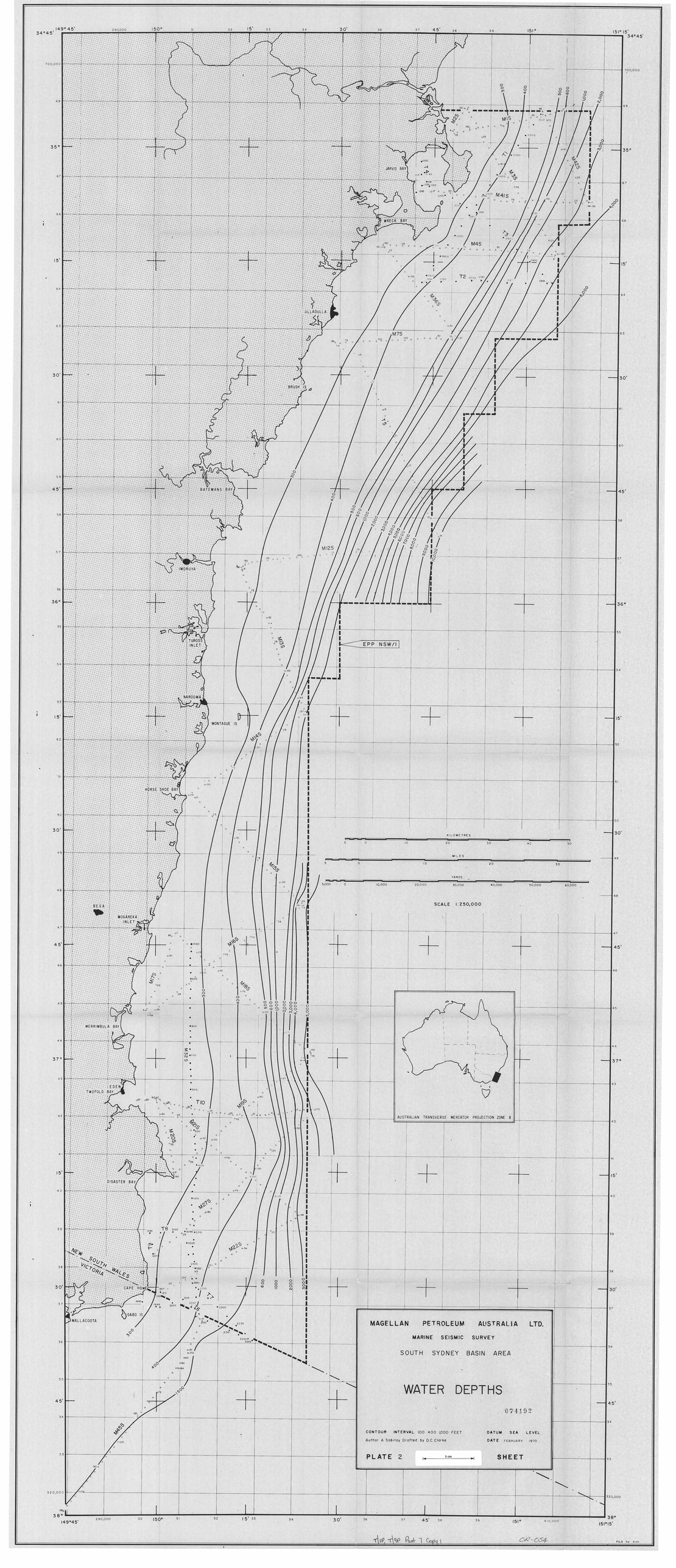
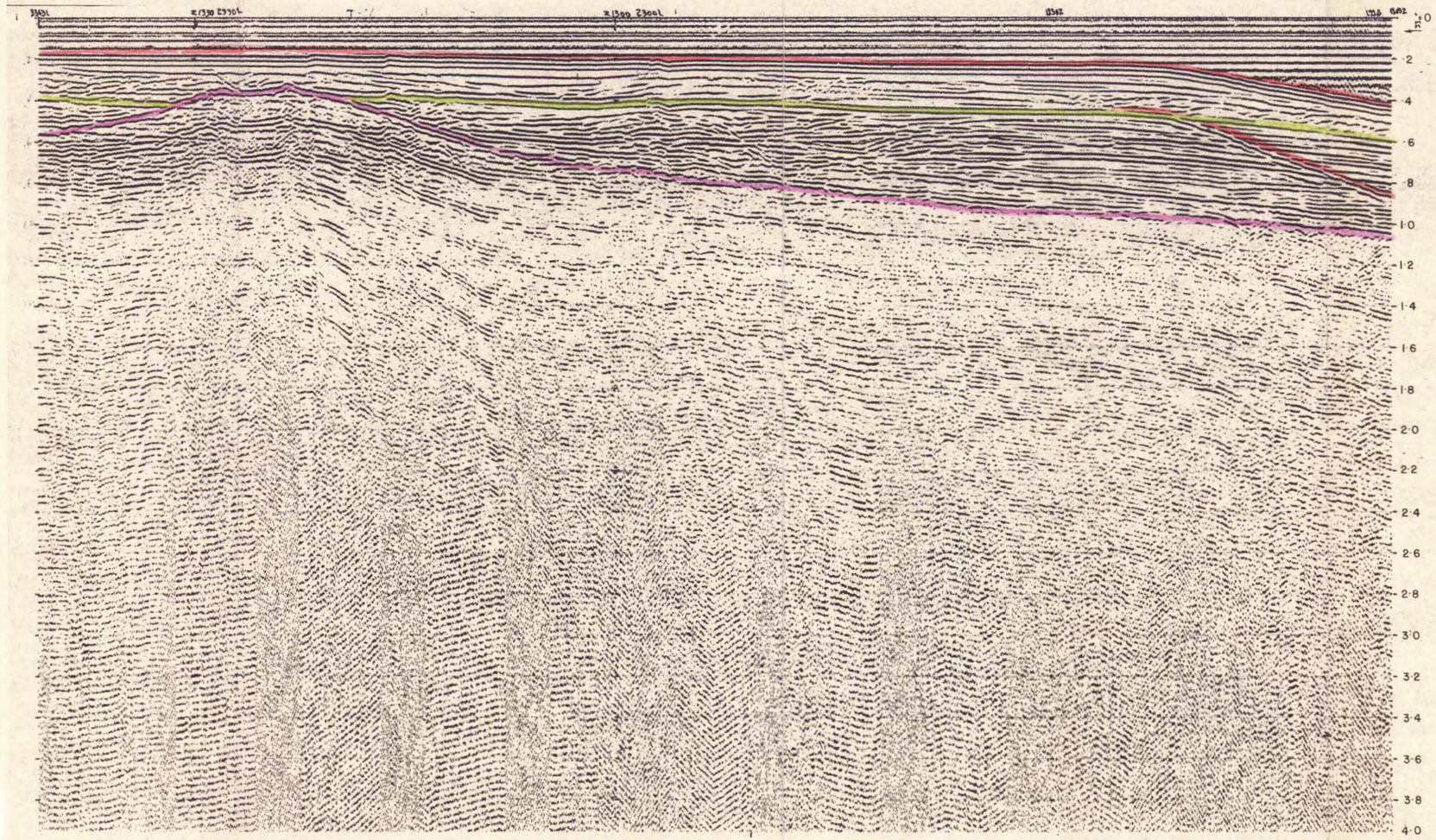


T/1P, T/9P Part 7 Copy 1

CR-054

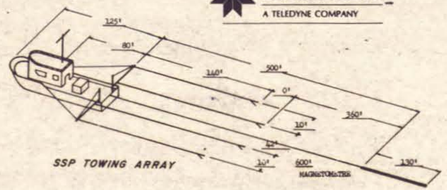
FILE No. 026



5 cm

T-7

TELEDYNE EXPLORATION
A TELEDYNE COMPANY



SSP TOWING ARRAY

LINE T-7, 8, 9 (DIR. AS INDICATED)
CLIENT MAGELLAN PETROLEUM AUSTRALIA
PROSPECT N.S.W. LEP-1
DATE 142-631
W.O. NO. 20 AUGUST 1969

POSITIONING RADAR, SHORAN
WEATHER BEAUFORT 3
MOTOR VESSEL TELEDEX IV
VESSEL SPEED 7 KNOTS APPROX.
FIX INTERVAL 30 MINUTES

PLATE 3

ACOUSTIC SOURCE SSP 160KJ
SOURCE DEPTH 25 FEET
FIRING RATE 4 SECONDS
HYDROPHONE TYPE AND SER. NO. MP-7 WELL LOG S/N F-23
HYDROSTREAMER DEPTH 35 FEET
TOWING NOISE 70 MICROVOLTS

FACSIMILE RECORDER TYPE RAYTHEON PER-196-A-2
TRACES/INCH 45
AMPLIFIER TYPE GS 111
FILTERS HI 47-1 LO 20-2
AMP. 1 IS USED AS THRESHOLD CH.
AMP. 2 IS USED AS EXPANDER CH. (AGC)
AMPS. 3&4 ARE USED WITH TAPE, IF TAPE IS USED
INPUTS TO 1&2 ARE PARALLEL
INPUTS TO 3&4 ARE PARALLEL
SIGNAL CONDITIONER MASTER GAIN IS 100 MICROVOLTS
PRESUPPRESSION ~~15V~~ IS NOT USED

TAPE RECORDER TYPE AMPEX SP300 1/2 INCH. S/N 1903
TAPE FILTERS 125-1 16-2
TAPE SPEED 3.75 IPS
TAPE NO. D-577 & 578

REMARKS: 1205 STARTED ON LINE T-7, (330°), TAPE D-577 @ 210 REVS.
L2343 Z1343 CHANGED THE COURSE OF THE VESSEL TO 350°. TAPE D-577 @ 708 REVS.
L0043 RESUMED RECORDING ON LINE T-7, TAPE D-577 @ 750 REVS.
Z1443 COMPLETED LINE T-7, TAPE D-577 @ 1002 REVS.
L0044 Z1444 STARTED ON LINE T-8, (270°), TAPE D-578 @ 0 REVS. SHOT POINT No 1.
L0128 Z1528 COMPLETED LINE T-8, SHOT POINT No 14. TAPE D-578 @ 304 REVS.
STARTED ON LINE T-9, (160°), TAPE D-578 @ 360 REVS.
L0130 Z1530 FIRST SHOT POINT No31, TAPE D-578 @ 372 REVS.
L0150 Z1550 COMPLETED LINE T-9, TAPE D-578 @ 482 REVS. SHOT POINT No 44.

CREW NO. MS 631
OPERATORS INITIALS R.S. R.S.
CLIENT REPRESENTATIVE MIKE [illegible]
CREW CHIEF W.B. SPRINGER

C74193

T/1P, T/9P Part 7 Copy 1

OR-054

T/P, T/GP Part 7 Copy 1

OR-054

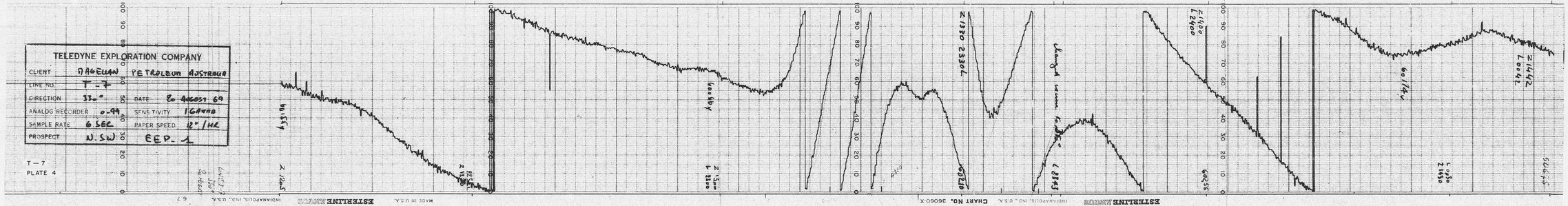
074194

TELEDYNE EXPLORATION COMPANY

CLIENT	MAGELLAN PETROLEUM AUSTRALIA		
LINE NO.	T-7	DATE	20 AUGUST 69
DIRECTION	330°	SENSITIVITY	1 GAMMA
ANALOG RECORDER	0-99	PAPER SPEED	12"/HR
SAMPLE RATE	6 SEC.		
PROSPECT	W.SW EEP. 1		

T – 7
PLATE 4

5 cm

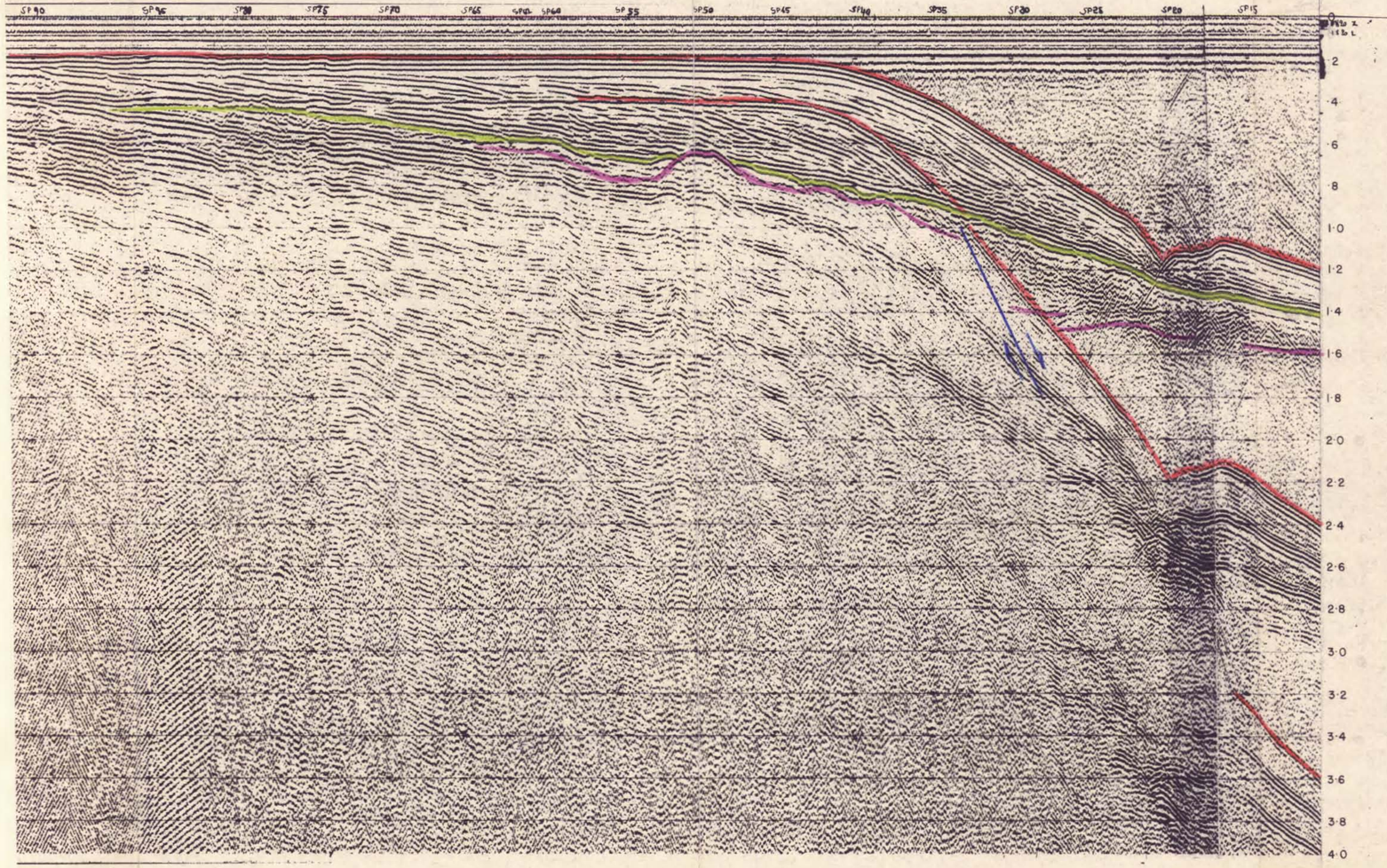

ESTERLINE ANGUS
INDIANAPOLIS, IND., U.S.A.
CHART NO. 36060-X
MADE IN U.S.A.
2 1/4"
2 1/8"
2 1/4"
2 1/8"
2 1/4"
2 1/8"

T/1P, T/9P Part 7
Copy 1

M-4S

TELEDYNE EXPLORATION
A TELEDYNE COMPANY

074195



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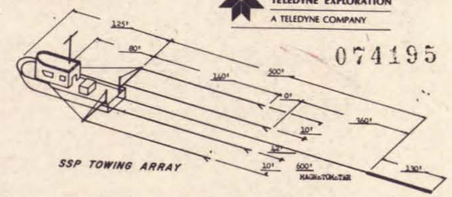


SSP TOWING ARRAY

PLATE 5

LINE M-1S, 2S, 3S, 4S, 36S (DIR. AS INDICATED)
CLIENT MAGELLAN PETROLEUM AUSTRALIA
PROSPECT N.S.W. EXP-1
DATE 17 AUGUST 1969
W.O. NO. 142-631

POSITIONING SHORAN
WEATHER BEAUFORT 5
MOTOR VESSEL TELEDEX IV
VESSEL SPEED 10 KNOTS APPROX.
FIX INTERVAL 5 SHOT POINT

ACOUSTIC SOURCE SSP 160 KJ
SOURCE DEPTH 25 FEET
FIRING RATE 4 SECONDS
HYDROPHONE TYPE AND SER. NO. MP-7 WELL LOG S/N Z-23
HYDROSTREAMER DEPTH 35 FEET
TOWING NOISE 80 MICROVOLTS

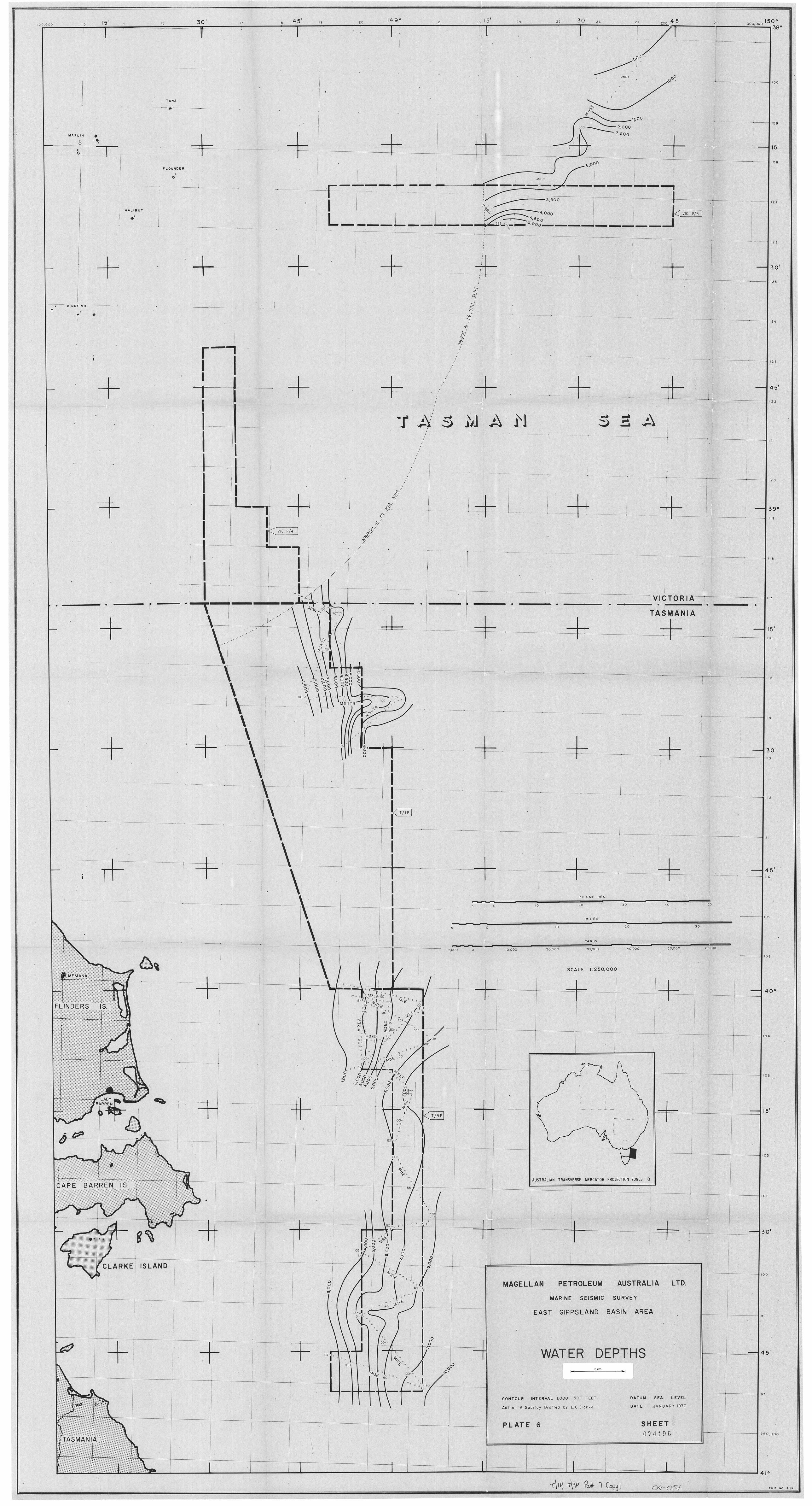
FACSIMILE RECORDER TYPE RAYTHEON PER-196-A-2
TRACES/INCH 45
AMPLIFIER TYPE GS 111
FILTERS HI 47-1 LO 20-2
AMP. 1 IS USED AS THRESHOLD CH.
AMP. 2 IS USED AS EXPANDER CH. (AGC)
AMPS. 3&4 ARE USED WITH TAPE, IF TAPE IS USED
INPUTS TO 1&2 ARE PARALLEL
INPUTS TO 3&4 ARE PARALLEL
SIGNAL CONDITIONER MASTER GAIN IS 100 MICROVOLTS
PRESUPPRESSION IS NOT USED

TAPE RECORDER TYPE AMPEX SP300 1/2 INCH. S/N 1093
TAPE FILTERS 125-1 16-2
TAPE SPEED 3.75 IPS
TAPE NO. D-560 THRU 563

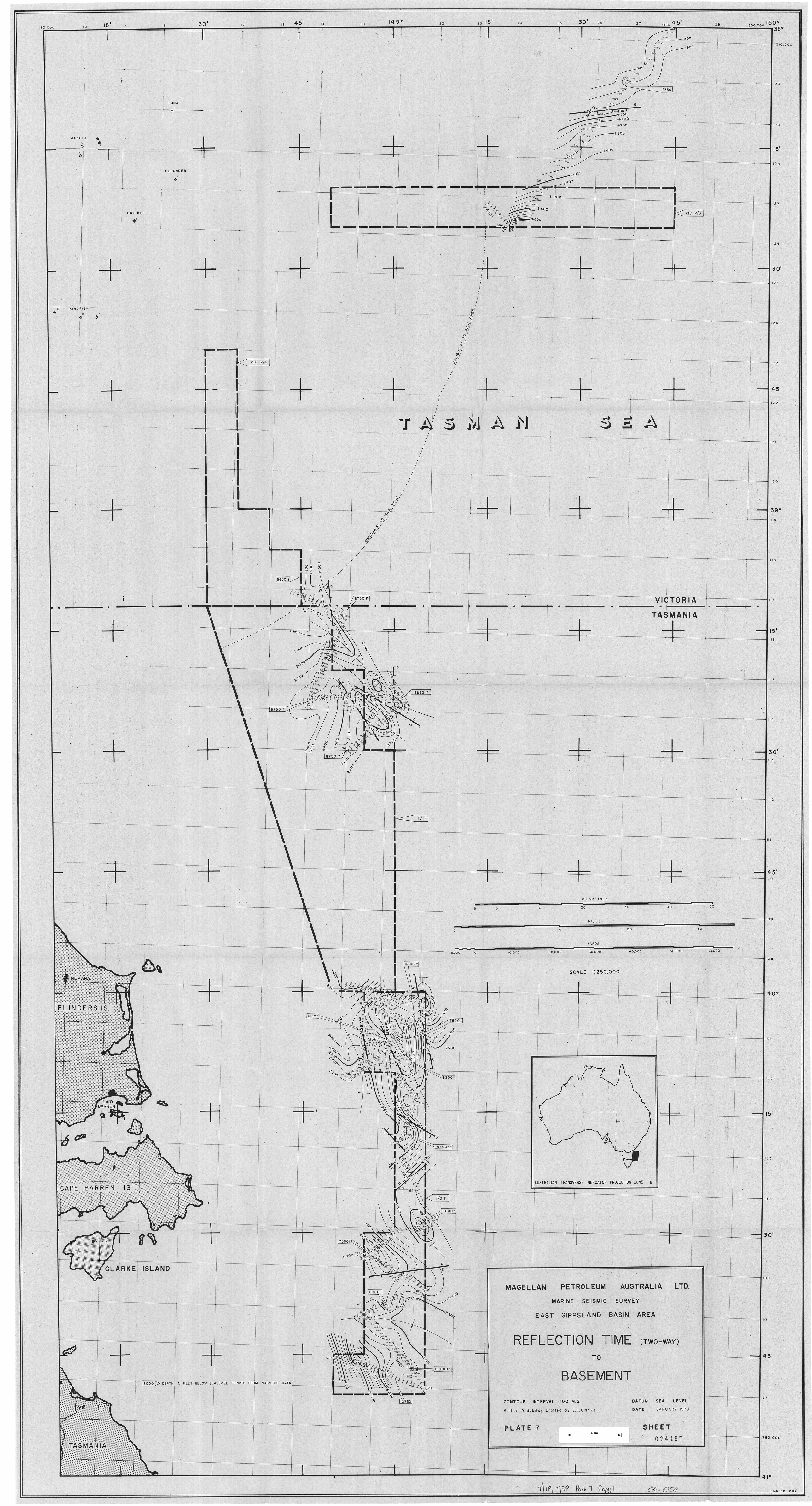
REMARKS: Z0820 STARTED ON LINE M-1 S. (240°), TAPE D-560 @ 180 REVS.
L 0151 Z0955 COMPLETED LINE M-1 S. TAPE D-560 @ 699 REVS. SHOT POINT No 113.
STARTED ON LINE M-2 S. (330°), SHOT POINT No 4.
L 0015 Z1015 COMPLETED LINE M-2 S. SHOT POINT No 25. TAPE D-560 @ 803 REVS.
STARTED ON LINE M-3 S. (150°), SHOT POINT No 1.
L 0101 Z1112 CHANGED TO TAPE D-561.
L 0140 Z1140 STOPPED SHOOTING TO REPLACE A BLOWN FUSE ON BANK #4. TAPE D-561 @ 185 REVS.
L 0194 Z1142 RESUMED SHOOTING ON LINE M-3 S. TAPE D-561 @ 203 REVS.
L 0211 Z1255 COMPLETED LINE M-3 S. TAPE D-561 @ 606 REVS. SHOT POINT No 137.
STARTED ON LINE M-4 S. (270°), SHOT POINT No 2.
L 0016 Z1420 SLOWED THE VESSEL TO 5 KNOTS. TAPE D-561 @ 979 REVS.
L 0081 Z1425 CHANGED TO TAPE D-562.
L 0151 Z1551 COMPLETED LINE M-4 S. SHOT POINT No 140. TAPE D-562 @ 509 REVS.
L 0153 Z1553 STARTED ON LINE M-36 S. (145°), SHOT POINT No 131. TAPE D-562 @ 524 REVS.
L 0130 Z1710 SPEEDED UP TO 10 KNOTS. TAPE D-562 @ 871 REVS.
L 0151 Z1737 CHANGED TO TAPE D-563.
L 0401 Z1805 COMPLETED LINE M-36 S. TAPE D-563 @ 200 REVS. SHOT POINT No 37.

CREW NO. MS 631
OPERATORS INITIALS R.S. M.S.
CLIENT REPRESENTATIVE SAM PERS, MIKE ROSE
CREW CHIEF W.B. SPRINGER

OR-054



T/1P, T/9P Part 7 Copy 1 CR-054



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FILE NO. 825

TASMAN SEA

VICTORIA

TASMANIA

TUNA

MARLIN

FLOUNDER

HALIBUT

KINGFISH

VIC/P3

VIC/P4

T/1P

T/9P

MEMANA

FLINDERS IS.

LADY BARREN I.

CAPE BARREN IS.

CLARKE ISLAND

TASMANIA

FAULTS CUT NEARLY ENTIRE SEDIMENTRY SECTION. STRONG BASAL TERTIARY EVENT CAN BE CORRELATED ACROSS FAULTS

FORESET BEDDING EVIDENT IN TOP 3000 FT OF SECTION

PREDOMINANTLY FLAT LYING TERTIARY SECTION OVERLYING UNCONFORMABLE PRE-TERTIARY FOLDED & INTRUDED SECTION

STRONG CONVERGENCE OF TERTIARY? BEDS ON LARGE BASEMENT HIGH

ABOUT 1500 FT OF TERTIARY? SECTION ON STRUCTURES CREST THICKENING TO ~3000FT ON FLANKS.

FORESET BEDDING DIPPING N.E. IN SHALLOW TERTIARY SECTION

POSSIBLE REEFS.

TERTIARY BEDS THIN SOUTHWARD & BECOME DISTORTED & DISCONTINUOUS

TERTIARY THICKS SOUTHWARD TO 2400 FT. FORESET BEDDING EVIDENT IN TOP 2000 FT

~2000-2500 FT OF TERTIARY BEDS ON CREST OF HIGH BASEMENT TOPOGRAPHY

HALIBUT A1 50 MILE ZONE

GRIFFITH A1 50 MILE ZONE

KILOMETRES 5 0 10 20 30 40 50

MILES 5 0 10 20 30

YARDS 5,000 0 10,000 20,000 30,000 40,000 50,000 60,000

SCALE 1:250,000

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION ZONE 8

MAGELLAN PETROLEUM AUSTRALIA LTD.

MARINE SEISMIC SURVEY

EAST GIPPSLAND BASIN AREA

TIME INTERVAL MAP BETWEEN WATER BOTTOM & BASEMENT

074198

CONTOUR INTERVAL .250 SEC. (TWO-WAY)

DATUM SEA LEVEL

Author A Sabitov Drafted by D.C.Clarke

DATE FEBRUARY 1970

5 cm

PLATE 8

T/1P, T/9P Part 1 Copy!

SHEET

GR-054

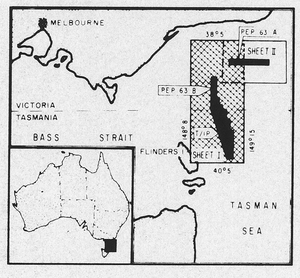
FILE NO 825

VICTORIA

TASMANIA

T/1P

FLINDERS ISLAND



AUSTRALIAN TRANSVERSE MERCATOR PROJECTION 10,000 YARD GRID

ZONE 8

KILOMETRES 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26

MILES 1 0 2 4 6 8 10 12 14 16 18

YARDS 5,000 0 5 10 15 20 25 30 35,000

SCALE 1:100,000

DATA ARE FEET BELOW SEA LEVEL

SHOT POINTS

- MAGELLAN PETROLIEUM SOUTHERN PTY LTD (1968)
- ESSO EXPLORATION & PRODUCTION AUSTRALIA INC.
- SHELL DEVELOPMENT (AUSTRALIA) PTY. LTD.
- MAGELLAN PETROLIEUM (1969) — C.D.P.
- MAGELLAN PETROLEUM — SPARKER RECONNAISSANCE (1969)

MAGELLAN PETROLEUM AUSTRALIA LTD.

MARINE SEISMIC SURVEY

EAST GIPPSLAND BASIN AREA

HORIZON A

(WITHIN MIOCENE)

5 cm

074199

CONTOUR INTERVAL 250 FEET DATUM SEA LEVEL

AUTHOR K. GRAYBILL DATE JUNE 1969

GEOPHYSICAL SERVICE INTERNATIONAL

REVISED: AL SABITAY DRAFTED: D C CLARKE FEBRUARY 1970

PLATE 9 **SHEET I**

T/1P, T/9P Part 7 Copy 1 OR-054

VICTORIA

TASMANIA

BASEMENT

BASEMENT

BASEMENT

T/1P

CONTOURS FROM PREVIOUS SUBSIDIZED SEISMIC SURVEYS

FLINDERS ISLAND

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION 10,000 YARD GRID

ZONE 8

KILOMETRES 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26

MILES 1 0 2 4 6 8 10 12 14 16 18

YARDS 5,000 0 5 10 15 20 25 30 35,000

SCALE 1 : 100,000

DATA ARE FEET BELOW SEA LEVEL

SHOT POINTS

- ○ MAGELLAN PETROLEUM SOUTHERN PTY. LTD. (1968)
- • ESSO EXPLORATION & PRODUCTION AUSTRALIA INC.
- · SHELL DEVELOPMENT (AUSTRALIA) PTY. LTD.
- • MAGELLAN PETROLEUM (1969) — C.D.P.
- ○ MAGELLAN PETROLEUM — SPARKER RECONNAISSANCE (1969)

MAGELLAN PETROLEUM AUSTRALIA LTD.

MARINE SEISMIC SURVEY

EAST GIPPSLAND BASIN AREA

HORIZON B

(TOP LATROBE COMPLEX)

5 cm

C74200

CONTOUR INTERVAL 250 FEET — DATUM SEA LEVEL

AUTHOR K. GRAYBILL — DATE JUNE 1969

GEOPHYSICAL SERVICE INTERNATIONAL

REVISED : AL SABITAY DRAFTED: D.C. CLARKE — FEBRUARY 1970

PLATE 10 — SHEET 1

T/1P, T/1P Part 1 Copy 1 OR-054

VICTORIA

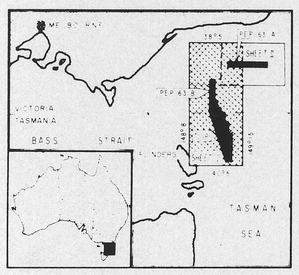
TASMANIA

T/1P

T/9P

CONTOURS FROM PREVIOUS SUBSIDIZED SEISMIC SURVEYS

FLINDERS ISLAND



AUSTRALIAN TRANSVERSE MERCATOR PROJECTION 10,000 YARD GRID

ZONE 8

KILOMETRES 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26

MILES 1 0 2 4 6 8 10 12 14 16 18

YARDS 5,000 0 5 10 15 20 25 30 35,000

SCALE 1 : 100,000

DATA ARE FEET BELOW SEA LEVEL

SHOT POINTS

- ○ MAGELLAN PETROLEUM SOUTHERN PTY. LTD. (1968)
- • ESSO EXPLORATION & PRODUCTION AUSTRALIA INC.
- · SHELL DEVELOPMENT (AUSTRALIA) PTY. LTD.
- • MAGELLAN PETROLEUM (1969) — C.D.P.
- ○ MAGELLAN PETROLEUM — SPARKER RECONNAISSANCE (1969)

MAGELLAN PETROLEUM AUSTRALIA LTD.

MARINE SEISMIC SURVEY

EAST GIPPSLAND BASIN AREA

HORIZON C

(BASEMENT)

074201

5 cm

CONTOUR INTERVAL 500 FEET

DATUM SEA LEVEL

AUTHOR K. GRAYBILL

GEOPHYSICAL SERVICE INTERNATIONAL

REVISED: AL SABITAY DRAFTED: D.C. CLARKE

DATE JUNE 1969

FEBRUARY 1970

PLATE II

SHEET I

OR-054

T/1P, T/9P Part 1 Copy 1

VICTORIA

TASMANIA

T/1P

FLINDERS ISLAND

50 MILE RADIUS FROM MACKERFIELD

M54T1 M54T2 M54T3 M54T4

M15T M16T M17T M18T M19T M20T M21T M22T M23T M24T M25T M26T M27T M28T M29T M30T M31T M32T M33T M34T M35T M36T M37T M38T M39T M40T M41T M42T M43T M44T M45T M46T M47T M48T M49T M50T M51T M52T M53T M54T M55T M56T M57T M58T M59T M60T

EC 58 EC 59 EC 60 EC 6 EC 62 EC 63 EC 64 EC 65 EC 66 EC 67 EC 68 EC 69 EC 70 EC 71 EC 72 EC 73 EC 74 EC 75 EC 76 EC 77 EC 78 EC 79 EC 80 EC 81 EC



AUSTRALIAN TRANSVERSE MERCATOR PROJECTION 10,000 YARD GRID

ZONE 8

KILOMETRES 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26

MILES 1 0 2 4 6 8 10 12 14 16 18

YARDS 5,000 0 5 10 15 20 25 30 35,000

SCALE 1 : 100,000

DATA ARE THICKNESS IN FEET

SHOT POINTS

- ○ MAGELLAN PETROLEUM SOUTHERN PTY. LTD. (1968)
- • ESSO EXPLORATION & PRODUCTION AUSTRALIA INC.
- · SHELL DEVELOPMENT (AUSTRALIA) PTY. LTD.
- • MAGELLAN PETROLEUM (1969) — C.D.P.
- ○ MAGELLAN PETROLEUM — SPARKER RECONNAISSANCE (1969)

MAGELLAN PETROLEUM AUSTRALIA LTD.

MARINE SEISMIC SURVEY

EAST GIPPSLAND BASIN AREA

ISOPACH A-B

074203

(WITHIN MIOCENE — TOP LATROBE COMPLEX)

5 cm

CONTOUR INTERVAL 250 FEET — DATUM SEA LEVEL

AUTHOR K. GRAYBILL — DATE JUNE 1969

GEOPHYSICAL SERVICE INTERNATIONAL

REVISED: AL SABITAY DRAFTED: D.C. CLARKE — FEBRUARY 1970

PLATE 13 — SHEET I

T/1P, T/9P Part 7 Copy 1 — OR-054

VICTORIA

TASMANIA

T/1P

FLINDERS ISLAND

CONTOURS FROM PREVIOUS SUBSIDIZED SEISMIC SURVEYS

SOME FAULTS FROM KINGFISH FIELD

THICK

THIN

M54T1 M54T2 M54T3 M54T4 M30T M15T M32T M34T M17T M19T M20T M36T M57T M58T M37T M56T M59T M55T M21T M38T M39T M22T M23T M60T M24T M25T

I II III IV V VI VII VIII IX X XI

AUSTRALIAN TRANSVERSE MERCATOR PROJECTION 10,000 YARD GRID

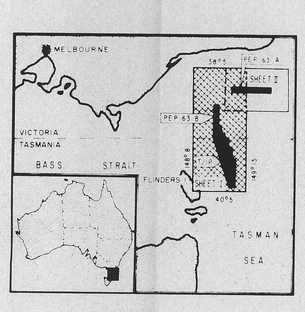
ZONE 8

KILOMETRES 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26

MILES 1 0 2 4 6 8 10 12 14 16 18

YARDS 5,000 0 5 10 15 20 25 30 35,000

SCALE 1:100,000



DATA ARE THICKNESS IN FEET

SHOT POINTS

- ○ MAGELLAN PETROLEUM SOUTHERN PTY. LTD. (1968)
- • ESSO EXPLORATION & PRODUCTION AUSTRALIA INC.
- · SHELL DEVELOPMENT (AUSTRALIA) PTY. LTD.
- • MAGELLAN PETROLEUM (1969) — C.D.P.
- ○ MAGELLAN PETROLEUM — SPARKER RECONNAISSANCE (1969)

MAGELLAN PETROLEUM AUSTRALIA LTD.

MARINE SEISMIC SURVEY

EAST GIPPSLAND BASIN AREA

ISOPACH B-C

074204

(TOP LATROBE COMPLEX — BASEMENT)

5 cm

CONTOUR INTERVAL 500 FEET DATUM SEA LEVEL

AUTHOR K. GRAYBILL DATE JUNE 1969

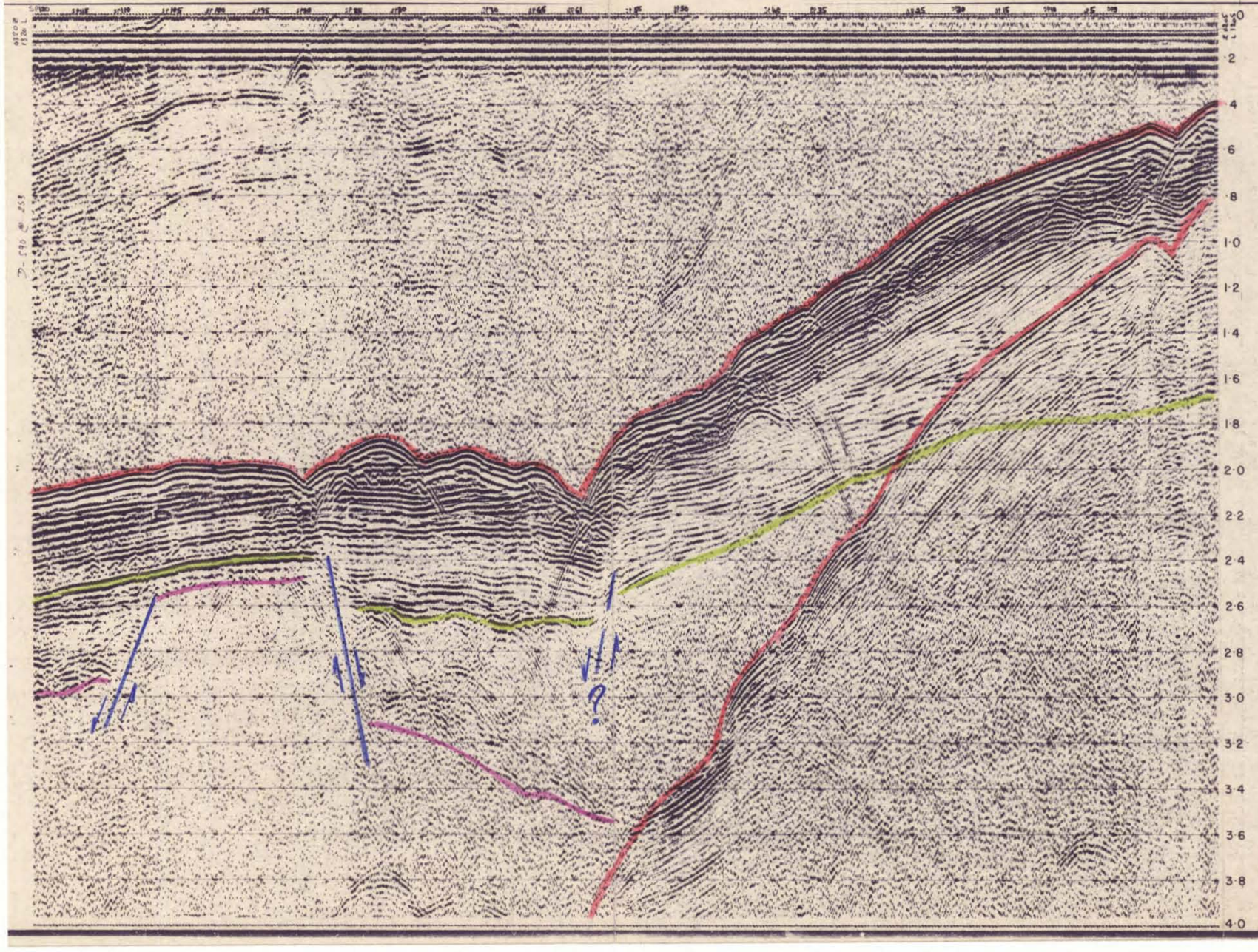
GEOPHYSICAL SERVICE INTERNATIONAL

REVISED: A.L. SABITAY DRAFTED: D.C. CLARKE FEBRUARY 1970

PLATE 14 SHEET I

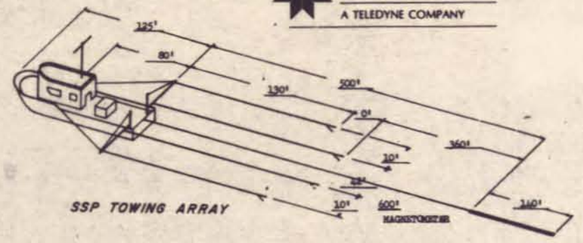
T/1P, T/9P Part 7 Copy 1 OR-054

074205



M-54 T3

TELEDYNE EXPLORATION
A TELEDYNE COMPANY



SSP TOWING ARRAY

LINE M-54 T1, T2, T3, T4 (DIR. AS INDICATED)
CLIENT MAGELLAN PETROLEUM AUSTRALIA
PROSPECT EAST GIPPSLAND
DATE 30-31 AUGUST 1969
W.G. NO. 142-631

PLATE 15

POSITIONING SHORAN
WEATHER BEAUFORT 3
MOTOR VESSEL TELESEIS IV
VESSEL SPEED 10 KNOTS APPROX.
FIX INTERVAL 5 SHOT POINT

ACOUSTIC SOURCE BPS 160 K3
SOURCE DEPTH 25 FEET
FIRING RATE 4 SECONDS
HYDROPHONE TYPE AND SER. NO. HP-7 WELL LOG S/N P-23
HYDROSTREAMER DEPTH 35 FEET
TOWING NOISE 60 MICROVOLTS

FACSIMILE RECORDER TYPE RAYTHEON PRR-196-4-2
TRACES/INCH 45
AMPLIFIER TYPE GR 131
FILTERS HI 125-3 LO 80-2
AMP 1 IS USED AS THRESHOLD CH.
AMP 2 IS USED AS EXPANDER CH. (AGC)
AMPS. 3&4 ARE USED WITH TAPE, IF TAPE IS USED
INPUTS TO 1&2 ARE PARALLEL
INPUTS TO 3&4 ARE PARALLEL
SIGNAL CONDITIONER MASTER GAIN IS 100 MICROVOLTS
PRESUPPRESSION 12/ IS NOT USED

TAPE RECORDER TYPE AMPEX SP300 1/2 INCH. S/N 1093
TAPE FILTERS 125-3 16-2
TAPE SPEED 3.75 IPS
TAPE NO. D-589 THRU 590

REMARKS:
2336L STARTED ON LINE M-54 T1, (111°).TAPE D-589 @ 0 REVS.
0950L 2350Z FIRTS SHOT POINT No 1 .TAPE D-589 @ 59 REVS.
1032L 0034Z COMPLETED LINE M-54 T1, SHOT POINT No 70. TAPE D-589 @ 336 REVS.
1033L 0035Z STARTED ON LINE M-54 T2,(200°). TAPE D-589 @ 400 REVS.
1045L 0045Z FIRST SHOT POINT No 1. TAPE D-589 @ 468 REVS.
1153L 0153Z COMPLETED LINE M-54 T2. SHOT POINT No 116. TAPE D-589 @ 798 REVS.
1205L 0205Z STARTED ON LINE M-54 T3. (069°). TAPE D-589 @ 850 REVS.
1212L 0212Z FIRST SHOT POINT No3. TAPE D-589 @ 880 REVS.
1244L 0244Z CHANGED TO TAPE D*590.
1320L 0320Z COMPLETED LINE M-54 T3. SHOT POINT No 120. TAPE D-590 @ 253 REVS.
1347L 0347Z STARTED ON LINE M-54 T4. (228o).SHOT POINT No 1. TAPE D-590 @ 300 REVS.
1447L 0447Z COMPLETED LINE M-54 T4. SHOT POINT No 94. TAPE D-590 @ 627 REVS.

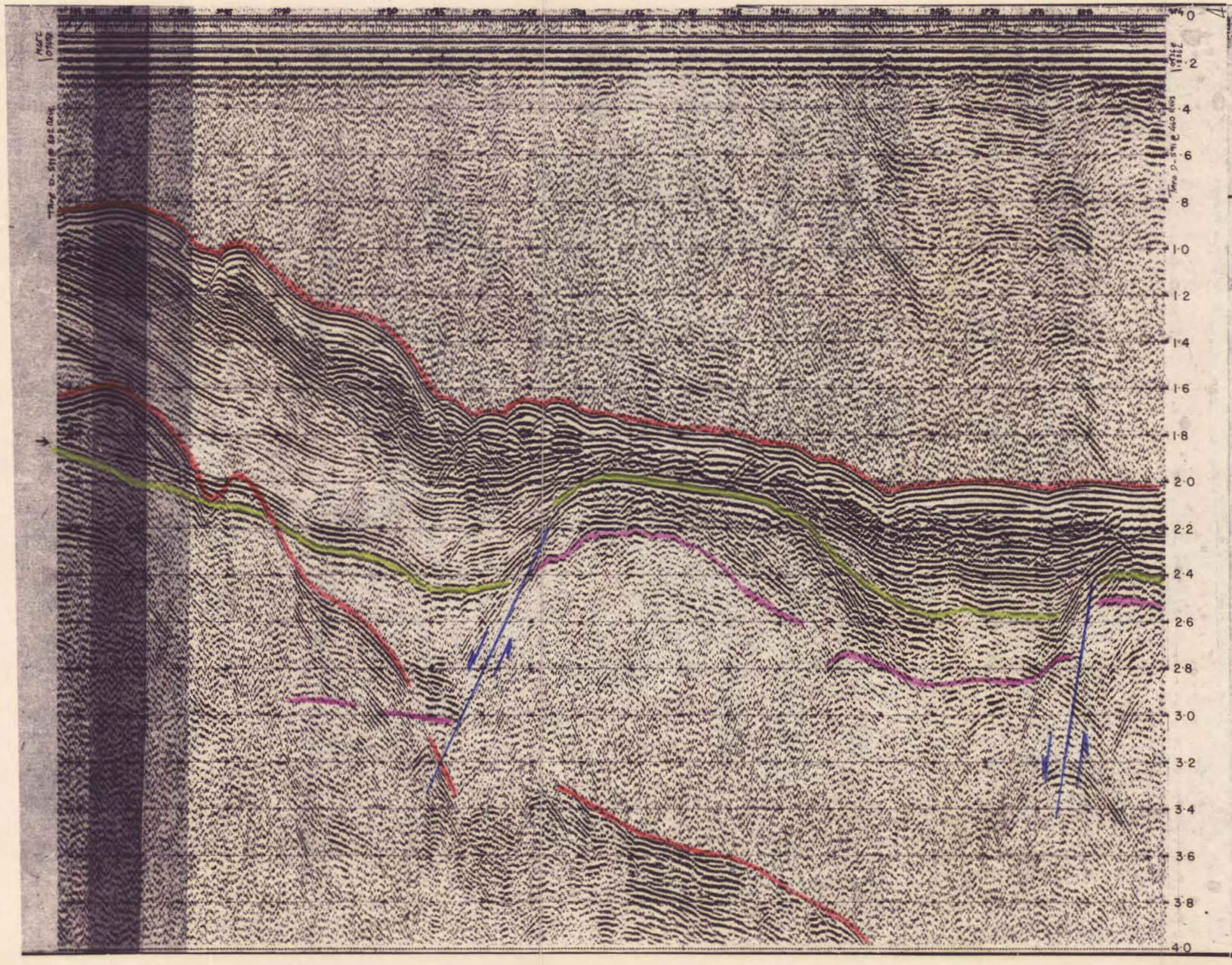
5 cm

CREW NO. MS 631
OPERATORS INITIALS R.S. M.S.
CLIENT REPRESENTATIVE AL SARITAY
CREW CHIEF W.H. SPRINGER

OR-054

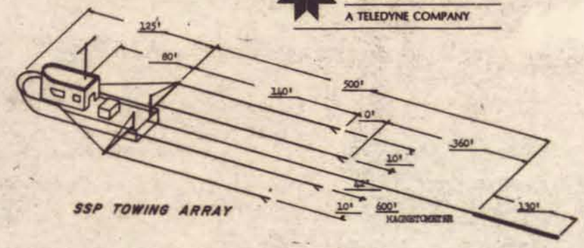
HIP, TAP Part 7 Copy 1

074206



M-2E

TELEDYNE EXPLORATION
A TELEDYNE COMPANY



SSP TOWING ARRAY

LINE M-1E, M-2E, EA, EB, M-3E, EA, EB, EC, ED, EF
CLIENT MAGELLAN PETROLEUM AUSTRALIA
PROSPECT EAST TASMANIA
DATE 2 SEPTEMBER 1969
W.O. NO. 142-631

PLATE 16

POSITIONING SHORAN
WEATHER BEAUFORT 3
MOTOR VESSEL TELEDEX IV
VESSEL SPEED 10 KNOTS
FIX INTERVAL 5 SHOT POINT

ACOUSTIC SOURCE SSP 160 EJ
SOURCE DEPTH 25 FEET
FIRING RATE 4 SECONDS
HYDROPHONE TYPE AND SER. NO. MP-7 WELL LOG S/N F-23
HYDROSTREAMER DEPTH 35 FEET
TOWING NOISE 70 MICROVOLTS

FACSIMILE RECORDER TYPE RAYTHEON PER 196-A-2
TRACES/INCH 45
AMPLIFIER TYPE GS 111
FILTERS HI 47-1 LO 16-2
AMP. 1 IS USED AS THRESHOLD CH.
AMP. 2 IS USED AS EXPANDER CH. (AGC)
AMPS. 3&4 ARE USED WITH TAPE, IF TAPE IS USED
INPUTS TO 1&2 ARE PARALLEL
INPUTS TO 3&4 ARE PARALLEL
SIGNAL CONDITIONER MASTER GAIN IS 100 MICROVOLTS
PRESUPPRESSION ~~TV~~ IS NOT USED

TAPE RECORDER TYPE AMPEX SP300 1/8 INCH. S/N 1093
TAPE FILTERS 125-1 16-2
TAPE SPEED 3.75 IPS
TAPE NO. D-591 THRU 594

REMARKS: 1783L STARTED ON LINE M-1 E. (100°). SHOT POINT No 1. TAPE D-591 @ 0 REVS.
0832Z 1832L COMPLETED LINE M-1 E. SHOT POINT No 106. TAPE D-591 @ 432 REVS.
0836Z 1836L STRATED ON LINE M-2 E. (225°). SHOT POINT No 4. TAPE D-591 @ 460 REVS.
0945Z 1945L COMPLETED LINE M-2 E. SHOT POINT No 106. TAPE D-591 @ 802 REVS.
0951Z 1951L STARTED ON LINE M-2 EA. (000°). SHOT POINT Is 3. TAPE D-591 @ 830 REVS.
1035Z 2035L COMPLETED LINE M-2 EA. SHOT POINT No 17. TAPE D-591 @ 1017.
1036Z 2036L STARTED ON LINE M-2 EB. (110°). SHOT POINT No 18. TAPE D-592 @ 8 REVS.
1107Z 2107L LOST POWER ON SHIP GENERATOR. STOPPED SHOOTING. SP 27. TAPE D-592 @ 210
1143Z 2143L RESUMED RECORDING ON LINE M-2 EB. SHOT POINT No 26. TAPE D-592 @ 250 REV
1224Z 2224L COMPLETED LINE M-2 EB. SHOT POINT No 39. TAPE D-592 @ 488 REVS.
1225Z 2225L STARTED ON LINE M-3 E. (250°). TAPE D-592 @ 530 REVS.
1231Z 2231L SHOT POINT No 85. TAPE D-592 @ 555 REVS.
1340Z 2340L COMPLETED LINE M-3 E. SHOT POINT No 22. TAPE D-592 @ 880 REVS.
1341Z 2341L STARTED ON LINE M-3 EA. (000°). SHOT POINT No 1. TAPE D-593 @ 0 REVS.
1450Z 0050L COMPLETED LINE M-3 EA. SHOT POINT No 24. TAPE D-593 @ 300 REVS.

5 cm

CREW NO. MS 631
OPERATORS INITIALS M.S. R.S.
CLIENT REPRESENTATIVE AL SABITAY
CREW CHIEF W.H. SPRINGER

T/1P, T/9P Part 7 Copy 1 OR-054