080001

OTWAY/KING PART-VII*

PORTLAND KING ISLAND SEISMIC SURVEY

FINAL SUBSIDY REPORT

HEMATITE PETROLEUM PTY. LTD.

MARCH 1973

OR-066.

CONTENTS

Abstract

The Portland-King Island Seismic Survey was shot by G.S.I. for Hematite in the offshore Otway Basin in October 1972.

Shooting used an airgun energy source to record 48 traces, 48 CDP, with a trace interval of 66.67 metres and a shot interval of 33.33 metres. Navigation was by satellite/sonar doppler. Processing was 24 fold, with a two-fold vertical stack, and using continuous velocity analysis to help interpretation. In addition to the 166.68 miles of new shooting, fifteen lines totalling 232 miles were reprocessed to assist in interpreting the structures on which the wells Prawn 1, Mussel 1, and Whelk 1 were drilled in the area.

The survey was successful in upgrading the seismic data in the basin, and two wells, Mussel 1 and Prawn 1, were confirmed as being drilled off-structure.

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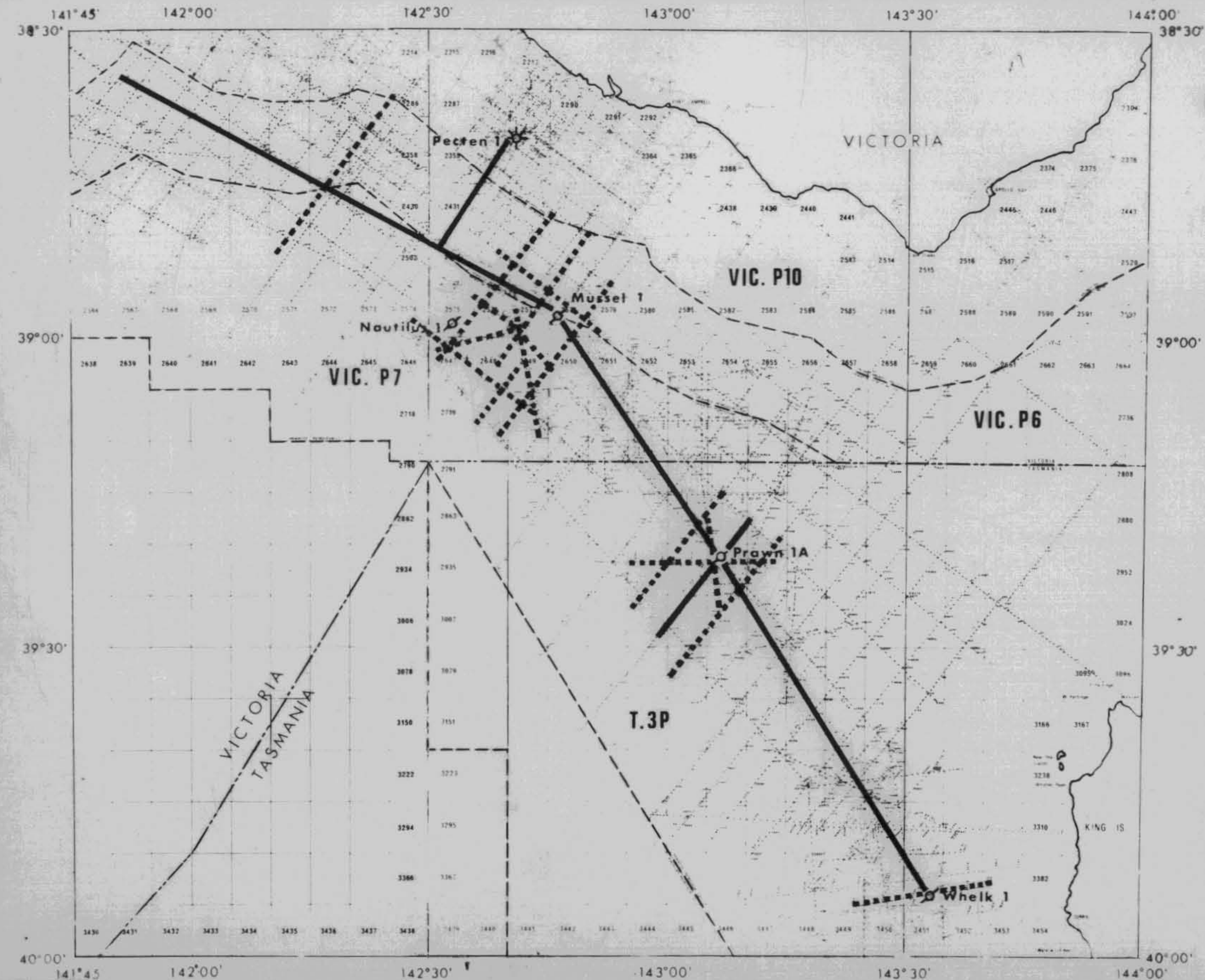


HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

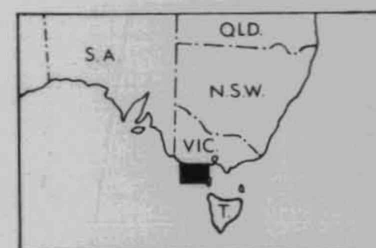
PORTLAND TO KING ISLAND SEISMIC SURVEY

LINE LOCATION

SCALE

Miles 0 – 25

Kilometres 0 – 25



LOCALITY MAP

LEGEND:

New Shooting

Reprocessing

Fig. 1

OG-3132

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1. General Data

The Portland-King Island Seismic survey was carried out for the operator, Hematite Petroleum Pty. Ltd., by Geophysical Service International, in an area extending from near Portland to near King Island, and in permits Vic/P6, Vic/P7, Vic/P10, and T/3P.

The seismic interpretation was undertaken by J.I. Denham, Senior Geophysicist, and E.G. Urschel, Geophysicist and the geological description was written by I. Mellins, Geologist and B.R. Brown, Senior Geologist.

Shooting commenced on 26th October, 1972, and was completed on 29th October, 1972.

Further data are given in the contractor's reports, which appear as Appendices 1, 2 and 3 to this report.

In addition to the field programme, an additional approximately 232 miles of older records were reprocessed.

2. Objectives

a) Regional Geology

During late Jurassic and early Cretaceous times, southern Victoria was the site of an east-west rift valley extending continuously from South Australia to Gippsland. A monotonous sequence of fluvio-lacustrine mudstones, felspathic and lithic sandstones, and minor coals, known as the Otway Group, accumulated in this trough and was probably derived from the bordering Palaeozoic and early Mesozoic cratonic highs then existent to the north and south. Seismic evidence indicates that these sediments attain thicknesses as great as 15,000 feet in the deeper parts of the basin.

During the early Upper Cretaceous, tectonic activity possibly associated with the separation of the Antarctic from the Australian continental plate caused down-warping, deformation and faulting of the Otway Group sediments and was accompanied by minor volcanism. Eventually, further widening of the two plates allowed ingression of the sea from the west. Marine transgressions moved diachronously across the area from west to east. Foraminiferal evidence (Taylor, 1964, 1972) from offshore and onshore wells in the eastern part of the Otway Basin supports this view.

Four major depositional cycles were developed across the area beginning in the mid-Cretaceous and continuing up to the Pliocene. At least three basin-wide unconformities, which can be reasonably well detected on seismic records, separate the successive sedimentation cycles.

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The major depositional breaks relate approximately to:

1. Top Otway Group: Unconformity between the Upper Cretaceous Sherbrook Group above and lower Cretaceous Otway Group and/or Palaeozoic rocks below.
2. Base of Wangerrip Group: Unconformity between Tertiary and Upper Cretaceous.

A local unconformity or disconformity in the mid-Oligocene developed in the Port Campbell area, east of the Warrnambool High.

The Upper Cretaceous cycle is represented by sediments of the Sherbrook Group which attain thicknesses of up to 4,500 feet. This first cycle consists of a suite of non-marine sands, thin coals, paralic silts and marine shales and minor dolomites, representing transgressive and regressive facies.

Sands at the base (Waarre Formation) and top (Curdies Formation) are believed to be the most prospective hydrocarbon reservoirs in the Sherbrook Group. The good reservoir properties of the Waarre and the effectiveness of the overlying cap rocks (Belfast Mudstone, Flaxmans Formation) are demonstrated by the oil and gas occurrences in the Port Campbell Embayment. The Belfast Mudstone is also regarded as a possible source rock for the hydrocarbons. The regional distribution of the stratigraphical subdivision of the Sherbrook Group has not been easy to determine from the four wells drilled and the correlation between wells remains problematical in the area to the west of King Island. The link between Whelk-1, Prawn-1 and Mussel-1 is confused

in the Prawn area. At Mussel-1 2002 feet of Belfast Mudstone overlies the more arenaceous Flaxmans and Waare formations which total 706 feet resting on the Otway Group. Prawn-1 only records 173 feet of Belfast Mudstone beneath which an arenoceous sequence of Upper Cretaceous sediments ranging from A.distocarinatus zone and C.triplex zone which is equivalent to the Flaxmans and Waare formations in Mussel-1. Previous Geophysical interpretations at Prawn-1 have not been able to reconcile the geophysical events and the recorded stratigraphy. The sediments seen in Prawn-1 apparently represent a localised development which shows evidence of thickening into a deep to the south-east on present seismic evidence, but thinning rapidly before Whelk-1, where no Belfast is present and 310 feet of Waare may be present.
The Prawn-1 Upper Cretaceous arenaceous clastics may be related to a rapidly subsiding fault controlled embayment which was filled equally rapidly by sediments derived from the north and east. The specific environmental conditions have been established neither from the sedimentary record nor the recent seismic survey.
<u>The Lower Tertiary cycle</u> is represented by the Wangerrip Group, of similar overall lithology to the previous cycle. Deposits of up to 1,500 feet are known in the offshore area.
In the Port Campbell area, a minor sedimentation cycle comprising paralic and marine muds, marls, and sandy limestone forms a transitional sequence

between the Wangerrip Group and the overlying more marine Heytesbury Group.

The main Upper Tertiary cycle is represented by the Heytesbury Group, a normal marine carbonate suite consisting of limestones and marls. The total Tertiary section thickens to the south-west of the Port Campbell-King Island area with overall regional dip to the south-west. Thicknesses reach about 6000 feet.

Tectonic activity at the end of the Miocene culminated in the Kosciuskan Orogeny, causing further uplift of the Otway Ranges and regression and shallowing of the sea. In the Pliocene and possibly the early Pleistocene, continental deposition became increasingly dominant as gradual uplift of the coastal areas continued. Gentle folding of the Tertiary sediments and extrusion of the New Volcanics probably occurred at this time.

The stratigraphic succession in the Port Campbell Embayment, onshore and offshore, can be summarised as follows (after Leslie, 1966):

Age	Rock Unit
Upper Oligocene - Pleistocene	Heytesbury Group - Port Campbell Limestone, Gellibrand Marl, Clifton Formation
	disconformity or transitional
mid-Eocene - Oligocene	Nirranda Group - Narrawaturk Marl, Mepunga Formation
	unconformity or transitional
Paleocene - mid-Eocene	Wangerrip Group - Dilwyn Formation, Rivernook Member, Pebble Point Formation
	unconformity or transitional

Upper Cretaceous	Sherbrook Group - Curdies Formation Paaratte Formation Belfast Formation Flaxman Formation Waarre Formation
	unconformity or transitional
Lower Cretaceous	Otway Group
	unconformity
Pre-Cretaceous	undifferentiated Palaeozoic/ Pre-Cambrian metasediments, intrusives, etc.

b) <u>Previous Geophysical Work</u>

The area of this survey has been covered by seismic surveys by Hematite in 1962-63 and 1964-65 and Esso in 1966-67, 1967, 1968 and 1969. The Hematite shooting used single coverage with some 3 CDP, analogue recording, and dynamite energy source. The 1966-67 survey introduced 6 CDP shooting and digital recording, although this was not digitally processed until a year later. The 1968 and 1969 surveys which comprise the latest available data used a gas exploder energy source with 48 CDP recording (processed 12 CDP), but this resulted in no significant improvement in record quality.

<u>Results of Previous Surveys</u>

The Hematite surveys covered the area with a regional grid to which the later Esso surveys added, giving a 5 x 10 to 5 x 5 mile grid with closer coverage in some locations. For Esso surveys record quality was fair to good down to the Upper Cretaceous/Tertiary unconformity, but relatively poor to very poor on the Esso records, and unusable on the Hematite records, below this level. A recent review of the data resulted in the conclusion that in view of the structural complexity evident below the Tertiary unconformity, the discontinuous reflections provided insufficient data to be confident of any interpretation. In particular it was not possible to confirm any of the "structures" drilled in this part of the basin. (Mussel, Prawn, Whelk).

The availability of improved data processing techniques suggested that reprocessing might improve data quality, and with this in mind two sections of line, totalling about 20 miles, were reprocessed experimentally.

This resulted in a small, but worthwhile improvement in record quality, and more importantly, provided an additional parameter-velocity - to assist in interpretation. This was displayed as automatically picked reflection segments, velocity sorted to exclude multiples and spurious events, and with average (R.M.S.) velocities shown. (see Figures 3,4,5).

The results were very satisfactory in one area (Mussel) and less so in the other (Prawn).

c) Objectives

The objectives of the survey were to improve data quality, providing a high grade tie between wells, and to establish the structural positions of three wells, Prawn No. 1, Mussel No. 1 and Whelk No. 1.

It was intended to use "high technology" data processing so as to extract the maximum possible information from the data, and to assess the usefulness of these methods in achieving the objectives.

Methods

(a) Shooting

Details of shooting methods are given in the contractor's reports (appendices 1 & 3). The streamer length, 48 traces at $66\frac{2}{3}$ metres intervals, was chosen so as to give a maximum usable offset down to about 2.5 seconds, to increase accuracy of velocity analyses, and to improve multiple discrimination at depth. The $66\frac{2}{3}$ metres interval, a reduction from the 100 metre interval used in previous surveys, gives closer depth points, and hence better continuity.

The shot interval of $33\frac{1}{3}$ metres to give 48 CDP coverage was the shortest practical, as this gave a shot interval of about 10 seconds at the normal shooting speed of about 6 knots.

"Geonav" satellite/sonar doppler navigation was used for two reasons, firstly, because of the disproportionate cost of setting up the three Shoran stations which would have been necessary for the small mileage, and secondly, the Geonav system fires the shots at constant distances rather than time intervals, ensuring accurate stacking geometry, this being particularly important for the long spread.

(b) Processing

Processing methods are described in the contractor's report (Appendix 2). Continuous velicity analyses were used throughout, primarily to provide velocity information for interpretation of the poorer quality deep data. In some cases the automatic picking programme followed events which would not otherwise be visible on the stacked section.

This stage of the processing had to be carried out outside Australia, and resulted both in long delays and poor interaction between the interpreter and processing. Given closer interaction or more time, results of this processing could be improved.

Processing was limited to 4.0 seconds, as useful data below this was not expected. The new shooting used alternate depth points for the velocity analysis programme, data from one system only being submitted, although displays are labelled "every depth point".

(c) Interpretation

Two horizons were mapped, top of Sherbrook Group - Base of Wangerrip Group unconformity, and the top of Otway Group - Base of Sherbrook Group unconformity. Only new or reprocessed records were included in the interpretation, including part of EO-31 reprocessed prior to the survey. For the first step in the interpretation the sorted segment display overlays were examined, with both "peaks only" and "troughs only" transparencies (see Appendix 2, Section II B 3.3) over the stacked section, and events thought to be valid selected at intervals of not less than 200 milli seconds. These events were selected on criteria of reflection strength and continuity, dip and velocity. Every 10 traces for old data and every 20 traces for new data a set of time and RMS velocity values was taken for the selected events. Where selected events were shorter than 10 points, the velocity was obtained from the printed segment listings.

For each set of figures, interval and average velocities were computed using Dix's formula. These interval velocities were used to assist in picking the records.

From these figures, following picking of the records, an average velocity figure was taken for each picked time (every 24 traces for new lines, 20 for old lines). Where a picked time did not correspond with a selected velocity event, the velocity was interpolated using the appropriate interval velocity.

The velocity values were then checked for ties and edited, values differing by 500 ft/sec. or more from adjoining figures, but with no great change in reflection time, being discarded, or in some cases reworked from the velocity displays, picking different events. The velocity figures were then smoothed along each line using a 5 point running average, broken at faults.

This procedure was followed for both horizons and the results used for depth calculations.

The times for Horizon B were corrected for onset by .025 sec., but a similar correction was not made for Horizon C, as the accuracy of picking the records is not sufficient to justify this precision.

4. Interpretation

Horizon B

Horizon B is tied to the base of Wangerrip unconformity at each of the wells, 4501 at Mussel-1, 4055 at Prawn-1, 2412 at Whelk-1 and 2555 at Pecten-1. There is generally little difficulty in picking this horizon, and it can mostly be recognised within a cycle on the records as the base at the zone of good reflections, with foreset bedding and channelling. However, to the west of line HO-24 on line HO-22 it loses its distinctive character and there is no sharp change in record appearance between the Paleocene and Upper Cretaceous section.

Velocity ties at the three wells with velocity surveys (Mussel-1, Prawn-1, Whelk-1) were fair only, and initially, there were a number of misties at line intersections. In part there may result from the relatively shallow event, which uses less than the full cable length, and hence lower multiplicity and partly from the varying wavelet shape of a reflection from an unconformity surface. It is estimated that the probable error of the velocity figures is about ±200 ft/sec. so that with the direct application of these figures to the times their variations may have affected the contouring with the 250 foot interval.

Structurally the map shows the expected offshore dip, and is quite similar to previous maps, although no attempt was made to integrate old data.

Horizon C

The Upper Cretaceous section has no strong or continuous reflections, so the base of this section was mapped, corresponding to the base of the Sherbrook Group. Except in the Whelk area, this is also the top of the Otway Group. The reflection character varies widely, being easiest to follow in those areas where there is an obvious angular unconformity, for example, on line HO-24. The reflection quality was good to poor on the new lines, and varied from fair to unusable on the reprocessed lines. In particular, line ER-39 was unusable at this level, apparently due to lack of penetration.

The automatically picked sorted segment displays were useful in picking this horizon, as they enabled events to be readily classified as primaries or multiples on the basis of velocity. In some cases events appeared on the segment displays which were almost completely obscured on the records.

The velocities varied widely in reliability with reflection quality. As the mapped horizon was mostly not a strong event, in most cases the velocity was interpolated between events above and below. Interval velocities were computed prior to picking the records, and were used as a pointer in separating Upper from Lower Cretaceous section, using a dividing line of 14,000 ft/second. This had to be used with considerable caution as the probable error in interval velocities can be very high, particularly if the interval is small or if a non-primary event is selected in error.

The velocities were used in the same way as for Horizon B, but as the contour interval was 500 feet the error in velocities will have little effect on contouring, even though the probable error is in many areas higher. Ties with wells and at line ties were mostly within the expected limits, and only a few velocities had to be re-examined. For this horizon, the smoothing method used for the velocities is much less than ideal because of the faulting and changes in dip, but, as a result of the large contour interval, it is not likely to have significantly affected the map.

From Whelk No. 1 in the southeast of the area, the base of the Upper Cretaceous dips into a trough on line HO-21, the deepest section being about SP 1440. From here it rises abruptly to a higher platform extending from southeast of Prawn No. 1 to just west of the intersection of HO-22 and HO-24, where it dips steeply into another trough. Line HO-21 immediately west of Prawn No. 1 appears to be almost along a major fault, with energy present in places from both blocks, making a satisfactory interpretation impossible.

In the two deep troughs, the Upper Cretaceous becomes conformable with the Lower Cretaceous and it is quite probable that Horizon C as mapped is not the boundary, and that deposition was continuous in these areas.

Whelk No. 1 is confirmed as being drilled on a very local basement high, the interpretation essentially agreeing with the previous ones.

Prawn No. 1 appears from this interpretation to be drilled on the west flank of a northerly trending anticline, on a small nose on the flank, but well below the crest. The structure is unusual and complicated, and this interpretation is not considered entirely satisfactory, further high grade data being necessary. However, although the well appears to be on a reversal on line HO-23, there is little evidence for a reversal at this point on HO-21, although there are cross-cutting events on this section.

Mussel No. 1 is on the eastern edge of a large high, barely within the closed (7500) contour. Record quality is not very good in this area, even on the new shooting, and further new shooting would be needed to confirm this interpretation, although no major change would be expected.

It should be noted that in many areas the record quality is such that faults have probably been missed, and that these were only interpreted where there was substantial evidence of their existence.

Conclusions

The primary objectives were fulfilled, establishing that Whelk No. 1 was drilled on a basement high, and that Mussel No. 1 and Prawn No. 1 were drilled off-structure. A satisfactory tie was made between wells, except that there is considerable uncertainty surrounding the ties to Prawn No. 1, as a result of its structural situation and unique stratigraphic succession.

Record quality was substantially improved, and for the first time it was possible to map with some degree of confidence. However, there is still room for improvement, although it is not clear how this can be achieved with present available techniques. Energy input could be increased by decreasing shot interval, although the present interval is close to the practical limit, and possibly more stringent noise limits could be imposed. The velocity analysis would be improved if every depth point were used rather than alternate depth points. It is not likely that 48 fold processing would significantly improve results, but further experiments will be considered.

The reprocessing was of mixed success, many of the records lacking deep energy, but in some cases being almost as useful as new shooting would have been.

The advanced processing was very successful in providing a further parameter, velocity, to assist in interpretation. In particular, the ability to discriminate between events on the basis of velocity was often vital. The effect of continuous velocity information on record quality by accurate stacking cannot be assessed, but was probably considerable.

The major shortcoming in processing was the time taken, and the necessity for shipping data overseas, where close supervision of processing was not possible. Full utilization of the velocity data obtained requires a lengthy interpretation effort. Further rigorous interpretation of all data, reinterpreting and recomputing velocities should provide more reliable depths for the horizons mapped.

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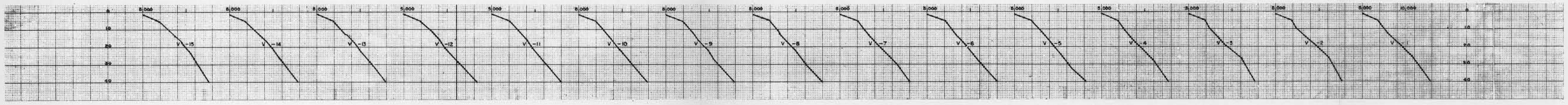
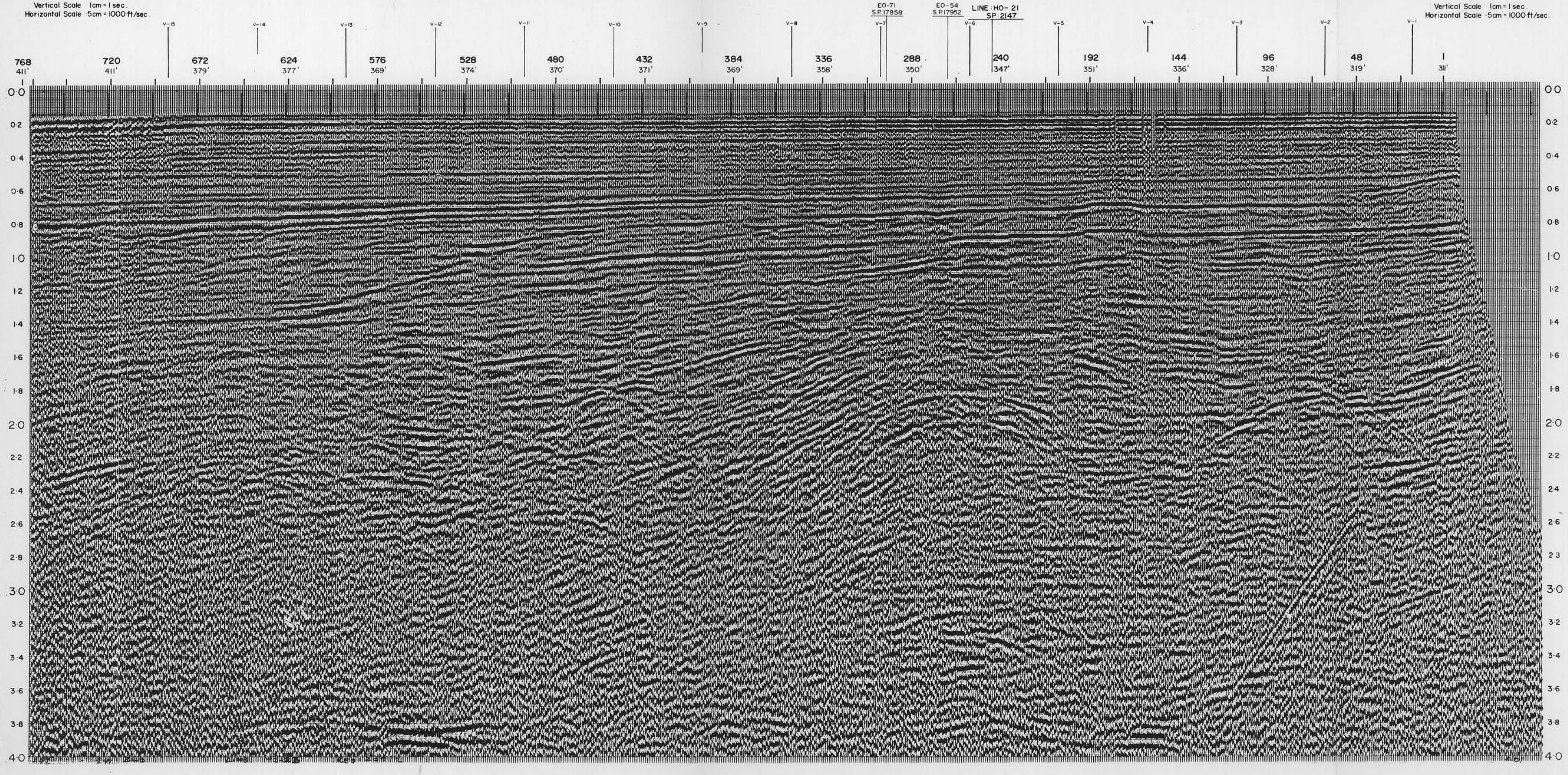


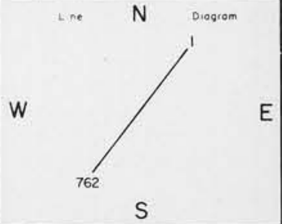


HEMATITE PETROLEUM PTY. LTD.

PORTLAND KING ISLAND SEISMIC SURVEY

HO-23

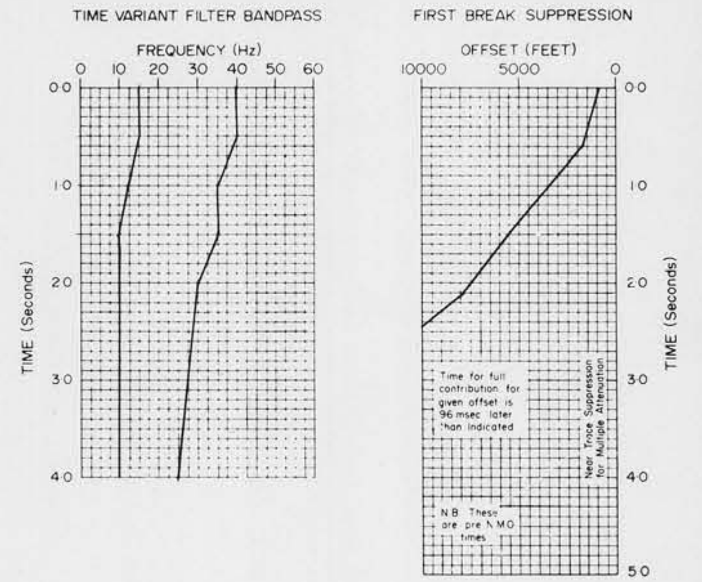
FIELD DATA: GSI Party 931
Recorded: 2 X 24 trace
Energy Source: AIRGUN 1300 cu. in
Sample Rate: 4 ms. Record Length: 5·0 sec.
Filter: 8 – 62 Hz Gain Control: AGC
SP Interval: $33\frac{1}{3}$ m Group Interval: $66\frac{2}{3}$ m
Streamer: 3200 m, 48 Groups, Towing Group 48
Date: OCT.'72



PROCESSING:

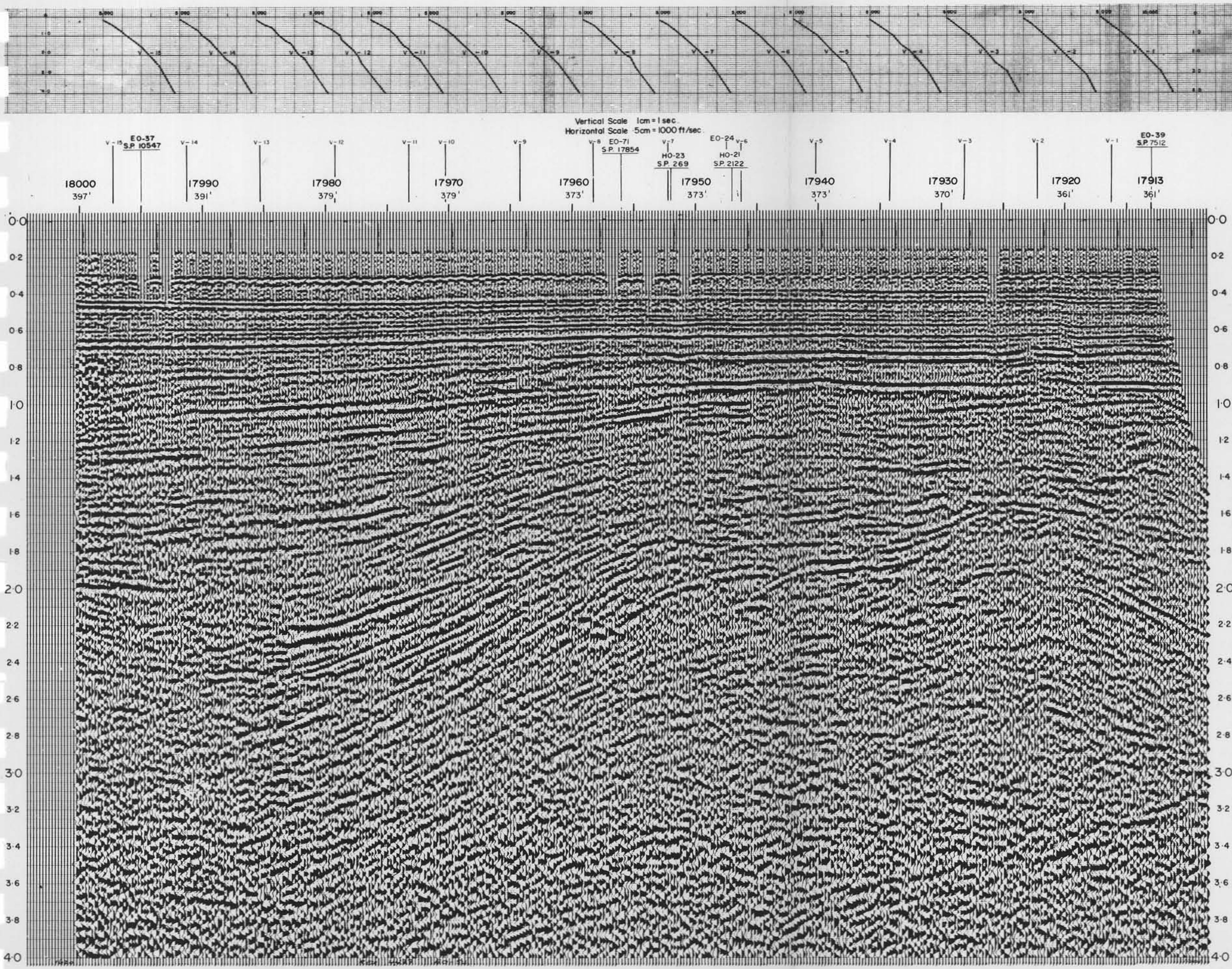
By GEOPHYSICAL SERVICE INTERNATIONAL, Sydney. Date Dec , 1972.
1 True Amplitude Recovery. 2 Vertical Stack
4 Deconvolution Before Stack: 2 Operator / Trace, 64 pts, 4 ms, Gap = __ ms at Maximum Water Depth.
3 Statics. 6 Common Depth Point Gather. 8 Normal Moveout Correction.
5 Time Variant Scaling, 5 Gates: 9 x 500 msec
7 Velocity Analysis Continuous 700 Package
9 24 Fold CDP STACK 11 Time Variant Filter.
10 Deconvolution After Stack: 2 Operators / Trace, 68 pts, 4 ms, Gap = 0 ms at Maximum Water Depth.
__ Coherency Scaling
12 Display Polarity Normal __ Depth Section.

Horizontal Scale = 0.5 mile/inch Vertical Scale = 3·75 in/sec.



5 cm

FIG. 2



HEMATITE PETROLEUM PTY. LTD.

PORTLAND KING ISLAND SEISMIC SURVEY

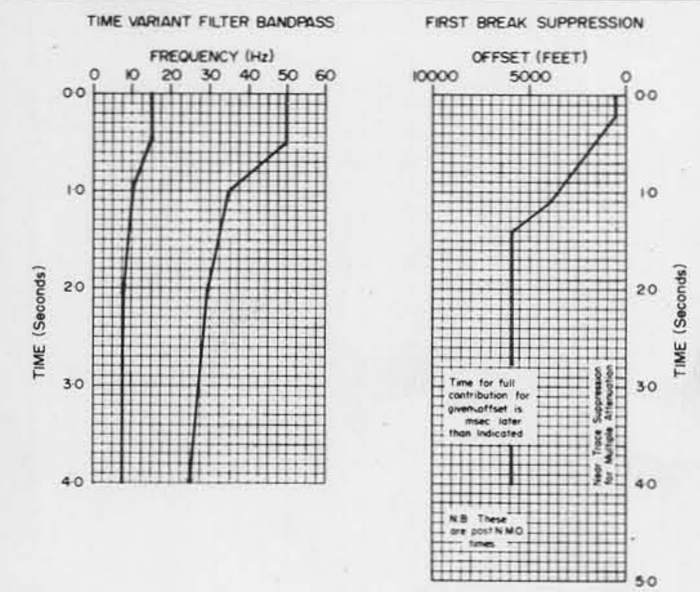
E0-54

FIELD DATA: G.S.I. Party 921, MV MERINO
Recorded: 1 X 24 trace 9000 System for 6 CDP
Energy Source: 100 lbs Dynamite
Sample Rate: 2 ms. Record Length: 4·0 sec.
Filter: 8-75 Hz Gain Control: AGC
SP Interval: 656 ft Group Interval: 328 ft
Streamer: 2400m, 24 Groups, Towing Group 24
Date: Dec '66 - Jan '67

Line Diagram: N, W 18004 — 17913 E, S

PROCESSING:
By GEOPHYSICAL SERVICE INTERNATIONAL, Sydney. Date Dec, 1972.
1 True Amplitude Recovery.
3 Deconvolution Before Stack: 1 Operator / Trace, 84 pts, 4 ms, Gap = __ ms at Maximum Water Depth.
2 Statics. 5 Common Depth Point Gather. 7 Normal Moveout Correction.
4 Time Variant Scaling, 8 Gates Length 2×200, 300, 4×400, 500ms.
6 Velocity Analysis Continuous 700 Package
8 6 Fold Stack. 10 Time Variant Filter.
9 Deconvolution After Stack: 2 Operators / Trace, 90 pts, 4 ms, Gap = 0 ms at Maximum Water Depth.
__ Coherency Scaling
11 Display Polarity Normal __ Depth Section.

Horizontal Scale 0·5 Mile/inch Vertical Scale = 3·75 in/sec.



5 cm

FIG. 3

APPENDIX I

OPERATIONS REPORT

080026

OPERATIONS REPORT
MARINE SEISMIC SURVEY
EO 4/2 PORTLAND KING ISLAND
VICTORIA

For

HEMATITE PETROLEUM PROPRIETARY LIMITED
440 COLLINS ST. MELBOURNE
VICTORIA

By

GEOPHYSICAL SERVICE INTERNATIONAL
P.O. BOX 437, CROWS NEST N.S.W., 2065

Party 931 M.V. Eugene McDermott II

Operations Supervisor : C. ROWELL

Quality Control Seismologist/s : P. KEEGAN, P. CHERNOFF

OCTOBER 1972

GSI-709

080027

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GSI-709

LIST OF PLATES

SECTION I

INTRODUCTION

A marine seismic reflection survey was conducted by the M.V. Eugene McDermott II in the Portland King Island area for HEMATITE PETROLEUM PTY. LTD. between 26 OCT. 72 and 29 OCT. 72.

166.68 miles of 48-fold reflection coverage were shot utilizing a 3200 meter streamer under continuous tow in conjunction with a Pneumatic Acoustic Energy Source (Airguns), generally operating 24 hours per day.

Recordings were made using two sets of 24 trace DFS III's, with 3 tape transports recording on 1" magnetic tape in 21 trace TIAC* Binary Gain Digital Format at 712 b.p.i. Record length was 5 seconds. In all instances the sample rate was 4 milliseconds.

The ship's location was determined by Geonav II.

* Trademark of Texas Instruments Inc.

SECTION II
OPERATION PROCEDURES

A. RECORDING:

A Texas Instruments Digital Field System III (DFS III) with 3 tape transports was used for all recording. A Servo Write Profiler was utilised to obtain 100% (Near Trace Gather) subsurface coverage (uncorrected section) of 4 second duration, directly from monitor recording.

Direct Read After Write (RAW) monitors were generated approximately every 12 pops for quality control purposes.

B. STREAMER:

The 3200 meter, neutrally buoyant, continuous tow streamer consisted of 48 live sections (L) each 50, meters in length 47 dead sections (D) each 16 2/3 meters in length and 6 Waterbreak/Depth Transducer sections each 2 meters in length, placed immediately in front of group 48 and between groups 40L and 40D, 30L and 30D, 20L and 20D, 10L and 10D, 2L and 2D.

Five nylon stretch sections were placed between group 48 and the recording vessel to attenuate ship generated noise. Nine Condeps** (cable depth controllers) were placed between the depth transducers on the streamer at the centre of dead groups 3D, 9D, 16D, 22D, 27D, 34D, 40D, and 48 live.

Three nylon stretch sections followed group 1 and was joined to the tailbuoy by 400 feet of nylon rope. Tailbuoy bearings were taken by radar every 40 pops (weather permitting), to ensure that maximum feathering angle was not exceeded.

The average streamer depth was 47' feet.

C. ENERGY SOURCE (AIRGUNS):

An Electro-Pneumatic Acoustic Energy Source known as "Airguns" was used for all reflection work.

The airgun has basically two moving parts, the shuttle and the solenoid. Compressed air is supplied to this unit at a pressure of 2000 lbs. per square inch. The shuttle is forced to close on initial application of pressure. Compressed air fills the reservoir chamber through a central orifice in

** Trademark of Continental Oil Company

the shuttle. To discharge the gun an electrical current activates the solenoid and retracts a plunger, thus enabling compressed air to pass through a port hole in the underside of a flange at the top of the shuttle. The pressure difference above and below the shuttle then thrusts it open. The air from the chamber then escapes through four port holes near the centre of the gun and expands rapidly through the water, producing a single bubble and resultant shock wave. The air bubble collapses in a manner similar to that caused by explosives with one notable exception in that its period is controllable and is placed in the desired seismic frequency band.

There are three variables used to control the frequency content of the shock waves. These are:-

i) depth of the airgun in the water,
ii) pressure at which the gun is operated, and
iii) size of the chambers used on the gun.

Using different guns of various chamber sizes broadens and flattens the frequency spectrum of the pulse (Plate 3).

The depth of the airguns was 30 feet and they were operated at a pressure of 2000 lbs. per square inch with the pressure never falling below 1850 lbs. per square inch. The individual airguns were arranged to produce an 1200 cubic inch array. This array consisted of:

i) 4 x 10 cubic inch guns.

ii) 6 x 20 cubic inch guns.

iii) 6 x 40 cubic inch guns.

iv) 5 x 80 cubic inch guns forming
1 x 240 cubic inch array plus
2 x 80 cubic inch guns (separate).

v) 4 x 100 cubic inch guns forming
1 x 200 cubic inch array plus
2 x 100 cubic inch guns (separate).

These arrays were arranged and spaced so as to operate as a tuned array which yield a flat frequency spectrum. (Plate 3).

The time co-ordinator unit triggered the Digital Field System which in turn discharged the Texas Instrument Airgun Control Unit (Blaster), causing a current to flow simultaneously through all solenoids, resulting in the guns firing. The guns were fired every 33 1/3 meters giving 48 -fold coverage. The airgun array was mounted on two strings, one port astern and the other starboard astern and towed behind the recording vessel at a distance of 27 meters from the stern to the centre of the array.

D. INSTRUMENTS AND NOISE TESTS:

Instrument tests were carried out prior to each day's operations and the results were examined in an analog form in the field. These tests consisted of Dynamic Range Determination, Amplifier Noise Test and Automatic Gain Control (AGC) Test. Frequent checks on tape speed and skew were made.

A set of monthly tests were carried out prior to commencement of operations. These tests included Harmonic Distortion, Gain Linearity, Periodic Calibration checks, skew checks and the above-mentioned tests.

The tests were analysed in the Sydney, Australia Processing Centre using TIAC routines.

A streamer noise analysis was made at the beginning of each line shot. Some of these tests were recorded on tape.

E. FATHOMETER:

A Ross Model 400A fathometer was used. This model operates at 50 K Hz. An Elac Deneb Model LAZ 17DDL; AGN8 fathometer was also used. This model operates at 20 K Hz. and is mainly used in water depths greater than 400 fathoms. Each fathogram was identified by line number, direction shot, time and date of first shotpoints and scale. The fathograms were labelled every 12 pops. The zero line for the fathograms was not corrected for the ship's draught.

F. SURVEY

The ships position at every pop was determined by Geonav II and a separate report will be supplied.

SECTION III

OPERATIONS

No major problems were encountered on this prospect. The weather was fair (force 2-4) with large swells, resulting in occasional noisy traces from front end and tailbuoy jerk.

The crew took advantage of time which would have otherwise been lost because of sea conditions to call into Portland to resupply.

Respectfully submitted,
GEOPHYSICAL SERVICE INTERNATIONAL

Charlie A. Martin
Marine Operations Mgr.

Quality Control Seismologist

APPENDICES

APPENDIX A

KEY PERSONNEL

C. ROWELL	Supervisor
T. KERLIN	Party Manager
B. PETTIGREW	Administrator
P. KEEGAN	Quality Control Seismologists
P. CHERNOFF	
D. LANYON	Instrument Engineers
M. MC LEAN	
T. MORGAN	Instrument Engineer Trainees
P. RIECHLE, J.TREVOR	Airgun Mechanics
P. STARK, A. DENNY	
J. FJAERIDE	Captain
J. GILBERT	Survey Supervisor
P. GOOWIN	Survey Operators
J. JESSKE	

APPENDIX B

EQUIPMENT

a) Recording

i) 3200 Meter Streamer (Plate 2)

Type Cable	:	48 live group, 47 dead group, neutrally buoyant, universal streamer
Length of live Section	:	50 meters
Length of dead Section	:	16 2/3/ meters
Length of Depth Transducer Section	:	2 meters
Distance Group 1 to 48 (centres)	:	3133 1/3 meters
Group interval	:	66 2/3 meters
Seismometer Type	:	Pavey Acceleration Cancelling
Seismometers per Group	:	30
Seismometer Interval	:	Linear, 3'9" except centre two which are 27'4" apart.

	Sensitivity	: 6.0 uV/u Bar
ii)	Recording Parameters	
	Amplifiers	: TI DFS III Binary Gain
	Gain Mode	: Binary Gain
	Record Length	: Normal 5.0 seconds
	Sample Rate	: 4 Milliseconds
	Gain Constant	: 30 db.
	Attack Rate	: 1500 db/sec.
	Final Gain	: 90 db.
	Trip	: As necessary
	Initial Gain	: 30-42 db.
	Upper Set Limit	: 62.5%
	Lower Set Limit	: 25%
	Filter -	
	Low Cut	: 8 Hz, 18 db/octave
	High Cut	: 62 Hz, 72 db/octave
	Release Rate	: Fast 94 db/sec.

Delay time for RAW Monitors caused by displacement of RAW and record heads	: 26.7 milliseconds

iii) Data Channel Allocations

Function	Monitor Trace No.	System	Tape Channel
Timing	-	Both	0
Streamer Odd Groups 1-47	1-24	System I	1-24
Streamer Even Groups 2-48	31-54	System II	1-24
Water Break 1 (between groups 2L-2D)	49	Both	31
Water Break 2 (between groups 10L-10D)	48	Both	28
Water Break 3 (between groups 20L-20D)	50	Both	29
Water Break 4 (between groups 30L-30D)	49	Both	31
Water Break 5 (between groups 40L-40D)	50	Both	27
Water Break 6 (infront of group 48)	48	Both	28
Field Time Break	4	System I	-
Field Time Break	28	System II	-
DFS Synthetic Time Break	8	System I	-
DFS Synthetic Time Break	32	System II	-

APENDIX C

OPERATION STATISTICS

Prospect	:	Portland - King Island
Operational period	:	26 Oct. - 29 Oct. 72
Time spent on recording	:	25.1 hours
Time lost due to bad weather	:	None, bad weather time was used to resupply.
Time lost due to other reasons (includes supplies, equipment failures and line changes).	:	42.5 hours
Field tapes used	:	41
Water depth range	:	395' - 200'
Total production mileage	:	166.68
Production shotpoints	:	8047
Autofires	:	14

b) Survey Vessel

M.V. "McDERMOTT II"

Flag	:	Bahamas
Homeport	:	Nassau
Trade	:	Foreign going.
Owners	:	World Wide Surveys Limited
Call Sign	:	ZQA - Z012
Length	:	171' L.O.A.
Breadth	:	39' 4- 7/8
Depth	:	14'
Draft	:	10'-11'
Official Number	:	343728
Gross Tonnage	:	911.66
Net Tonnage	:	244.21
Engine Horsepower	:	2 x 1150

APPENDIX D

LIST OF FIELD TAPES, SHOTPOINT NUMBERS AND MILEAGE

DATE	LINE	SHOTPOINTS	FIELD TAPE NUMBERS ODD	EVEN	MILEAGE
26 OCT 72	HO-21	001-3772	H-2	H-1	78.13
			H-4	H-3	
			H-5	H-4	
			H-7	H-6	
			H-8	H-7	
			H-10	H-9	
			H-11	H-10	
			H-13	H-12	
			H-14	H-13	
			H-16	H-15	
			H-17	H-16	
			H-19	H-18	
	HO-22	001-2738	H-20	H-19	56.71
27 OCT 72			H-22	H-21	
			H-23	H-22	
			H-25	H-24	
			H-26	H-25	
			H-28	H-27	
			H-29	H-28	
			H-31	H-30	
			H-32	H-31	

DATE	LINE	SHOTPOINTS	FIELD TAPE NUMBERS ODD	EVEN	MILEAGE
	HO-23	001-768	H-34	H-33	15.91
			H-35	H-34	
			H-37	H-36	
28 OCT 72	HO-24	001-824	H-38	H-37	19.93
			H-40	H-39	
			H-41	H-40	

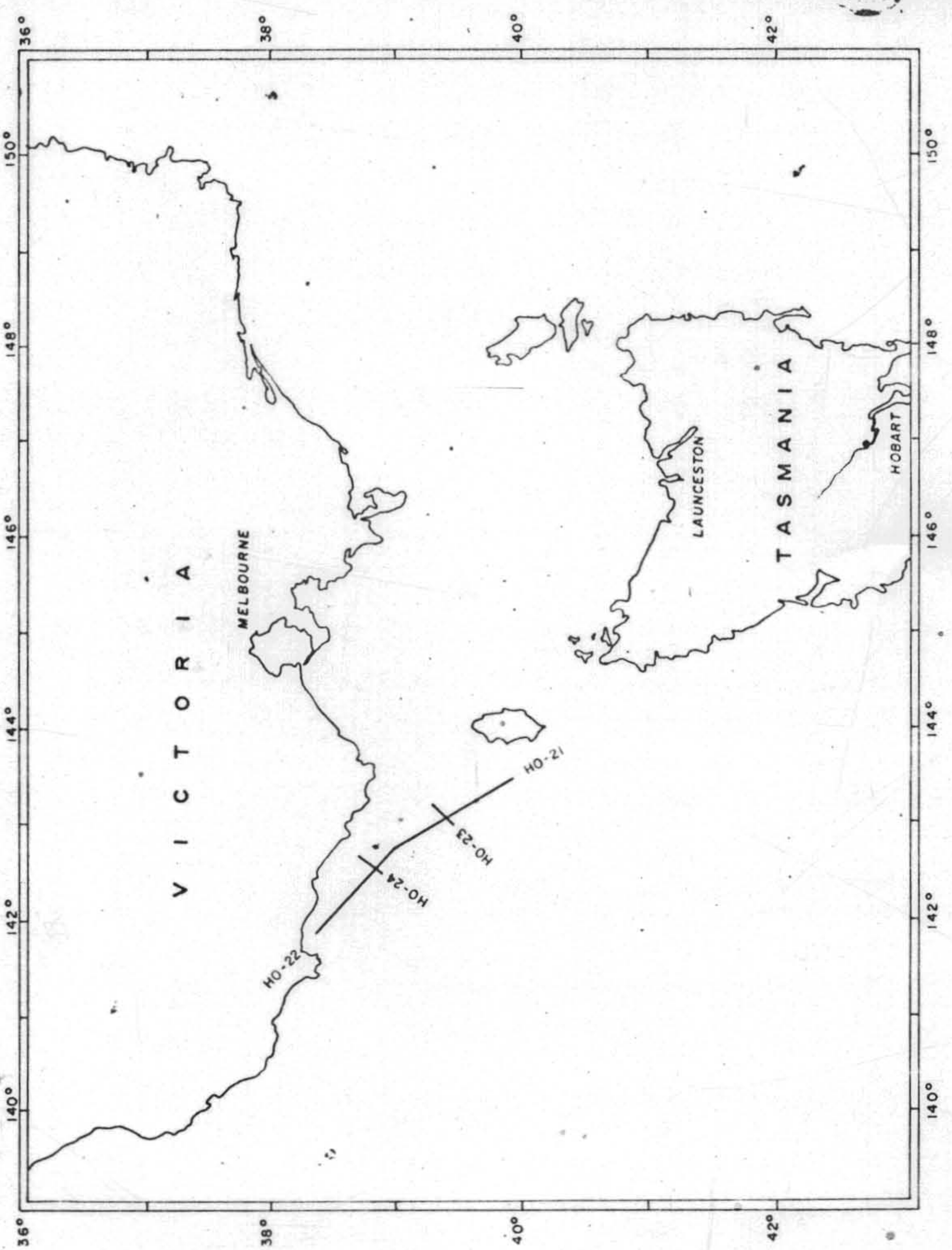
TOTAL MILES 170.68

CHARGEABLE MILES 166.68

GSI-709

PLATES

080046



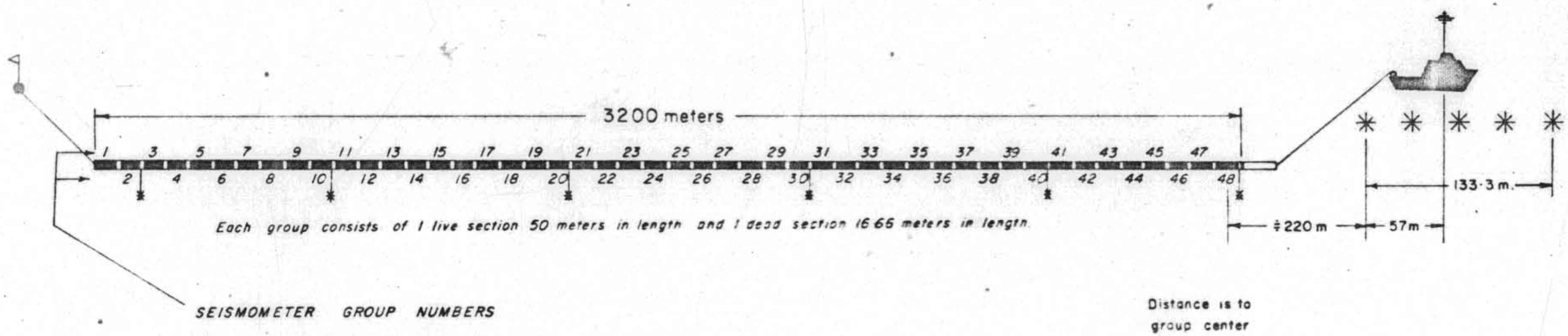
HEMATITE PETROLEUM PROPRIETARY LIMITED

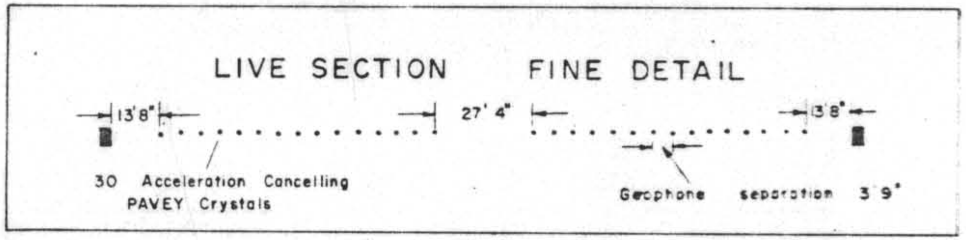
LOCATION OF PROSPECT
E04/2 PORTLAND KING ISLAND

GEOPHYSICAL SERVICE INTERNATIONAL PARTY 931

PLATE I

5 cm





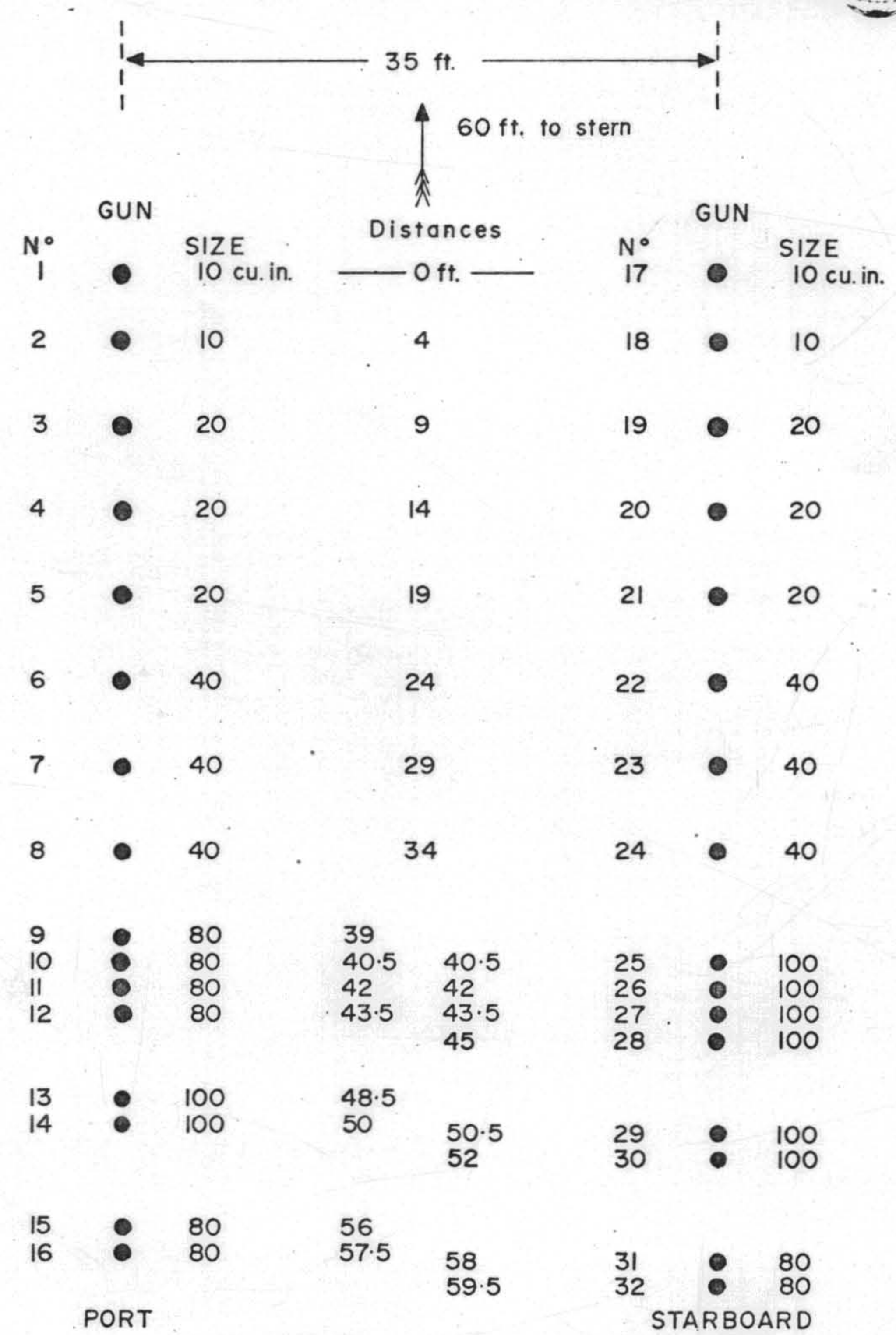
WATER BREAKS	DISPLAYED ON SEISMOGRAM TRACES	RECORDED ON TAPE CHANNELS
1	30	31
2	27	28
3	28	29
4	30	31
5	26	27
6	27	28

5 cm

MARINE CABLE DIAGRAM
3200 METER
(OFF END SPREAD – 48 GROUPS)
G.S.I. Party 931
Ship M/V Eugene Mc Dermott II
Client Hematite Petroleum Pty. Ltd.
Area E04/2 Portland King Island
Date October, 1972

PLATE II

080048



m/v EUGENE Mc DERMOTT II

AIR GUN ARRAY

0 5 feet

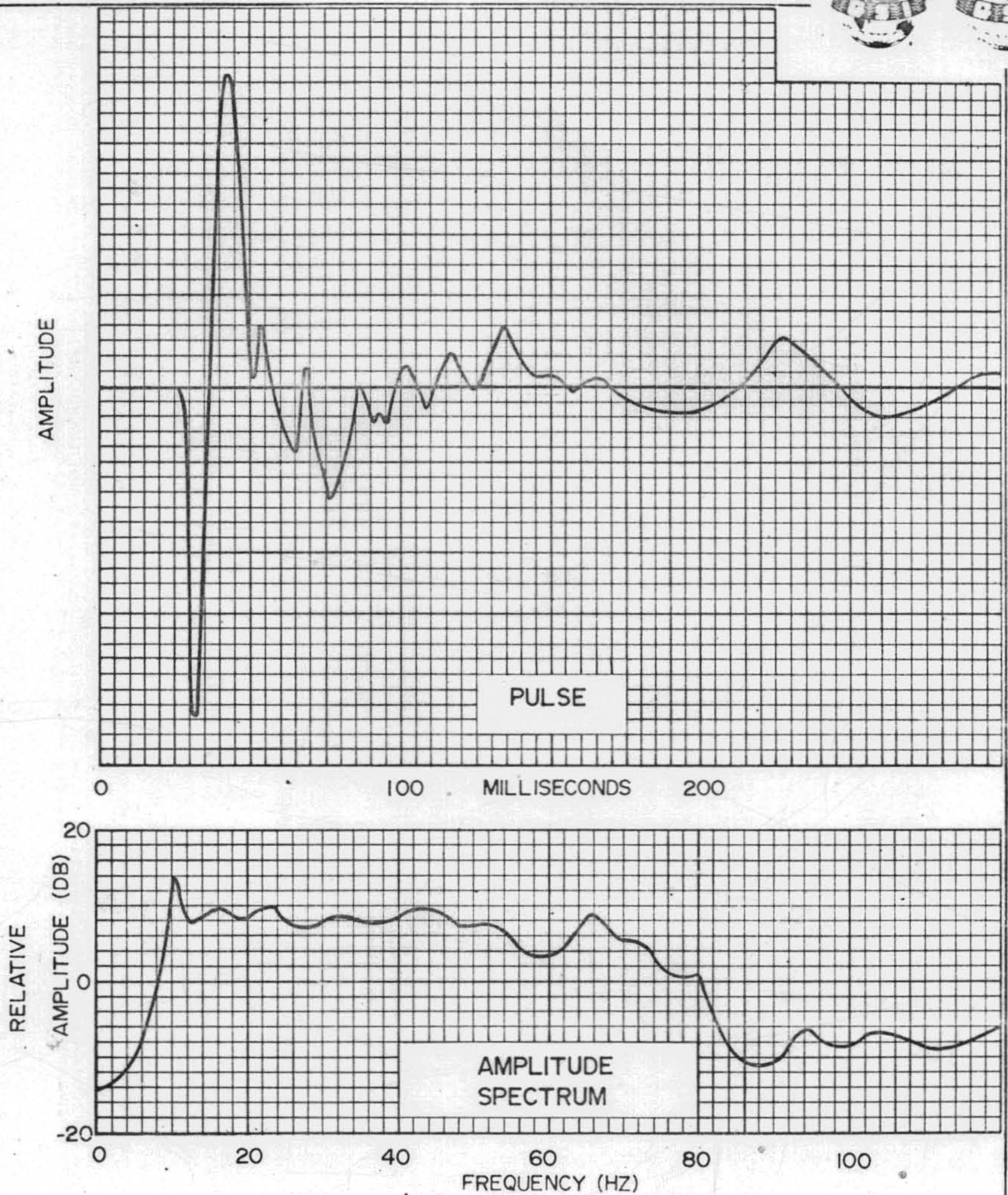
APRIL 1972

GSI-709

PLATE III

5 cm

080049



GUN	SIZES
4X10 CU. IN	2X80 CU. IN
6X20 "	2X100 "
6X40 "	1X200 "
	1X240 "

AIRGUN ARRAY PULSE AND SPECTRUM

Vessel EUGENE MCDERMOTT II
Array Capacity 1200 CU. IN
Recording Filter OUT - 248 Hz
Date FEB 1972

GSI-709

PLATE IV

5 cm

GSI-709

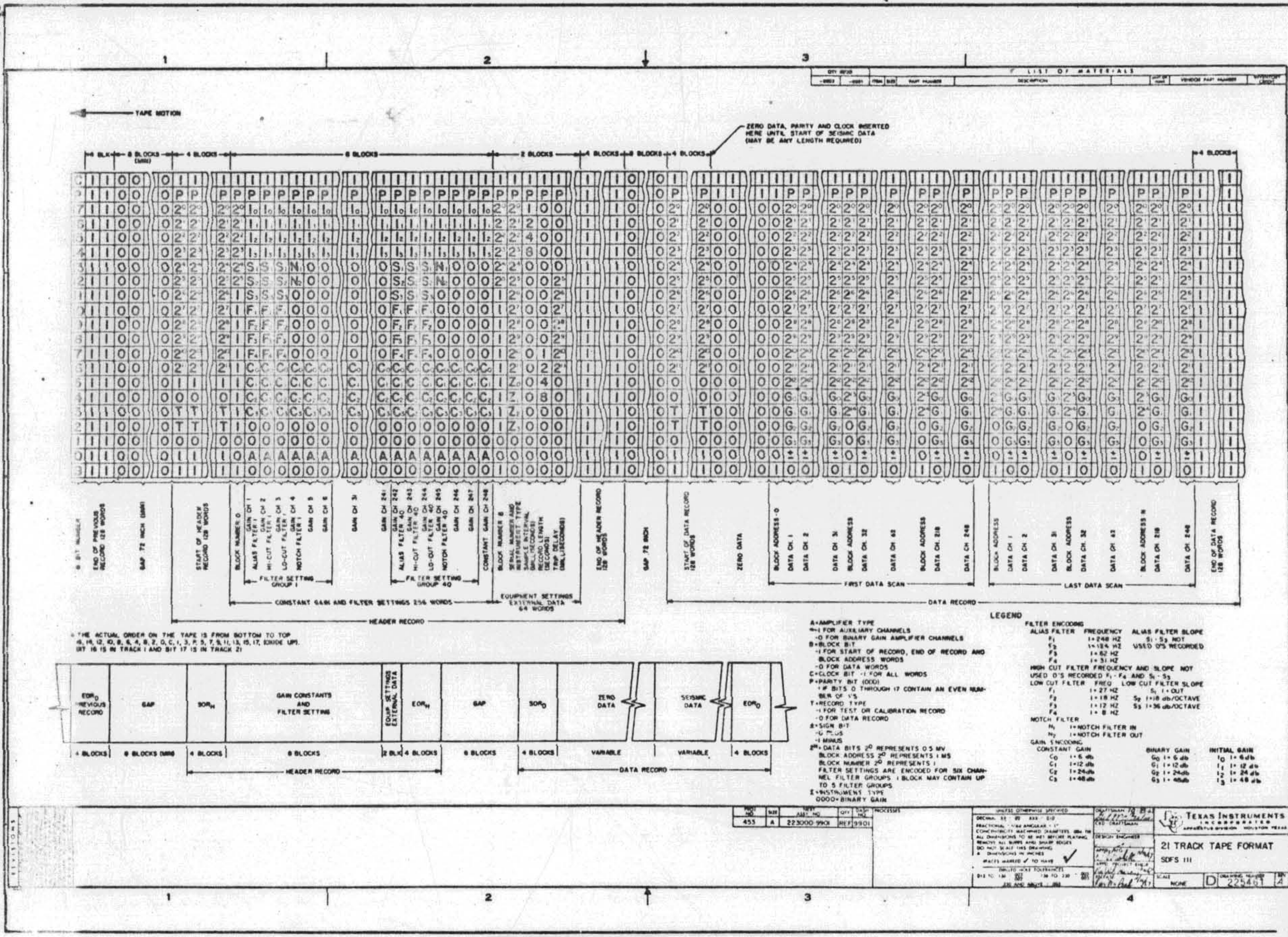


PLATE V

080050

5 cm

APPENDIX 2

PROCESSING REPORT

PROCESSING REPORT

MARINE SEISMIC SURVEY

PORTLAND-KING ISLAND
1972

For

HEMATITE PETROLEUM PTY. LTD.
140 William Street,
MELBOURNE. VICTORIA 3000

By

GEOPHYSICAL SERVICE INTERNATIONAL
120 Christie Street,
ST. LEONARDS. N.S.W. 2065

PARTY 101-HEM-1 - NOVEMBER, 1972 - JANUARY, 1973.

TABLE OF CONTENTS

SECTION I

INTRODUCTION

A marine seismic reflection survey of 166.68 miles was conducted by Geophysical Service International (M.V. "Eugene McDermott II") in the Portland-King Island area for Hematite Petroleum Pty. Ltd. between 26th October and 29th October, 1972.

All data were recorded as 48-fold common depth point coverage utilizing a 48 trace, 3200 meter, acceleration cancelling streamer under continuous tow and a 1300 cubic inch tuned airgun array. Field and survey operations are fully discussed under separate covers.

Digital data processing was performed in the Sydney and Singapore offices of Geophysical Service International. All data were vertically stacked (2 on 1) and processed as 24-fold CDP, 48 trace data. Continuous Velocity Analysis was determined by the 700 Package event detection module at our Singapore office.

Concurrently with this new survey, some re-processing of previous work in the area was carried out with G.S.I.'s latest 700 Package techniques.

The EO and EP surveys were shot 6-fold, dynamite, 2400 meter cable, 24 trace recording, symmetrical split (1967-1968). The ER survey was shot 48-fold, Aquapulse, 2400 meter cable, 24 trace recording, off-end (1968).

SECTION II

DIGITAL PROCESSING

The following processing sequence was applied to the data. All data were processed to a record time of 4.0 seconds at a sample period of 4 milliseconds.

A. SEQUENCE

1. Vertical Stack :

   a. True Amplitude Recovery.

   b. Trace Edit.

   c. Vertical Stack (as required).

2. Pre-Processing :

   a. Trace Edit.

   b. Pre-deconvolution Ramp Scaling.

   c. Static Corrections.

   d. Deconvolution.

   e. Time Variant Scaling.

   f. Common Depth Point Gather.

   g. Near Trace Gather.

   h. Annotation of Water Depth and Offset Information.

3. Velocity Processing :

Full 700 Package continuous velocity analysis.

a. Moveout scan, dip search and reflection identification.

b. Plot of picked events as a function of velocity, amplitude and dip.

c. V^2T plot.

d. Primary Segment Display.

4. Post-Processing :

a. Normal Moveout Correction.

b. Single-fold Display.

c. Common Depth Point Stack.

d. Time Variant Deconvolution (TVD).

e. Time Variant Filtering (TVF).

f. Display.

B. PROGRAM AND PARAMETER DETAILS

1. Vertical Stack :

a. True Amplitude Recovery (TAR)

TAR was applied to all field records. This process removed the gain imposed by the DFS III Binary Gain Control System and corrected for inelastic attenuation and spherical divergence losses.

b. Trace Edit

Trace editing (zeroing or polarity reversing) was performed, where applicable, using the field playbacks and field quality control reports as a guide.

c. Even/Odd Vertical Stack (New Shooting)

Even/Odd Vertical Stack was performed reducing the 48-fold common depth point coverage to 24-fold. The Even 24 groups were stacked with the Odd 24 groups of the succeeding shot. Although an offset mix was involved, by using the Even and Odd groups from consecutive shots any depth point smear was eliminated. Tests indicated this method of Vertical Stack produced the best results in the deeper zones of interest. Using the field Q.C. reports as a guide, as well as on a random basis, the Vertical Stack records were displayed for further editing.

2 on 1 Vertical Stack (ER Survey)

The Aquapulse shooting required reduction from 48-fold coverage to 24-fold coverage. This was performed by stacking the traces of the first shot with the traces of the second shot, the third with the fourth, etc.

The six-fold recording was not stacked prior to CDP gather.

2. Pre-Processing :

a. Trace Edit

Trace editing was performed based on the Vertical Stack displays. This consisted primarily of trace zeroing.

b. Pre-deconvolution Ramp Scaling

Pre-deconvolution ramp scaling was designed to suppress direct arrival energy. This was to prevent the high amplitude direct arrivals from being "blown-up" when the deconvolution operator was applied.

c. Static Corrections

Static corrections were applied to correct for a sea level datum. A positive static correction was applied to compensate for the depth of the airgun array and streamer below sea level. A water velocity of 5000 ft./sec. was assumed when making these corrections.

d. Deconvolution

The approximate deconvolution was accomplished by the application of a whitening filter designed from auto-correlation functions, which were derived from the trace to be deconvolved. Two filters were designed per trace and applied with a 50% overlap, such that the first filter tapered off while the second filter tapered on. The operators were designed as double section operators; i.e., to dereverberate the first and second water bottom reverberations.

e. Time Variant Scaling (TVS)

Time Variant Scalers were computed and applied in time gates to make the average absolute amplitude in each gate equal to a constant. A scaler was computed for each gate on each trace and linearly ramped from a maximum at the gate centre time to zero at the centre times of the adjacent time gates prior to application. Each trace was divided into equal time gates of 500 milliseconds. The initial time of the first gate was maintained at approximately 100 milliseconds after the direct arrival energy. For the dynamite shooting, due to high amplitude first arrivals, each trace was divided into consecutive time gates of 200, 200, 300, 400, 400, 400, 500 milliseconds.

f. Common Depth Point (CDP) Gather

All data were output from the Pre-Processing Module in CDP format. For the data now reduced to 24-fold, each 24 trace output record represented one CDP point.
For the six-fold data, each 24 trace output record represented four CDP points.

g. Near Trace Gather

As a processing aid, a near trace gather section was also output. This single-fold section consisted of the shortest offset trace from each CDP gather after the above processes were applied. These sections were displayed with a bandpass filter applied.

H. Annotation

The offset and the shot plus receiver water depth for each trace was annotated in channel 25 of the CDP gather record.

3. Velocity Analysis :

1. Program 700-2 provides a continuous velocity analysis technique which was used to determine the complete velocity field along a line.

   Inputs to this program are pre-processed CDP gather records. For the 2400 meter, 24 trace data (EO, EP and ER Surveys) every depth point was submitted. For the 3200 meter, 48 trace data (HO Survey) only data from one system (Evens) were submitted, resulting in alternate depth point processing.
   On these CDP records the following processes were performed:-

o Moveout and Dip Scan Building -

  A moveout scan is generated for each depth point and is formed by the application of a constant shift to each trace in proportion to the square of the offset of the trace and then stacking by mixing together all the traces in the gather to form a scan trace. The moveout applied is then incremented by a constant amount and the process repeated until the range of moveout applied exceeds the expected seismic range.

Dip scans are built by stacking together series of moveout scans from consecutive depth points along linear planes of dip which are automatically incremented within a specified dip aperture designed to cover the expected range of dips on the seismic section. Dip apertures for each processing time gate were determined from near trace gather sections. The number of consecutive moveout scans stacked to form a dip scan is termed the SMASH rate and may also vary with the time gates.

- Interpretation of Moveout/Dip Scans to detect valid events with time, amplitude and moveout, and dip information -

  The automatic interpretation is based on the fact that any coherent event on the gather record will stack at the optimum moveout value to a maximum (or minimum for negative values) in the two-dimensional time moveout plane of the scan. When stacking again takes place along the dip plane, which most approximates the true geological time-dip, maximum dip scan response will be achieved. The dip scan domain is a three-dimensional one in which every coherent event from the input gather records will be represented by a maximum or minimum at that time, moveout and dip which correctly describes the original seismic event.

The resulting "TAMD picks" represent the mean time, amplitude, moveout and dip of the seismic event over a space gate of width SMASH depth points. The move-up rate is another important consideration. It refers to the number of depth points between the centre of each successive dip scan set and for these lines was made equal to the SMASH rate to give a continuous suite of dip scan sets.

- Output to magnetic tape the event files for each Space/Time gate -

  After the event detection is performed for all space points in each time gate the Event files are written on magnetic tape.

- Extensions of the Event files in each time gate to produce work files -

  Using search windows in time, amplitude, moveout and dip, the picked seismic events from neighbouring dip scan files can be correlated and those evolving from the same seismic horizon identified and connected. This process is called Extension and the set of connected seismic horizon events are termed Segments which are output as Work (Segment) files.

o Summary files and Consolidation files -

After all time gates have been processed, the program outputs Summary and Consolidation files in the following manner.

- Hook-up of segments between time gates to allow continuous segments across time gates.

- Output Summary Files.

- Consolidation of Summary files into continuous segments with time, amplitude and moveout at every depth point.

- Output of Consolidated Segment files on magnetic tape to be submitted for display on analysis routines.

2. Program 701 - Velocity Analysis Module - provides statistical displays (scattergrams of velocity, amplitude and dip as a function of time over the entire space and also over specified space gates. The RMS velocities are computed from the segment times and moveouts averaged over each space gate and plotted as a coded symbol for each segment. The symbols are coded according to segment length within each space gate or according to the relative length in the entire Consolidated file. The highest amplitude segment within each 100 msec. gate is also shown by circling the rank or grading symbol. Dip and amplitude information is plotted on the right-hand side of the velocity versus time plot.

A scattergram with a listing was generated for the entire space and for each individual space gate.

All segments appearing on the scattergrams were plotted again as velocity squared times time on the V^2T plots. A line drawn through points plotted implies an interval velocity equal to the velocity of the V^2T line to which the drawn line is parallel.

3. Program 602 - Segment Sort and Display - displays the Consolidated file in a fashion suitable for section overlay. Various sorting and annotation techniques are available to aid in the interpretation of the file.

Initially, the total file was displayed as a quality control measure. Only segments greater than 12 depth points were plotted with segment numbers annotated on segments longer than 24 depth points.

The final displays (segments 6 d.p.).

a) Primary Peaks with RMS velocities averaged and annotated every 10 depth points.

b) Primary Troughs with RMS velocities averaged and annotated every 10 depth points.

c) Primary Peaks and Troughs with every segment number annotated.

Input to Program 602 was the Consolidated file and output was on CRT frame. These were enlarged to a horizontal scale of the section to be overlain (see "Display").

4. Post-Processing :

The CDP gather records were input to the Post-Processing Module and the following processes applied:-

a. Normal Moveout Correction

The Normal Moveout Correction was performed utilizing the velocity functions interpreted from the scattergrams. A velocity function was input at the location of each velocity module. A linear interpolation was performed between these functions and a velocity function calculated for and applied to each of the intermediate depth points. All velocity functions are referenced to the water top.

b. Single-Fold Display

A single-fold section with the final stacking velocities applied was generated from the normal moveout program. This section was filtered and displayed on paper.

c. Common Depth Point Stack

Common Depth Point Stack was performed with a scaling response equal to the square root of the number of live traces divided by the fold. The first break suppression ramps were derived from single-fold records, to remove unwanted water borne energy, refractions and low frequencies due to stretching in the moveout process.

d. Time Variant Deconvolution (TVD)

Time Variant Deconvolution is a multiple operator, whitening, deconvolution designed from and applied to each trace in a series of overlapping gates. Two operators were used on all lines. The TVD operators were designed from two 50% overlapping gates extending from 200 msec. below the water bottom to 4000 msec.

e. Time Variant Filtering (TVF)

A time variant, zero phase, digital filter was applied as shown on the side panel of each record section.

f. Display

All plotter displays were in a wiggle trace/variable area format at a horizontal scale of .5 mile/inch and a vertical scale of 3.75 inches/second.
For the 3200 meter, 48 trace, streamer this resulted in trace spacing of 24 traces/inch.
For the 2400 meter, 24 trace, streamer 16 traces/inch were used.

SECTION III

DISCUSSION

The 3200 meter streamer, as opposed to the 2400 meter streamer, produces more reliable velocity information due to the increased offset. Stack response is improved especially below 2800 milliseconds where the data becomes full 24-fold. Multiple attenuation is optimised with the increase in normal moveout differences between primary and multiple reflections.

Shallower data, however, suffers from a decrease in coverage. This decreased fold needs to be weighed against the multiple problem in the area.

G.S.I. would like to thank Mr. J.I. Denham of Hematite Petroleum Pty. Ltd. for his assistance and co-operation during the processing of this survey.

Respectfully submitted,
GEOPHYSICAL SERVICE INTERNATIONAL

W. Pailthorpe - Party Chief

K.W. Graybill - Supervisor

APPENDIX A

FINAL STACK, TAPE LOGS

080070

TIAC PROCESSING TAPE LOG GSI-865-A

REEL TVD-64160 PROCESS TVD PROSPECT OTWAY

LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS	LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS
EP-51	6392				1001		Eo-54	17913				601	
					1002								
					3								
	6470				16			18000				620	
Eo-37	10469				21		EP-52	6609				631	
												3632	
												633	
	10594				45			6754				661	
EP-10	4324				201		Eo-71	17799				701	
												703	
												3704	
	4450				225							705	
EP-14	4461				301								
								17909				723	
							Eo-29	5849				731	
	4582				325								
EP-12	4583				401							745	
												3746	
	4726				431							3751	
Eo-24	8259				501							752	
					510								
					3511			6000				762	
							Eo-31	6119				231	
					3514								
					515								
	8255				520			6182				243	

AC PROCESSING TAPE LOG GSI-883-A

080071

REEL ________ PROCESS ________ PROSPECT ________

LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS
EO-39	1377				121	
					125	
					3126	
					3132	
					133	
	1535				154	

080072

TIAC PROCESSING TAPE LOG G91-665-A

REEL TVD-6850 PROCESS TVD PROSPECT OTWAY

LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS	LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS
ER-39	7580				1								
	7755				37								
ER-61	7902				41								
	8026				66								
ER-45	7145				101								
	7315				136								

080073

TIAC PROCESSING TAPE LOG GSI-665-A

REEL TVD. 6625 PROCESS TVD PROSPECT OTWAY

LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS
Ho-24	1				1001	
	400				1023	
	401				1031	
	825				1054	
Ho-23	1				331	
	768				372	
Ho-22	1				4001	
	2738				4165	

080074

TIAC PROCESSING TAPE LOG GSI-865-A

REEL TVD-5692 PROCESS TVD PROSPECT OTWAY

LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS	LINE	S.P. OR PROFILE	REQUEST #	INPUT RECORD	INPUT REEL	OUTPUT RECORD	REMARKS
H69-21	1				61								
	3773				520								

APPENDIX B

LINE AND SHOTPOINT INDEX

LINE	SHOTPOINTS	SHOT	MILES
E0-24	8260-8359	Jan. 1967	12.375
E0-29	5850-6000	"	18.750
E0-31	6120-6183	"	7.875
E0-37	10470-10594	"	15.500
E0-39	7377-7535	"	19.750
E0-54	18000-17913	"	10.875
E0-71	17800-17909	"	13.625
EP-10	4325-4445	Jan. 1968	15.000
EP-12	4583-4726	"	17.870
EP-14	4462-4582	"	15.000
EP-51	6393-6470	"	9.620
EP-52	6755-6610	"	18.125
ER-39	7580-7755	Nov. 1968	21.875
ER-45	7145-7315	"	21.250
ER-61	7902-8024	"	15.250
H0-21	1-3772	Oct. 1972	78.130
H0-22	1-2738	"	56.710
H0-23	1-768	"	15.910
H0-24	1-824	"	15.930

APPENDIX C

PARAMETERS FOR 700 PACKAGE

LINE	SHOTPOINTS	TIME GATES (msec.)	SMASH RATE	DIP WINDOW (msec.)
EP-10	4325-4446	200-800	2	-3, 3
		800-1600	4	-5, 5
		1600-4000	6	-10, 7
EP-12	4584-4726	200-800	2	-3, 4
		800-1600	4	-7, 9
		1600-4000	6	-10, 7
EP-14	4462-4578	200-800	2	-5, 3
		800-1600	4	-5, 4
		1600-4000	6	-7, 6
EP-51	6393-6470	200-800	2	-8, 10
		800-1600	4	-7, 8
		1600-4000	6	-5, 6
EP-52	6610-6750	200-800	2	-11, 10
		800-1600	4	-7, 9
		1600-4000	6	-7, 10
EO-24	8260-8355	200-800	2	-9, 8
		800-1600	4	-7, 9
		1600-4000	6	-11, 7

LINE	SHOTPOINTS	TIME GATES (msec.)	SMASH RATE	DIP WINDOW (msec.)
EO-29	5850-6000	200-800	2	-10, 10
		800-1600	4	-6, 8
		1600-4000	6	-10, 9
EO-31	6120-6179	200-800	2	-4, 4
		800-1600	4	-4, 7
		1600-4000	6	-6, 8
EO-37	10470-10588	200-800	2	-2, 5
		800-1600	4	-6, 9
		1600-4000	6	-8, 6
EO-39	7379-7535	200-800	2	-10, 5
		800-1600	4	-7, 6
		1600-4000	6	-9, 8
EO-54	17914-18000	200-800	2	-3, 3
		800-1600	4	-7, 9
		1600-4000	6	-10, 14
EO-71	17800-17905	200-800	2	-2, 6
		800-1600	4	-8, 7
		1600-4000	6	-9, 9
ER-39	7580-7640	200-800	2	-4, 6
		800-1600	4	-7, 5
		1600-4000	6	-9, 8

LINE	SHOTPOINTS	TIME GATES (msec.)	SMASH RATE	DIP WINDOW (msec.)
ER-39	7640-7702	200-800	2	-2, 4
		800-1600	4	-4, 8
		1600-4000	6	-8, 8
	7700-7752	200-800	2	-3, 8
		800-1600	4	-4, 9
		1600-4000	6	-5, 10
ER-45	7145-7207	200-800	2	-5, 6
		800-1600	4	-2, 9
		1600-4000	6	-4, 8
	7205-7267	200-800	2	-3, 4
		800-1600	4	-3, 8
		1600-4000	6	-6, 9
	7265-7315	200-800	2	-2, 4
		800-1600	4	-5, 5
		1600-4000	6	-8, 4
ER-61	7902-7964	200-800	2	-2, 6
		800-1600	4	-3, 8
		1600-4000	6	-7, 10
	7962-8023	200-800	2	-4, 5
		800-1600	4	-7, 5
		1600-4000	6	-10, 6

LINE	SHOTPOINTS	TIME GATES (msec.)	SMASH RATE	DIP WINDOW (msec.)
HO-21	1-479	180-800	3	-12, 6
		800-1600	3	-16, 16
		1600-4000	4	-14, 20
	433-911	180-800	3	-4, 4
		800-1600	3	-8, 8
		1600-4000	4	-16, 20
	865-1343	180-800	3	-3, 3
		800-1600	4	-4, 6
		1600-4000	6	-4, 11
	1297-1775	180-800	3	-12, 14
		800-1600	3	-10, 8
		1600-4000	4	-18, 14
	1729-2207	150-800	3	-3, 4
		800-1600	4	-3, 4
		1600-4000	6	-5, 6
	2161-2639	150-800	3	-4, 4
		800-1600	4	-4, 6
		1600-4000	6	-4, 7
	2593-3071	150-800	3	-4, 4
		800-1600	4	-4, 5
		1600-4000	6	-7, 6

LINE	SHOTPOINTS	TIME GATES (msec.)	SMASH RATE	DIP WINDOW (msec.)
HO-21	3025-3503	150-800	3	-4, 5
		800-1600	4	-5, 5
		1600-4000	6	-7, 7
	3457-3727	150-800	3	-4, 5
		800-1600	4	-5, 5
		1600-4000	6	-7, 7
HO-22	1-479	160-800	3	-4, 10
		800-1600	4	-5, 7
		1600-4000	6	-5, 8
	433-911	160-800	3	-7, 12
		800-1600	4	-7, 12
		1600-4000	6	-7, 10
	671-1150	160-800	3	-10, 16
	Re-run with wider dip windows	800-1600	3	-10, 16
		1600-4000	4	-16, 20
	865-1343	160-800	3	-6, 8
		800-1600	4	-5, 7
		1600-4000	6	-9, 9
	1297-1775	150-800	3	-6, 9
		800-1600	4	-6, 9
		1600-4000	6	-7, 9

LINE	SHOTPOINTS	TIME GATES (msec.)	SMASH RATE	DIP WINDOW (msec.)
HO-22	1729-2207	140-800	3	-7, 9
		800-1600	4	-7, 9
		1600-4000	6	-6, 9
	2161-2639	140-800	3	-4, 5
		800-1600	4	-4, 6
		1600-4000	6	-4, 7
	2593-2693	130-800	3	-3, 5
		800-1600	4	-4, 3
		1600-4000	6	-4, 4
HO-23	1-476	180-800	3	-6, 8
		800-1400	3	-5, 10
		1400-2200	4	-14, 16
		2200-4000	6	-14, 18
	433-720	180-800	3	-6, 8
		800-1400	3	-5, 10
		1400-2200	4	-14, 16
		2200-4000	6	-14, 16
HO-24	1-353	150-800	3	-4, 8
		800-1600	3	-16, 10
		1600-2400	4	-14, 7
		2400-4000	6	-12, 8
	401-779	150-1000	3	-4, 8
		1000-2000	4	-14, 8
		2000-4000	6	-6, 7

HEMATITE PETROLEUM PROPRIETARY LIMITED

LOCATION OF PROSPECT

EO4/2 PORTLAND KING ISLAND

GEOPHYSICAL SERVICE INTERNATIONAL PARTY 931

5 cm

PLATE 1

080082

APPENDIX 3

NAVIGATION REPORT

080084

GEONAV SURVEY
OF THE
OTWAY BASIN

Prepared for

HEMATITE PETROLEUM PROPRIETARY LIMITED

Prepared by

GEOPHYSICAL SERVICE INTERNATIONAL

February 1973

GSI-709

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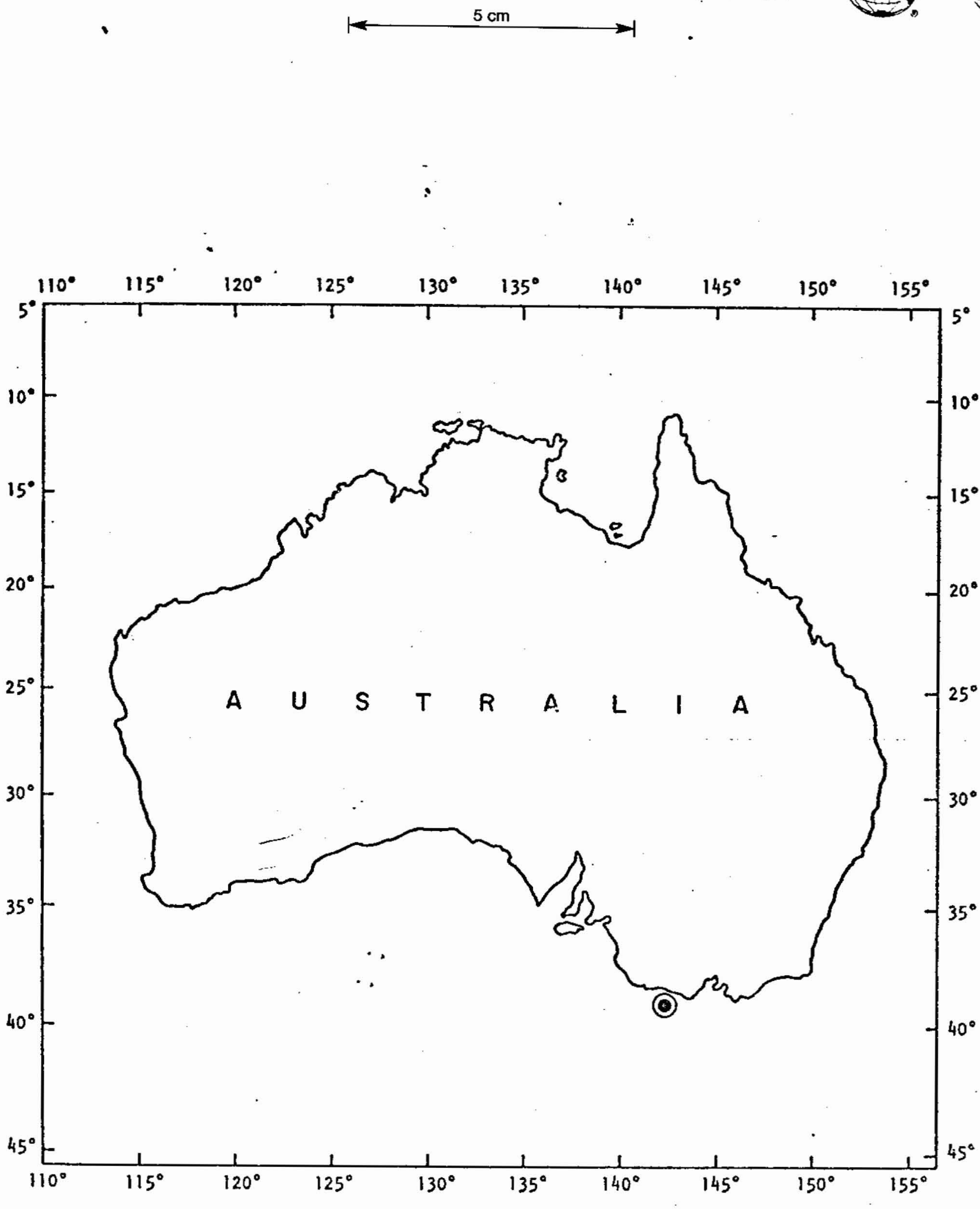

Figure 1. Location of Area Surveyed

INTRODUCTION

From 26 October to 29 October 1972, Geophysical Service International, Party 931, aboard the M/V McDERMOTT II conducted a marine geophysical survey for Hematite Petroleum Proprietary Limited in the Otway Basin. The prospect, designated the Portland-King Island prospect, is located near 39° S latitude and 143° E longitude (Figure 1).

GEONAV, an integrated satellite positioning system (described in Appendix A), was the onboard navigation system and provided horizontal control for the survey. No secondary system was used in this project.

Mylar base maps, scaled 1:100,000 and 1:250,000, showing shotpoint locations were generated at the processing center. The maps, employing a Transverse Mercator projection and standard U.T.M. parameters, have been submitted under separate cover. Grid and graticule listings of the shotpoints have also been submitted prior to this report. The shotpoint locations are based on the Australian National Spheroid and the Australian Geodetic Datum.

SUMMARY OF OPERATIONS

The seismic survey was conducted with an airgun energy source and a 3200-m, 48-group streamer. A 33-1/3-m shotpoint interval was controlled by the GEONAV system, and the position of each shotpoint was recorded on magnetic tape. This shotpoint interval produced 48-fold seismic data. Shotpoint positions represent the center of the airgun array at the moment of discharge. The plot frequency for the 1:100,000 scale map is every sixth (6) shotpoint and for the 1:250,000 scale, every twenty-fourth (24) shotpoint. Only satellite fixes occurring during the shooting of a line are plotted or annotated in the listings.

The lines, the first and last shotpoints, and the direction of shooting are identified in Table 1. Lines appear in the order shot and any pecularities are described in the footnotes.

GEONAV operated quite well during the survey. The maximum time between fixes while on line was 2-3/4 hours; most fixes were less than 1-1/2 hours apart. The beginning and ending line coordinates where given to the GEONAV operator by the client representative on board. The coordinates were referenced to the local datum; therefore, a constant +3.17' in latitude and -3.42' in longitude were applied to all coordinates to convert to the global datum to which the satellite navigation is referenced. The weather was generally fair but the boat stopped shooting prior to Line H-23 due to heavy seas and returned to port and waited a day. While docked at Portland, 17 fixes were taken to refine the correction factors used to "shift" the local datum to the APL.

In processing the navigation data, another datum transformation from APL to the Australian Geodetic Datum, was applied to shotpoint and satellite positions. This "shift" is a nonconstant transformation accomplished by using weighted mean shifts of the origin of one datum with respect to the other. Transformation parameters are determined beforehand by comparing coordinates at known points on the local datum with coordinates for the same points obtained by satellite fixes. The parameters used to transform the datums in this project are values published in the Smithsonian Astrophysical Observatory Special Report 200. The values are

$$\Delta X = -89 \text{ m} \qquad \Delta Y = -34 \text{ m} \qquad \Delta Z = +86 \text{ m}$$

The standard deviation of these values is given as ± 13 m.

After the datum shift was accomplished, U.T.M. coordinates, using zone-54 parameters and the Australian National Spheroid, were computed and used for final mapping and listing. The defining values for the Australian National Spheroid are

GSI-709

Semimajor axis: 6,378,160.0 m

Flattening: $\frac{1}{298.25}$

Table 1

LINE NUMBER, FIRST AND LAST SHOTPOINTS, AND DIRECTION SHOT

Line No.	First Shotpoint	Last Shotpoint	Direction Shot
HO-21	1	3772	SE - NW
HO-22	1	2738	SE - NW
HO-23	1	768	NE - SW
HO-24	1	401(1)	SW - NE
HO-24A	401	824	SW - NE

(1)Circle due to excessive streamer noise

APPENDIX A

GEONAV POSITIONING SYSTEM

APPENDIX A

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LIST OF ILLUSTRATIONS

APPENDIX A*

GEONAV** POSITIONING SYSTEM

A. INTRODUCTION

The GeoNav integrated marine navigation system records and displays continuous position computed from U.S. Navy navigation satellite, doppler sonar, gyrocompass, attitude control, and velocimeter data. The system performs automatic line and shot control based on distance-measured equal shotpoint spacing along the great circle path between the end positions of a seismic line.

B. FIELD OPERATION

The GeoNav system computes the great-circle path for a seismic line based on end points input as geographical positions by the GeoNav operator. While on-line, the vessel's deviation from the great-circle path is plotted on a pair of track plotters to a preset scale (normally 200 m/in). One of these plotters is on the bridge, where the helmsman steers the vessel to minimize deviations as they are plotted.

Automatic shot control is obtained by measuring the distance traveled on the surface. Each time the required pop interval is traversed the digital field system and the shot relay for the seismic energy source are activated automatically. The required pop interval is computed from group and coverage information input by the operator.

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* This appendix is adapted from a paper entitled, "Self-contained Quality Control in Marine Satellite Navigation," by John M. Hughes and Rudolf Unger, presented at the 27th Annual Meeting of the Institute of Navigation, June 29, 1971 in Pasadena, California.

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The line and shot control module allows for extensions at either end of a line, line deflections (doglegs), and circling. In all these cases, continuity of shotpoint spacing along the great-circle path is preserved automatically. Subsurface coverage at the beginning and end of a line is guaranteed by taking into account possible position shifts due to satellite fix corrections and by computing the appropriate lead-in and lead-out. The track-plotters output a special lead-in display for each line and annotates line parameters, shotpoints, and satellite fixes.

All shotpoint positions, line parameters, position fixes, and other relevant navigation data are recorded on magnetic tape. Hardcopy redundancy of this recorded data is provided by teletype printout and track-plotter annotation.

C. POST MISSION PROCESSING

The navigation accuracy obtainable in real time is improved in post mission processing by infinite time smoothing of the recorded navigation data. Shotpoint and satellite fix positions are weighted against "past" and "future" position information using statistical filtering parameters based on satellite variance estimates and velocity and heading calibration factors output at each satellite fix.

Post mission processing also computes the position shift from satellite receiver antenna position to any desired offset position (seismic source, common depth points, etc.), and the position shift due to conversion from the APL* satellite system reference ellipsoid to a given local datum.

*Applied Physics Laboratory, Johns Hopkins University.

The post mission processing end product is the computerized map and listing of transverse Mercator projected positions.

D. SYSTEM DESCRIPTION

1. General

The GeoNav system establishes its absolute geographical location from information transmitted by satellites of the U.S. Navy Navigational Satellite System. The vessel's continuous path of travel is computed by a dead reckoning system consisting of a velocity measurement system (VMS) and an azimuth measurement system (AMS). The VMS derives its values from four-beam independent doppler sonar velocity measurements compensated for the ship's pitch and roll, and for variations in the sound propagation velocity. The AMS consists of a gyrocompass externally compensated for the ship's dynamics.

At intervals averaging approximately 1.5 hours at the equator and less at higher latitudes, the dead reckoned position is corrected by a satellite position fix. Each satellite fix printout contains an estimate of fix accuracy and provides calibration factors for the dead reckoning system. In this manner, a self-contained quality control is established.

The Navy currently has five satellites in non-synchronous, circular, polar orbits of about 600 mi. altitude. A core memory onboard the satellite contains its orbital position information which is updated approximately every 12 to 18 hours from ground tracking and injection stations. The satellite continuously transmits this data as its navigation message phase encoded onto two carrier frequencies.

The vessel's satellite receiver automatically locks onto the satellite signals when it appears in sight. A satellite pass may have a duration of up to 20 minutes during which period the satellite navigation message is redundantly received, and a number of integrated doppler frequency shift (doppler count) measurements are acquired. From the navigation message the satellite positions along its orbit are derived. The doppler counts yield measures of range difference between the vessel position and the satellite positions along its orbit. Comparing the doppler shifts of the two carrier frequencies permits elimination of the ionospheric refraction influence. Automatic data editing and an iterative process of fitting computed and measured range differences ultimately result in a correction to the dead reckoned position.

Besides the tasks of navigation and data quality control, the GeoNav computer performs the line and shot control as described in Section B.

2. Detailed Description

Figure 1 is a block diagram of the GeoNav system as configured for GSI. The system employs a Magnavox MX702CA satellite receiver configured for the transfer of doppler counts synchronized with the completion of each line of the satellite message (a line takes 4.6 sec of the 2-min cycle). This permits implementation of the so-called "short doppler" satellite solution whereby the doppler counts are integrated over segments corresponding to an integer multiple of satellite lines.

The satellite receiver also receives both of the two transmitted satellite frequencies, demodulates the signals, and organizes the demodulated bits into 12-bit data words for transfer to the computer. Each 12-bit data word is accompanied by three bits of code which identify the nature of the data being transferred. Also a part of the satellite receiver is a 5-MHz oven-stabilized crystal oscillator which is the reference oscillator for the

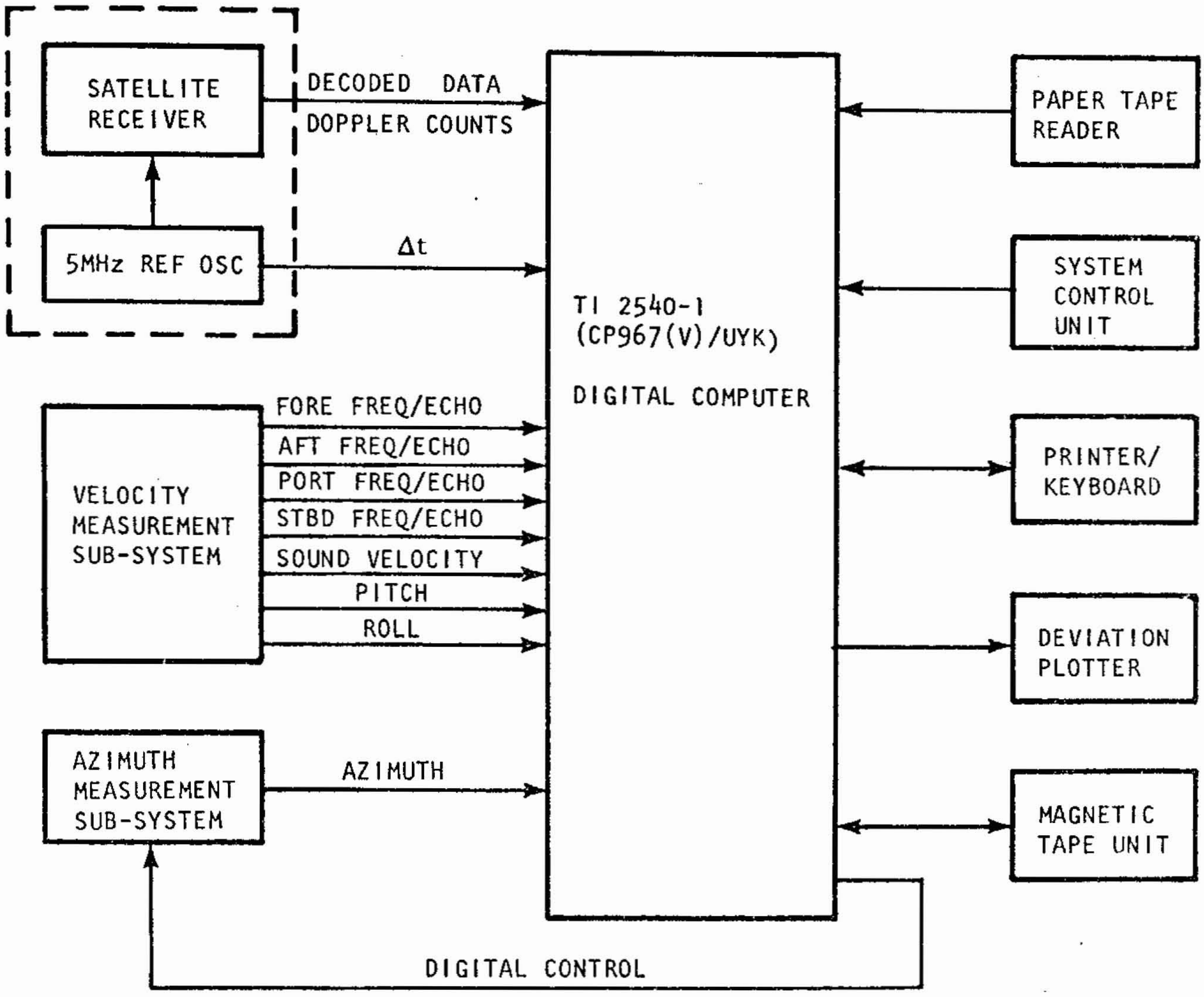


Fig. 1. GeoNav System Block Diagram.

satellite receiver in addition to being the relative time reference for the GeoNav system.

Figure 2 is a block diagram of the GeoNav velocity measurement subsystem. The sonar transducer and associated electronics are the Edo Western 435C pulse-frequency tracking system modified by Texas Instruments to yield only the frequencies of the four sonar beams (Figure 2 shows only one channel) and the time of arrival of their echoes.

The GeoNav velocity measurement subsystem provides parameters for computing the vessel's velocity in a plane tangent to the earth's surface. Components of this velocity are the projections of the ship's fore-aft and port-starboard axes on this tangent plane. To permit navigation from these data, these velocity vectors must be resolved into velocity components in northerly and easterly directions.

Figure 3 is a block diagram of the GeoNav azimuth measurement subsystem. Basic to it is the Sperry MK227-0 gyrocompass which provides X1 and X36 synchro outputs of vessel azimuth in addition to a 400-Hz reference, the amplitude of which is modulated by control from the computer, utilizing an amplitude modulator built by Texas Instruments. This external control from the computer is derived from an algorithm which compensates the gyrocompass for the effects of vessel dynamics on the compass.

A synchro-to-digital converter, Astrosystems A603-5-S149, translates the X1 and X36 information from the gyrocompass to digital form for transfer to the computer. Now available is the information necessary to resolve the data from the velocity measurement subsystem into components of velocity in northerly and easterly directions in the local earth-tangent plane. Basic instrument accuracies are shown in Table I.

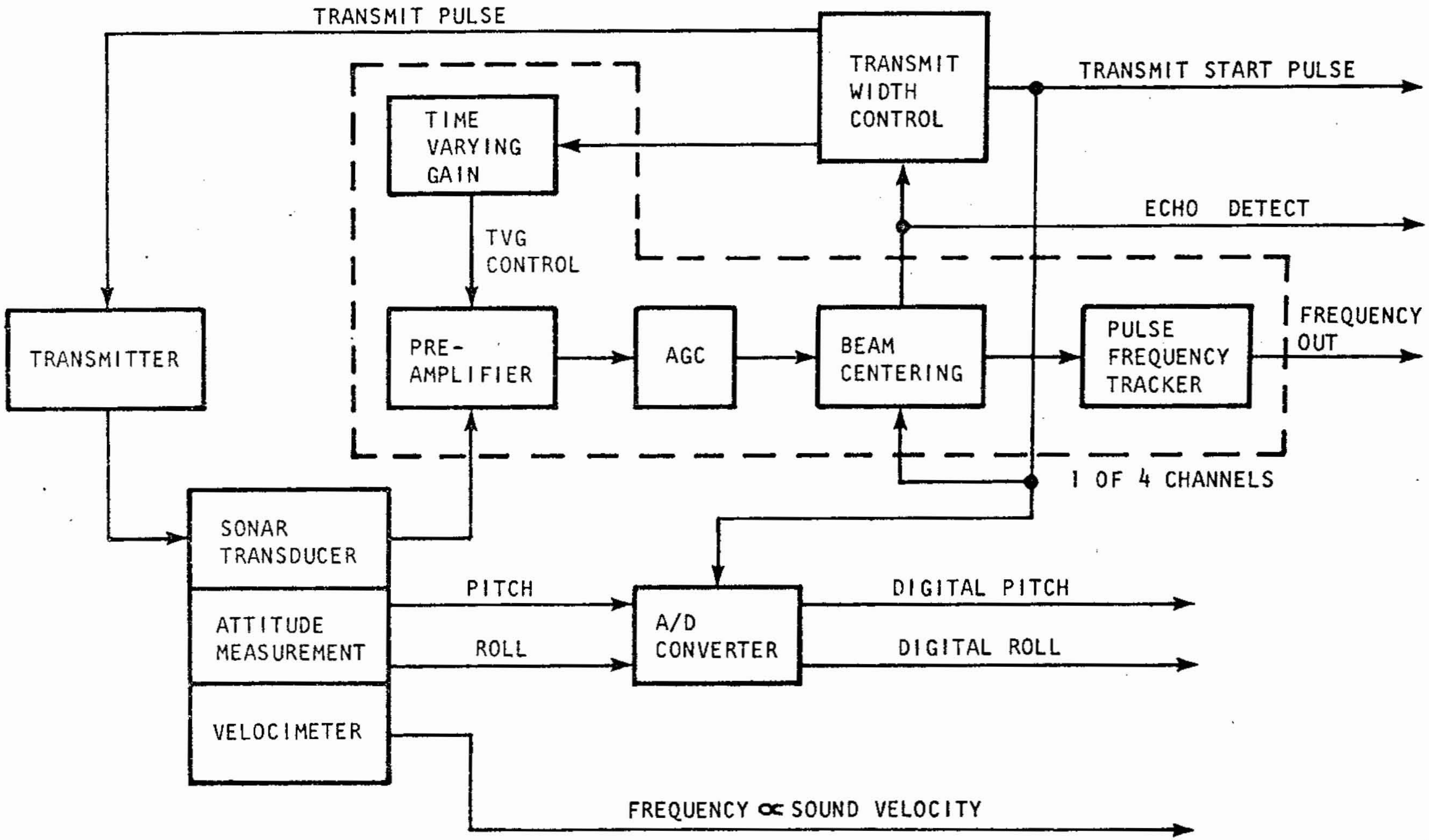


Fig. 2. Velocity Measurement Subsystem Block Diagram

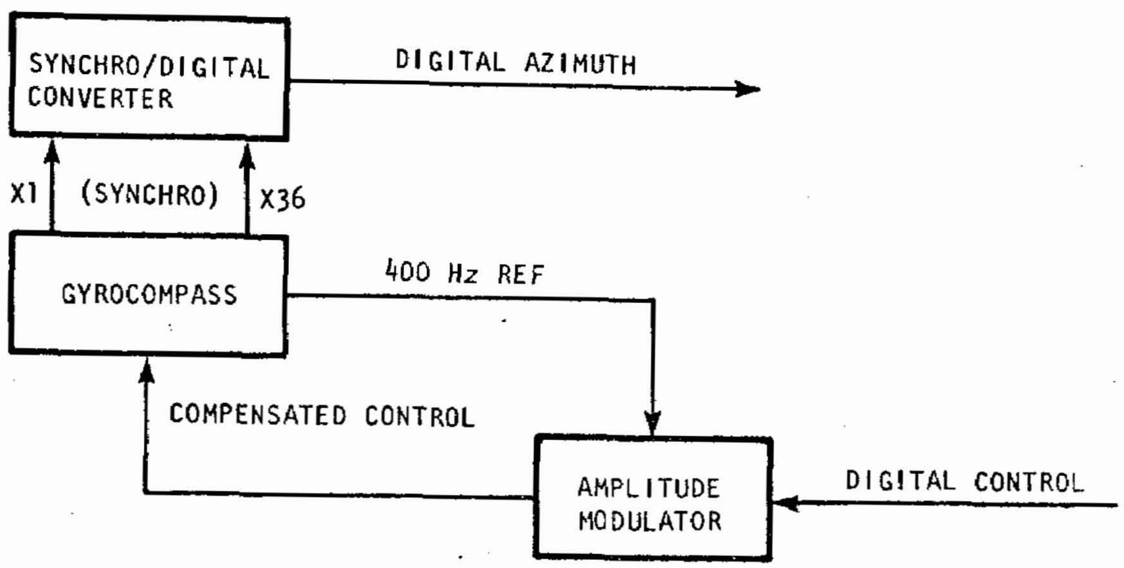


Fig. 3. Azimuth Measurement Subsystem Block Diagram.

Table I. Instrument Accuracy

Unit	Accuracy
Gyrocompass (with compensation)	0.2°
Doppler Sonar	
<100 Ftm	0.2%
100-160 Ftm	0.5%
Inclinometer	0.1°
Velocimeter	0.01%

Focal point of the GeoNav system is the TI 2540-3 (CP967(V)/UYK) digital computer; all sensor data must pass through the computer, and consequently, can be monitored by it. The GeoNav operating system software performs the satellite-fix solution and supplies velocity and azimuth measurement subsystem data to the dead reckoning system. The computer also performs position filtering, quality control of all sensors, and seismic-line and shot control. In this manner, data from all sensors are integrated to provide optimum continuous navigation, guidance, and shot control. In addition, data from the velocity measurement subsystem are used to compute the water depth for each sonar transmit/receive cycle. An extension of this technique permits using the system in bottom topography studies.

The system control panel, digital plotter, and printer/keyboard permit effectively using system outputs and system communications. A magnetic-tape unit is included for hardcopy data recording to permit post mission analysis.

The computer monitors the basic measurement processes of the various sensors. Anomalous measurements are noted and compensated for. The following paragraphs detail the techniques employed.

E. GEONAV SELF CONTAINED QUALITY CONTROL

1. Continuous Sensor Quality Control

The doppler sonar and associated parameters necessary for velocity measurement are of foremost importance. The basic sonar measurement provides a component of frequency from each of the four sonar axes (fore, aft, port, and starboard. These measurements are relative to the plane to which the sonar transducer is attached. Since this plane is normally free to roll and pitch with the vessel, vessel attitude must be measured. For similar reasons, the velocity of the vessel must be measured normal to the sonar transducer mounting plane. These sonar frequency measurements must be corrected for the velocity of sound in water. To complete the data set, the frequency of the transmitted sonar energy is required to resolve the velocity component normal to the sonar mounting plane.

In all cases, the basic measurement data are examined by the computer for reasonableness and rate of change; if found anomalous, the GeoNav operating system alerts the operator to the error condition. This is the most basic level of system quality control.

Another ancillary item of data measured by GeoNav is the time of arrival of the echoes from the four sonar beams with respect to the transmitted energy pulse. These measurements permit extension of GeoNav sonar quality control to include reasonableness of the locale of the sonar echoes. When combined with sound velocity data, these measurements extend GeoNav's usefulness as a depth-controlling device. The four sonar echoes per transmitted pulse also provide a powerful tool for bottom topography studies.

Likewise, data from the azimuth measurement subsystem are examined for reasonableness of magnitude and rate of change. The operator is informed of anomalies.

The value of this method of quality control is limited, however, since the rate of change of the variables can legitimately vary over a large range depending on the vessel's design and sea conditions. Hence, a wide range of variation must be permitted. Similarly, individual anomalous values are useful only in detecting obvious hardware malfunctions. What is required is an alternative means of verifying a sensor's performance by comparing its data with data from another source. The following paragraphs describe how GeoNav does this.

2. Quality Control on Satellite Position Fixes

Digital data received from the orbiting satellites are independent of the velocity and azimuth measurement subsystems comprising the dead reckoning system. Since the vessel's velocity and azimuth do affect the doppler count, fixes derived from the decoded data and associated doppler counts are not independent of the dead reckoning system. The following describes the quality control that verifies incoming satellite data, quality assurance during computation, and interpretation of results, all of which permits use of satellite fixes as independent references.

All data received from a satellite observation are preserved in the computer's memory. At the end of a satellite pass, the software performs a validation sequence verifying the quality of incoming data. Since the same data is received several times during one pass of the satellite, one validity test is to see whether repeated data bits actually appear identical in the computer. This bit majority voting is performed on like bits of like parameters over the entire range of redundant satellite messages stored in memory. In the event the bit error rate is excessive, the entire satellite observation is invalidated and the operator informed of the excessive error rate. When this occurs, it is highly probable that there is a noisy receiver channel requiring repair or, less likely, a bad satellite being observed.

The two frequencies transmitted by the satellite are received by GeoNav, and the doppler counts received from the two receiver channels are preserved in memory. These data are reduced to refraction counts and compared against preset limits to insure reasonable refraction data. In case the refraction counts are not reasonable, the pass is rejected and the operator alerted that the receiver should be verified for proper operation of the doppler counters. All data are validated automatically in preparation for entering the satellite solution.

The bit majority voting scheme is altered when a satellite injection is detected. In this instance, the system attempts to utilize only data received following the injection to insure that the most current data and the best prediction of the satellite's orbit is used in the position-fix solution. Data received before the injection is ignored and replaced as necessary by extrapolating back based on parameters received after the injection, using curve-fitting techniques. Similar techniques are used to interpolate for parameters which may have been missed due to poor signal quality, fade, etc., or for parameter points at the short doppler intervals selected by the software system. The choice of whether to extrapolate is based on whether the following conditions (arranged in decreasing importance) can be achieved.

- A data set of valid fixed parameters
- A minimum range requiring extrapolation of variable parameters yet still coinciding with the maximum range of good doppler counts

- Maximum range of valid variable parameters
- Most recent data

This concludes the preprocessing of satellite data. The resulting data set is free of erroneous message data and invalid doppler counts.

Further quality control of satellite fixes is handled as an editing function. Inasmuch as satellite doppler and, more especially, the refraction count are known to degrade when the satellite is near the horizon, doppler counts received below 7.5° are rejected.

Another quality control tool available to GeoNav operators is a constant which specifies the minimum number of short doppler intervals on both sides of the satellite's closest approach which the software (GNSDOP) will demand before computing a fix. This constant insures symmetricity of the data (same number of short doppler counts on each side of closest approach) and is an indirect control of the minimum satellite elevation angle acceptable to the system. If, after checking the aforementioned editing criteria the system determines that there is the required symmetricity but not enough data above 7.5° (at least 10 short doppler intervals), the editing software will accept just enough short doppler segments below 7.5° (maintaining symmetricity) to meet minimum requirements.

Additional control permits rejection of an entire satellite observation if any portion of the data was collected while the observation angle exceeded some angle selected by the operator. This angle is typically 70° to 75° and is adjusted according to satellite alerts for the area of operation.

The preceding paragraphs describe some major elements of editing included in the GeoNav satellite software package. Together, all of these insure a high degree of quality for the data entering into a satellite-fix solution and intermediate to the solution. To use the resulting fix effectively as a measure of the quality of the GeoNav sensor subsystem data, the quality of a given fix solution must be measured. The GeoNav system does this with a unique, proprietary algorithm that estimates statistical variances north and east for the satellite fix. These estimates are not derived from a priori statistics of satellite fixes versus elevation angle but from only the incoming satellite data set. Figure 4 is a bull's-eye of satellite-fix distribution from a set of 100 fixes received in GSI's Dallas laboratory. These data were recorded with a minimum requirement of five short doppler segments on both sides of closest approach and with a maximum elevation angle of 75°.

The foregoing discussion covers the condition in which the satellite receiver is stationary. To obtain experimental data, a week of satellite observations were recorded on magnetic tape using a GeoNav system operating with the standard operating software. The resulting satellite fixes were tabulated, and known velocity and heading errors were introduced into the dead-reckoning or navigator's estimates. The satellite fixes were then recomputed and compared with the previously tabulated data and plotted. The resulting curves are those shown in Figures 5 and 6. It is noteworthy that the major component of satellite-fix error versus velocity error is that previously published in numerous journals. However, the smaller component of fix error shows a tendency to split, depending on the direction of satellite travel with respect to the observer, e.g., clockwise or counter-clockwise. These errors are as shown for 1 knot north in Figure 5 and 1 knot east in Figure 6 at latitude 32°N. These curves would converge to zero at the equator and be in reversed orientation in the southern hemisphere. In either

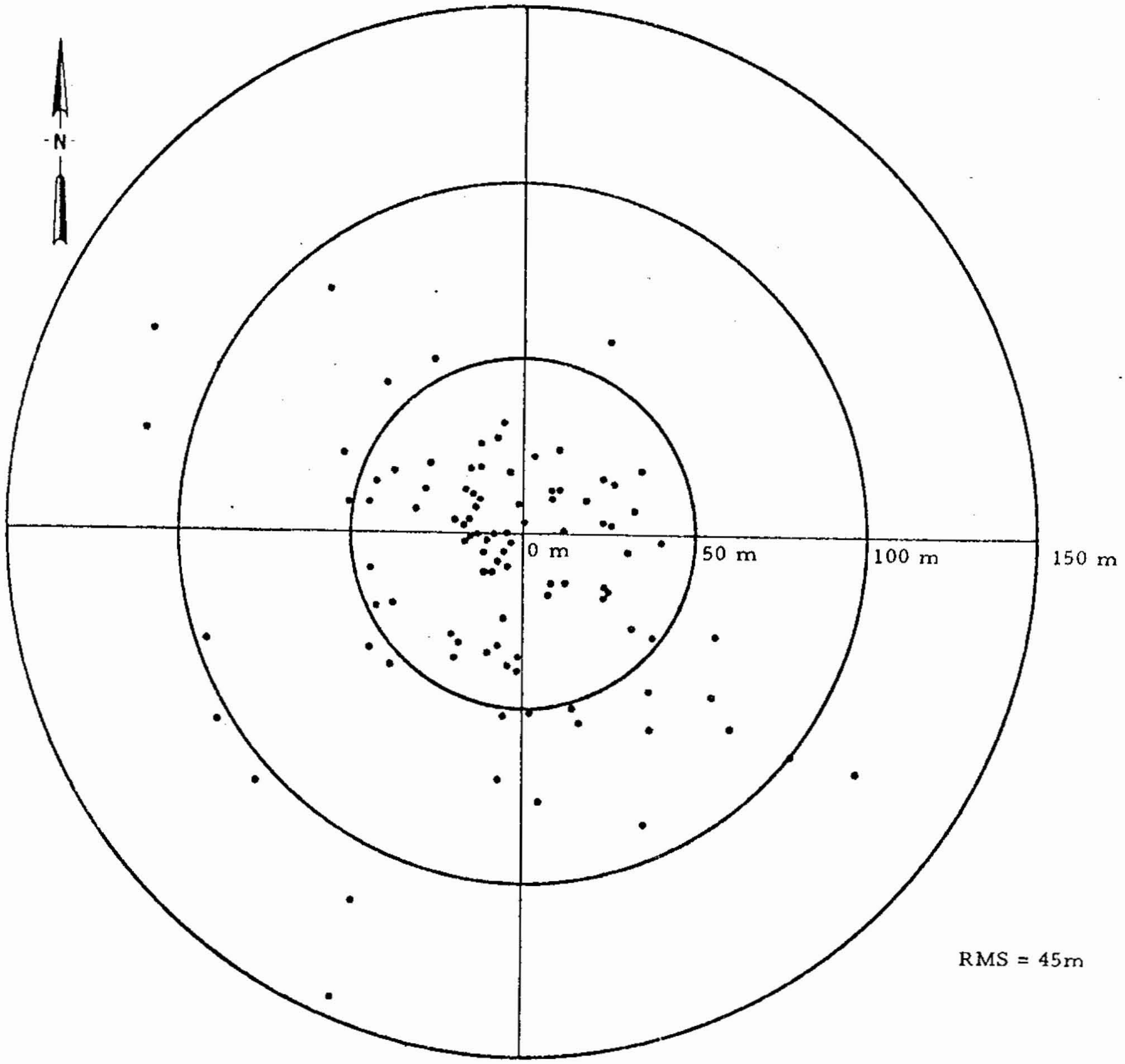
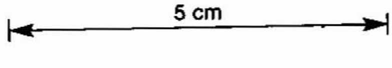


Fig. 4. Satellite-Fix Distribution.



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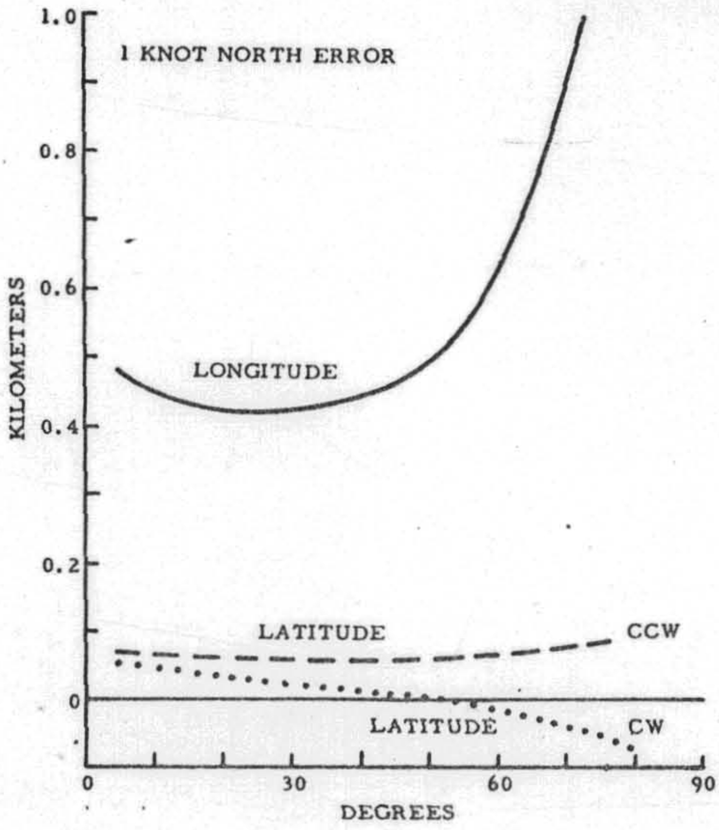

Fig. 5. Satellite Fix errors at Latitude 32°N, Due to Forced Dead Reckoning Errors.

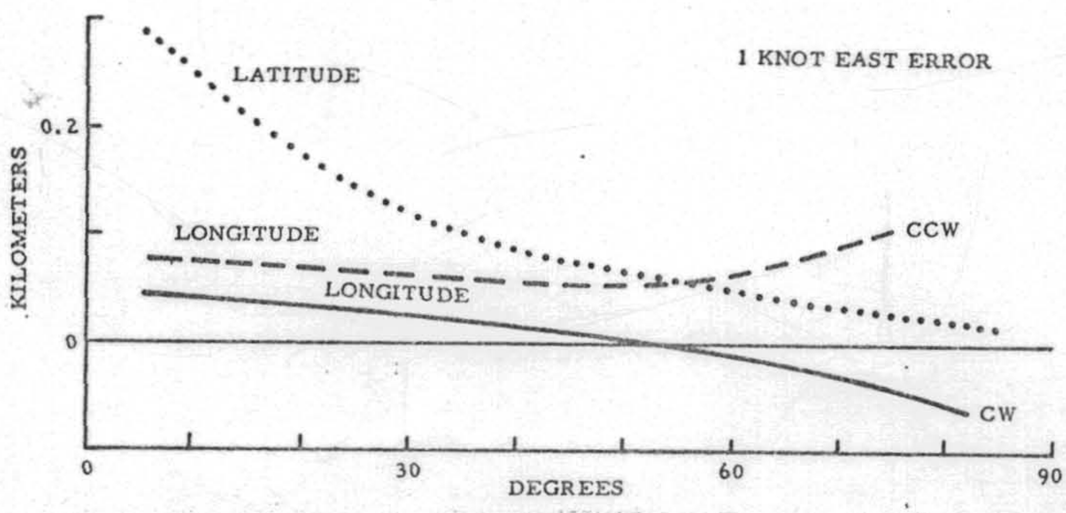

Fig. 6. Satellite Fix Errors at Latitude 32°N, Due to Forced Dead Reckoning Errors.

hemisphere, the magnitude of the error diverges as the pole is approached. In short, major satellite-fix errors are caused by dead-reckoning error, but the magnitude of these errors is such that they should be readily recognized. Hence, the problem reverts to one of identifying quality in a satellite-fix computation.

The previously described variances provided as part of the satellite-fix solution are independent of dead-reckoning error. To obtain a measure of the reliability of the variance computation, a set of satellite fixes was tabulated in the laboratory and each result and its variance estimates compared with the known antenna location. The curves shown in Figure 7 were obtained where the data were plotted as standard deviation versus satellite elevation angle. Figure 8 shows the same type of data recorded in the Far East while operating at approximately 40^{o}S latitude. Figure 9 shows the difference between the variance estimate in the laboratory and the actual position error. This curve shows that the reliability of the variance estimate decreases at low elevation angles but that the estimate is reliable for satellites in the range 15^{o} to 70^{o}. Note that the error estimate tends to exceed the actual error, thereby avoiding an over-dependence on the satellite fix results. Hence, we have a reference with a reliable estimate of its accuracy which we can now use as a tool for verifying the quality of the velocity and azimuth measurement subsystems.

3. Velocity/Heading Quality Control

Velocity and azimuth subsystem performance can be evaluated by relating the position correction resulting from a satellite position fix to the distance between fixes. See Figure 10.

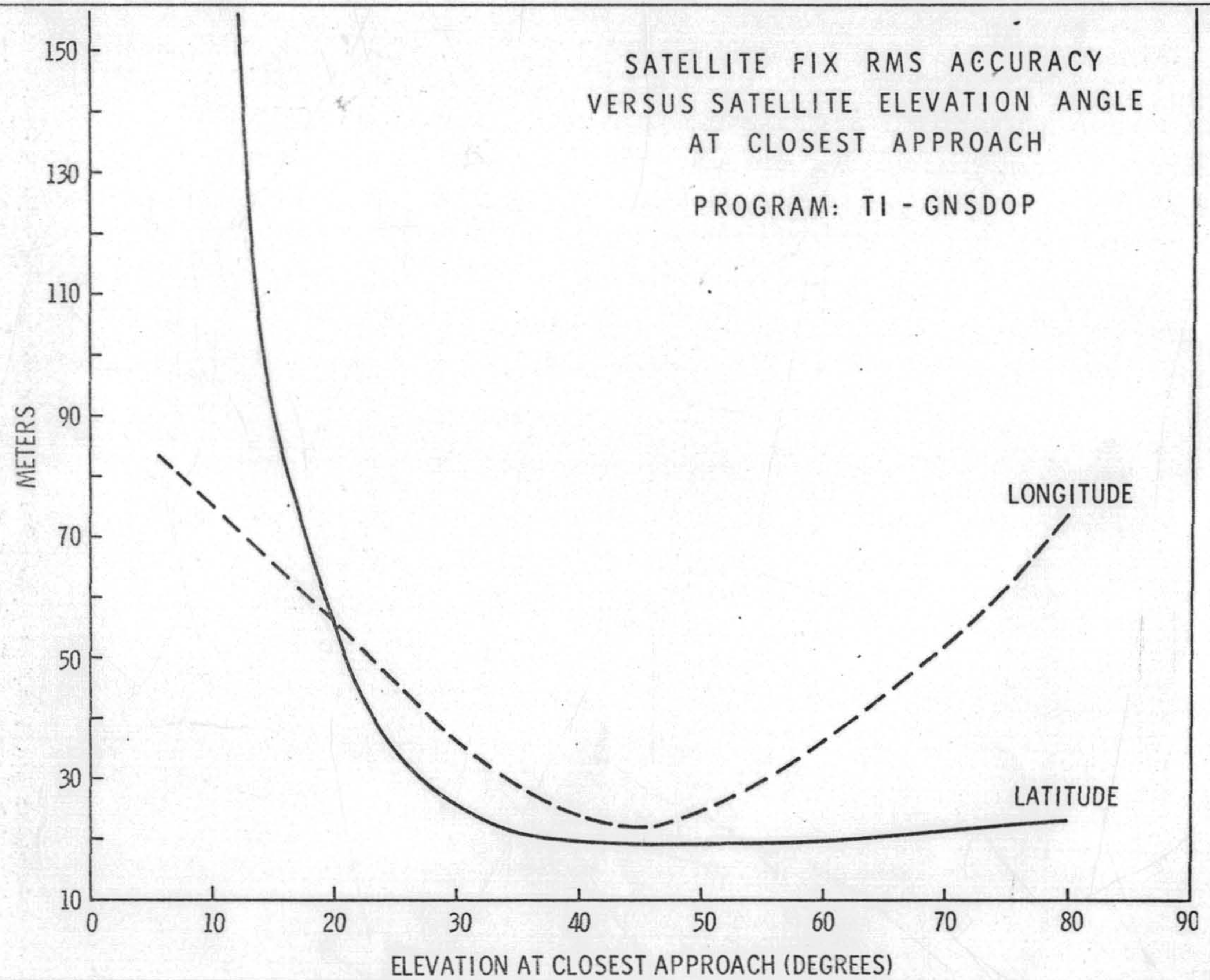

Fig. 7. Standard Deviation Versus Satellite Elevation Angle.

5 cm

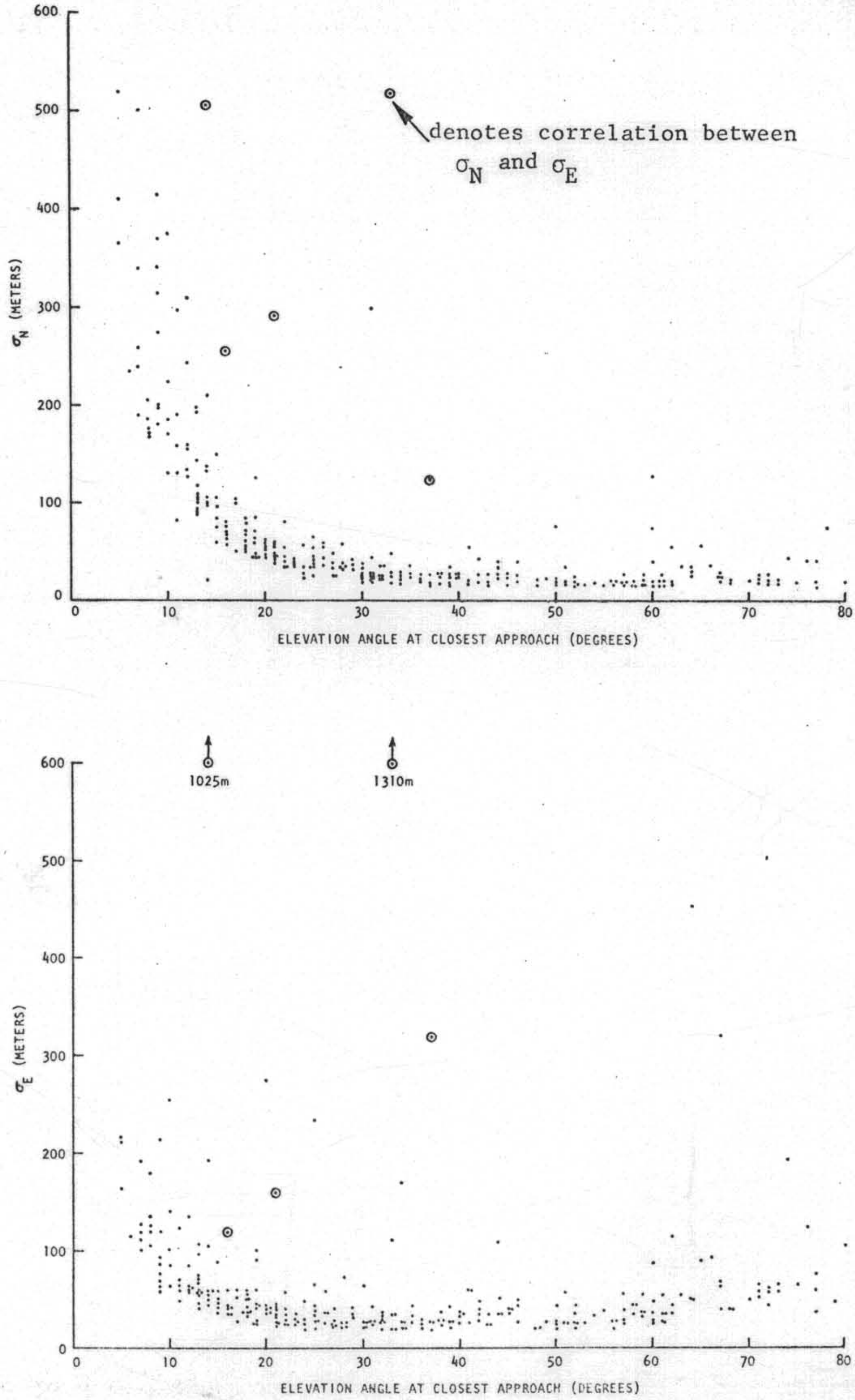

Fig. 8. Satellite-position Fix Standard-Deviation Estimate, Far East.

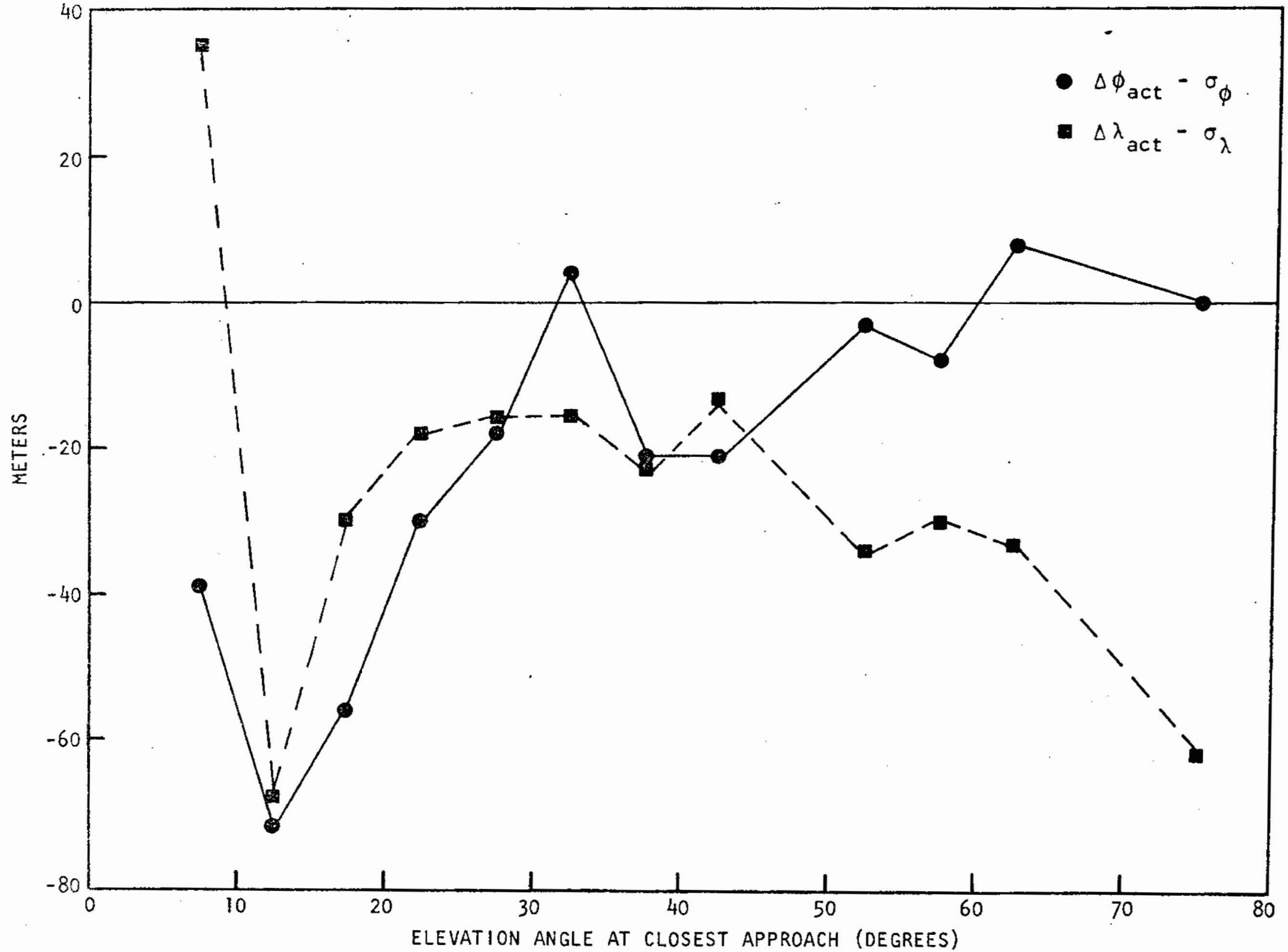

Fig. 9. Differences Between Variance Estimate In Laboratory and Actual Position Error.

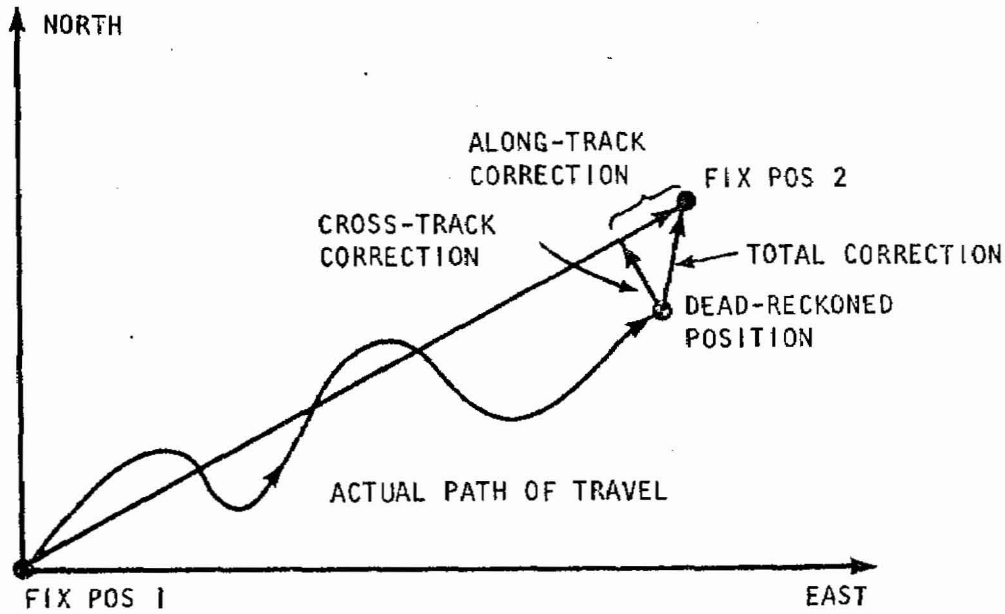

Fig. 10. Calibration Principle.

The total dead-reckoning error accumulated during the time between position fixes (fix interval) is a result of errors in along-track and cross-track velocity measurement and the error in azimuth measurement. Geometrically, this total error comprises two orthogonal error vectors. One vector is colinear with the direction of the shortest distance between each pair of position fixes. This component is basically the result of the error in the fore-aft or along-track velocity measurement. The orthogonal component combines the error in the port-starboard or cross-track velocity measurement and the error in measurement of the ship's azimuth. The heading error expresses any misalignment between the gyrocompass and the fore-aft direction as determined by the sonar beams. Thus, the error components are a direct and separate measure of average along-track and cross-track velocity errors. By prorating the vector magnitudes to the direct distance between fixes, we obtain relative or percent error factors.

Analytically, the total dead-reckoning error can be separated into total velocity error and heading error. In this, it is assumed that the relative errors in all velocity measurements are caused by the same sources, and higher-order cross-terms between velocity and heading error are ignored. The assumption is correct as far as the doppler sonar instrumentation is concerned and is plausible with respect to any environmental error sources.

Let

K = relative error in velocity measurements

θ_e = absolute heading error

Then

$V_{true} = (1 - K)V_{meas}$, true velocity

$\theta_{true} = \theta_{meas} - \theta_e$, true heading

In dead reckoning, the fore-aft, port-starboard, and up-down velocities about the measured azimuth are resolved into velocity-north and velocity-east components, which are subsequently integrated over time:

$$\phi = \phi_o + \int_T \frac{VN}{R_N(\phi)} dt, \text{ latitude}$$

$$\lambda = \lambda_o + \int_T \frac{VE}{R_E(\phi)} dt, \text{ longitude}$$

where (ϕ_o, λ_o) is an initial position, VN and VE are the velocity-north and -east components, and R_N and R_E are the radii of the earth's curvature in north and east directions.

Each velocity component contains an error which is a function of both the relative velocity error, K, and the heading error, θ_e. Therefore, dead-reckoned latitude and longitude also contain errors which are (different) functions of the error parameters, K, θ_e:

$$\phi_e = f(K, \theta_e)$$

$$\lambda_e = g(K, \theta_e)$$

A position fix, if sufficiently accurate, immediately yields the position error (ϕ_e, λ_e). By neglecting second- and higher-order cross-terms as mentioned, the error parameters or "calibration factors" K and θ_e can be found directly.

Two requirements must be met for satisfactory calibration:

- The fixes at either end of the dead-reckoning interval must be sufficiently accurate
- The direct distance between fixes must be sufficiently large

For example, for a distance of 10 km between lines, a 100-m radial fix error causes an error of 1% in velocity calibration or 0.01 rad = 0.57° in heading calibration.

The calibration method is independent of the actual travel path between fixes because deterministic errors compensate when traveling in opposite directions. In this respect, closed-loop navigation never reflects deterministic error, and the error at loop closure results from accumulated random errors. Thus, separate measurement of deterministic velocity and heading errors derived from position fixes of known accuracy have been established. At each satellite fix GeoNav prints out the estimated fix accuracy, the distance between fixes, and the calibration factors, plus all other necessary position update information, therefore providing continuous performance evaluation.

This velocity/heading calibration principle has been exercised extensively: first, in testing doppler sonar and gyrocompass instrument errors in the Gulf of Mexico in March 1970 by sailing between oil rigs, where the accurately known positions were substituted for satellite fixes; second, in the same period with a simulated seismic survey performed against electronic positioning; and third, by continuous data collection from actual worldwide field operations. Table II shows that the calibration factors obtained from the test run between known, fixed positions agree with the instrument errors specified.

Table II. Velocity-Heading Error Statistics

Distance Traveled (km)	Heading Error (m)	Velocity Error (m)	Total Error RMS (m)
24.1 (E⟶W)	-4.2	24	24
24.1 (W⟶E)	≈0.0	0	0
24.1 (E⟶W)	16.8	-24	29
24.1 (W⟶E)	29.4	0	29
24.1 (E⟶W)	4.2	-24	24
24.1 (W⟶E)	16.8	+48	51
44.5 (NE⟶SW)	96.0	-89	131
44.5 (SW⟶NE	8.0	0	8

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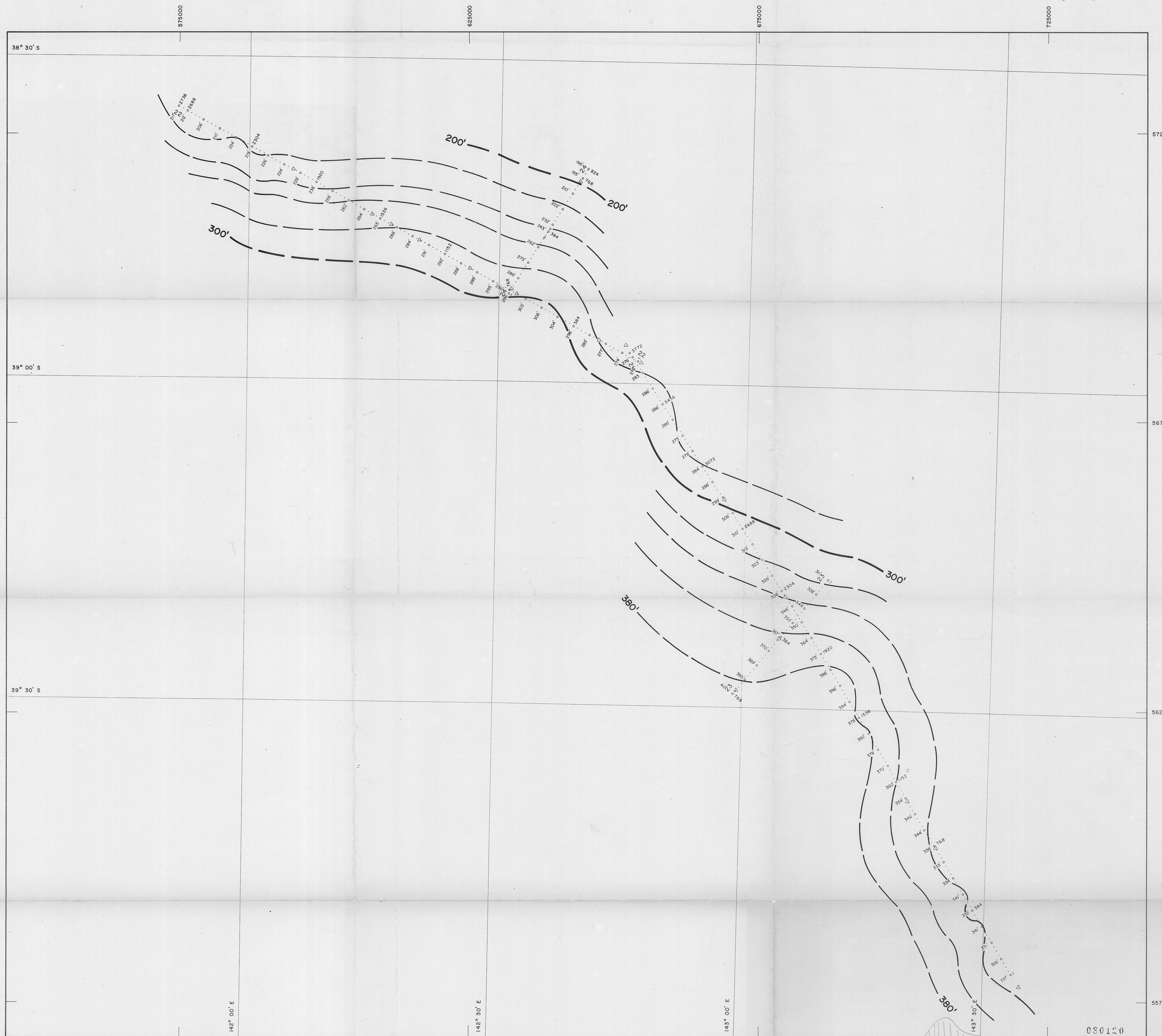


TRANSVERSE MERCATOR PROJECTION
UTM ZONE 54
CENTRAL MERIDIAN: 141°00' E
SCALE FACTOR AT CM: 0.9996
LATITUDE OF ORIGIN: 00°00'00.00"
GRID INTERVAL: 50,000 METERS
REFERENCE SPHEROID: AUSTRALIAN NATIONAL
DATUM: AUSTRALIAN GEODETIC

N

LEGEND

○ · SHOTPOINTS
MAPPED POINTS = AIRGUN POSITION
POPS/SHOTPOINT = 1

△ SATELLITE FIX

SCALE 1:250,000

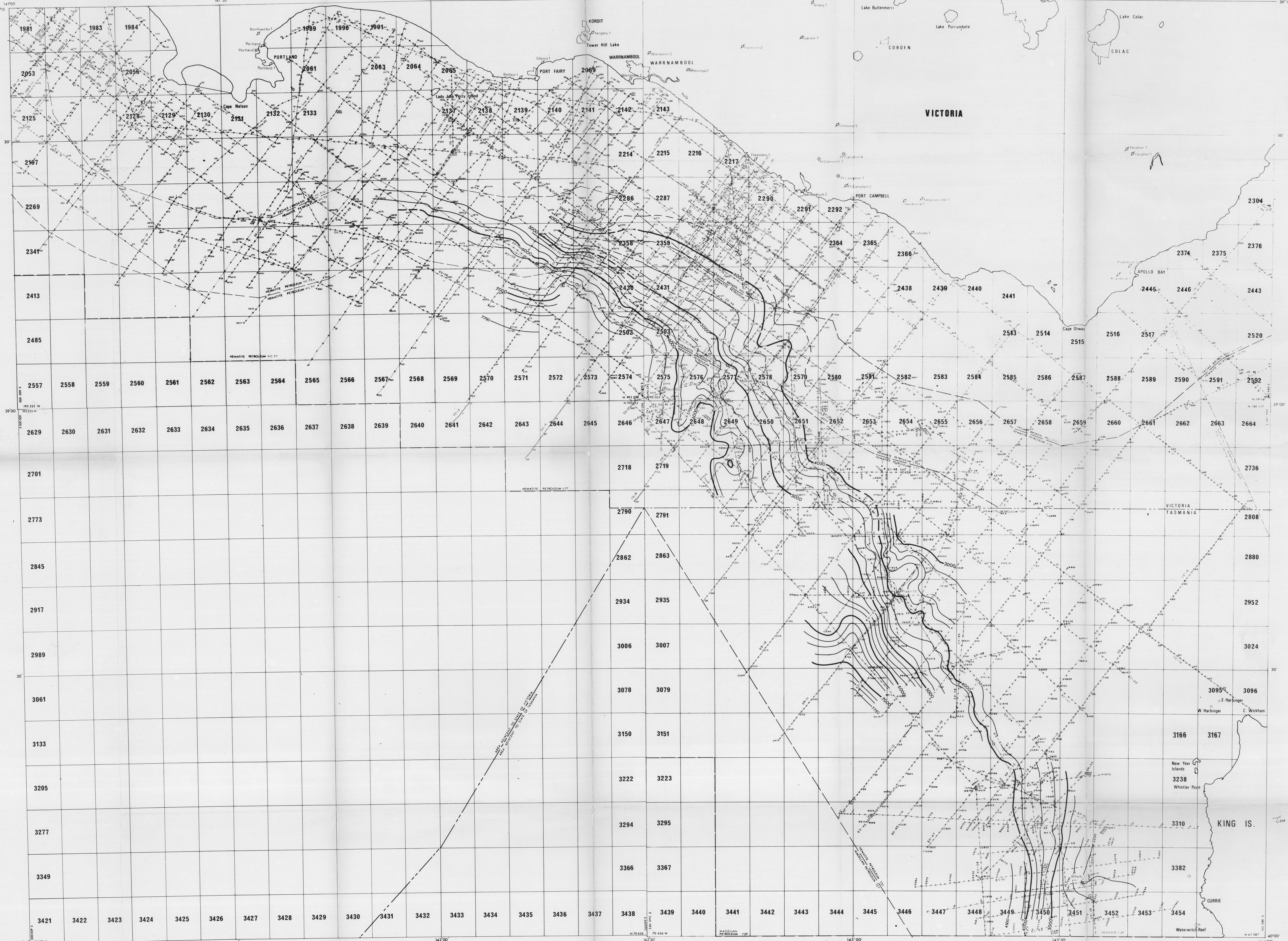
0 KILOMETERS 10

5 cm

WATER DEPTH MAP
CONTOUR INTERVAL 20'
BASS STRAIT
PORTLAND, KING ISLAND PROSPECT
SURVEYED FOR
HEMATITE PETROLEUM PROPRIETARY LIMITED
BY
GEOPHYSICAL SERVICE INTERNATIONAL
A DIVISION OF TEXAS INSTRUMENTS AUSTRALIA LIMITED
POSITIONING SYSTEM: GEONAV OCT. 1972

OR-066

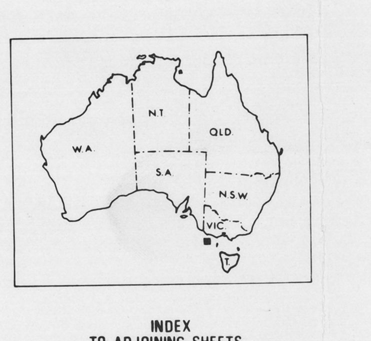
OTWAY/KING PART-VII*



Scale 1:250,000

MILES

KILOMETRES



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	GRANT	WICKHAM
		STOKES

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Reference: Petroleum (Submerged Lands) Act 1967-68 of the Commonwealth of Australia.
Petroleum (Submerged Lands) Act 1967-68 of the State concerned.

LEGEND

- Oil
- Gas
- Oil & Gas
- Oil show
- Gas show
- Oil & Gas shows
- Drilling
- Dry hole (Abandoned)

ZONE 6 | ZONE 7

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

HORIZON B

(Top of Upper Cretaceous)

Contour interval : 250 ft. Datum : Sea level

Author : E. G. Urschel Date : March 1973

To accompany final subsidy report

5 cm

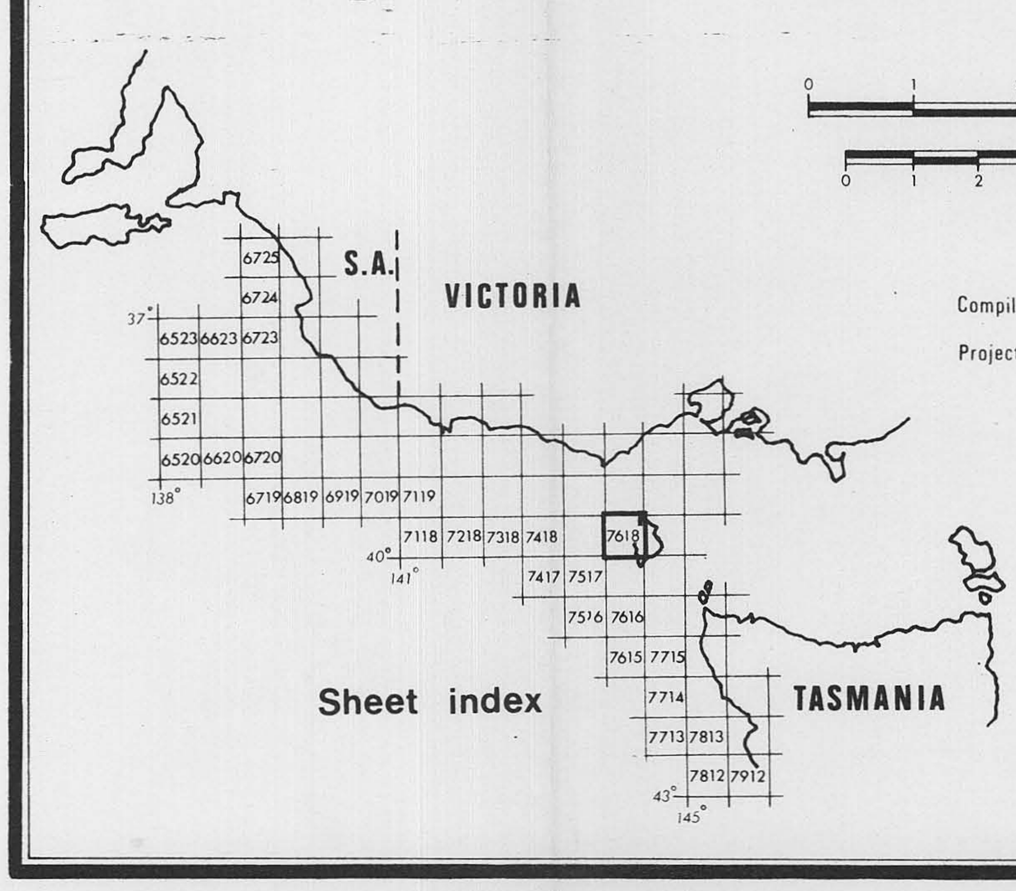
OG 3031

Scale 1: 100,000

MILES

KILOMETERS

Compiled by Hematite Petroleum Pty. Ltd.
Projection, UTM. Zone 54 C.M. 147°E



HEMATITE PETROLEUM PTY. LTD.
OTWAY BASIN

PORTLAND TO KING ISLAND SEISMIC SURVEY

HORIZON B

Top of Upper Cretaceous

Contour interval: 250 feet
Datum: Sea level
Author: E.G. Urschel
Date: March 1973

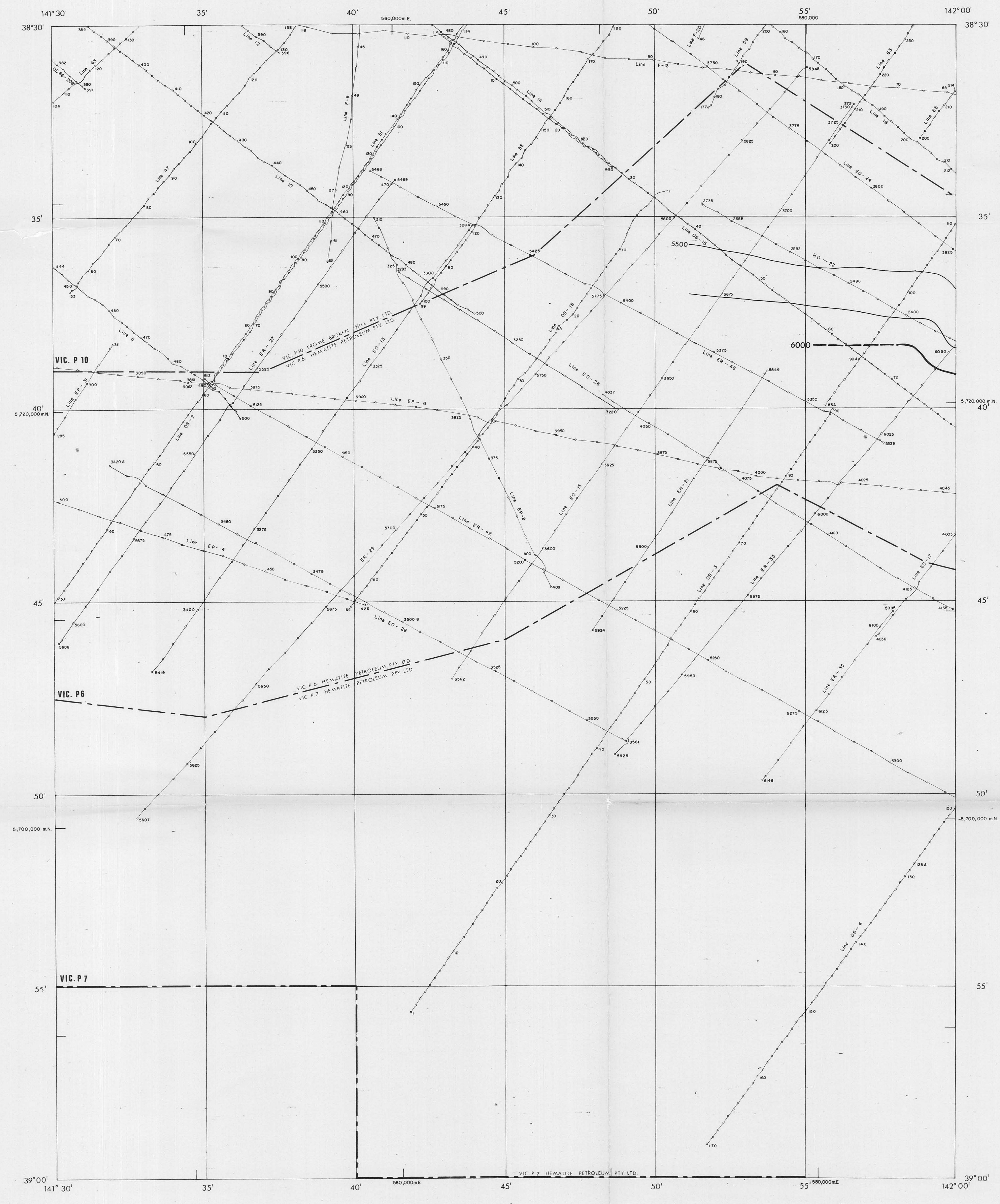
To accompany final subsidy report

5 cm

030122

OR-066

SHEET 7618 Encl. 1a



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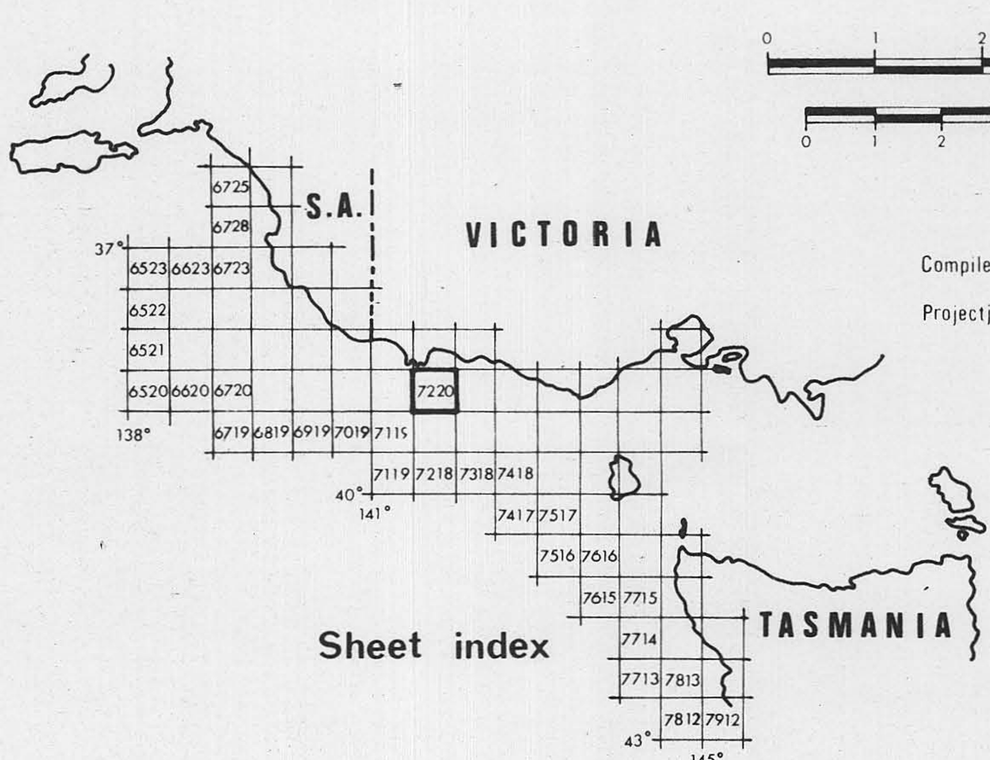
KILOMETRES

Compiled by Hematite Petroleum Pty Ltd.

Projection U.T.M. Zone 54 C.M. 141°E



HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND–KING ISLAND SEISMIC SURVEY

HORIZON B

(Top of Upper Cretaceous)

Contour interval : 250 feet

Datum : Sea level

Author : E.G. Urschel

Date : March 1973

5 cm

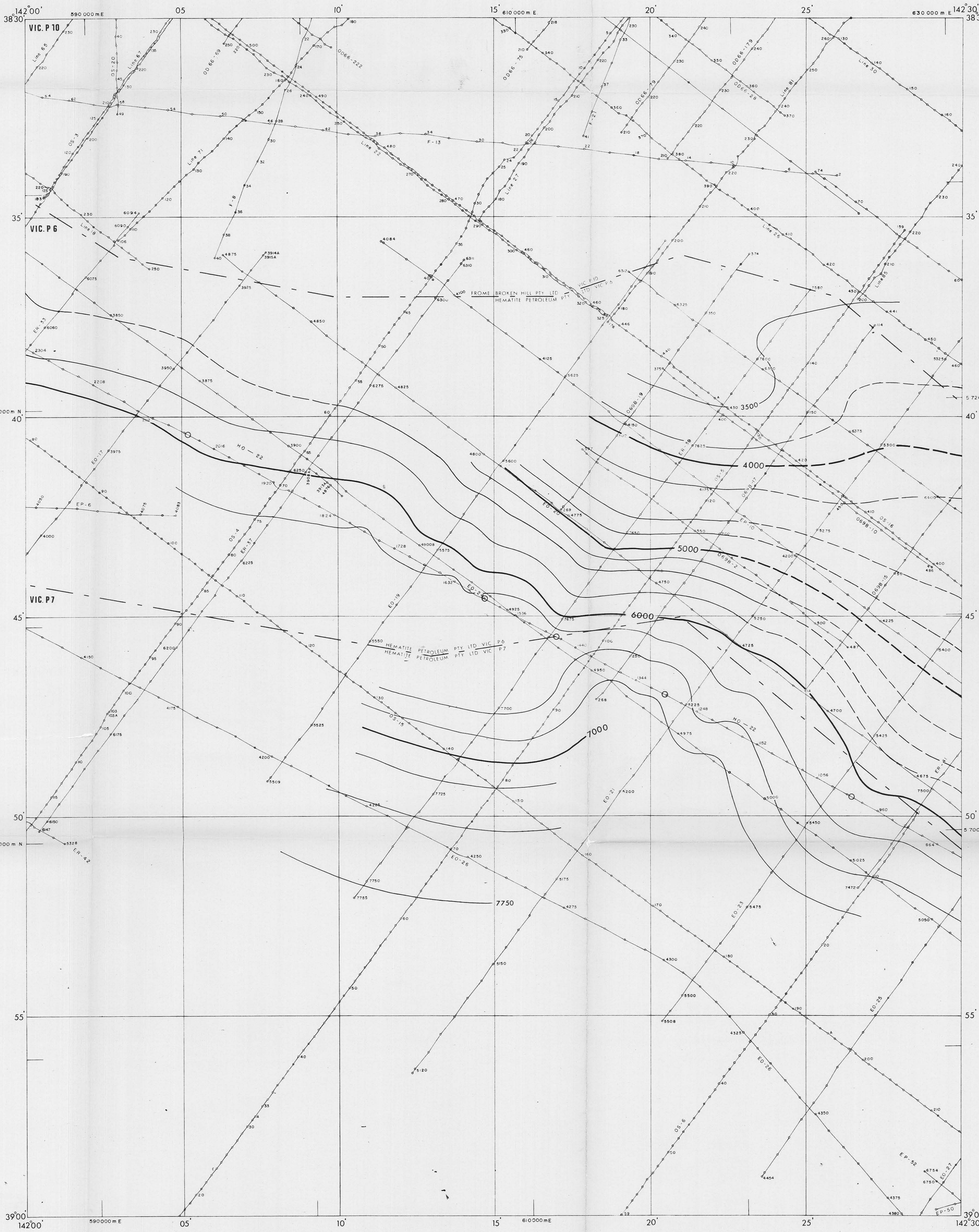
To accompany final subsidy report

080123

SHEET 7220 Encl. 1b

OR-066

OTWAY/KING PART-VII*



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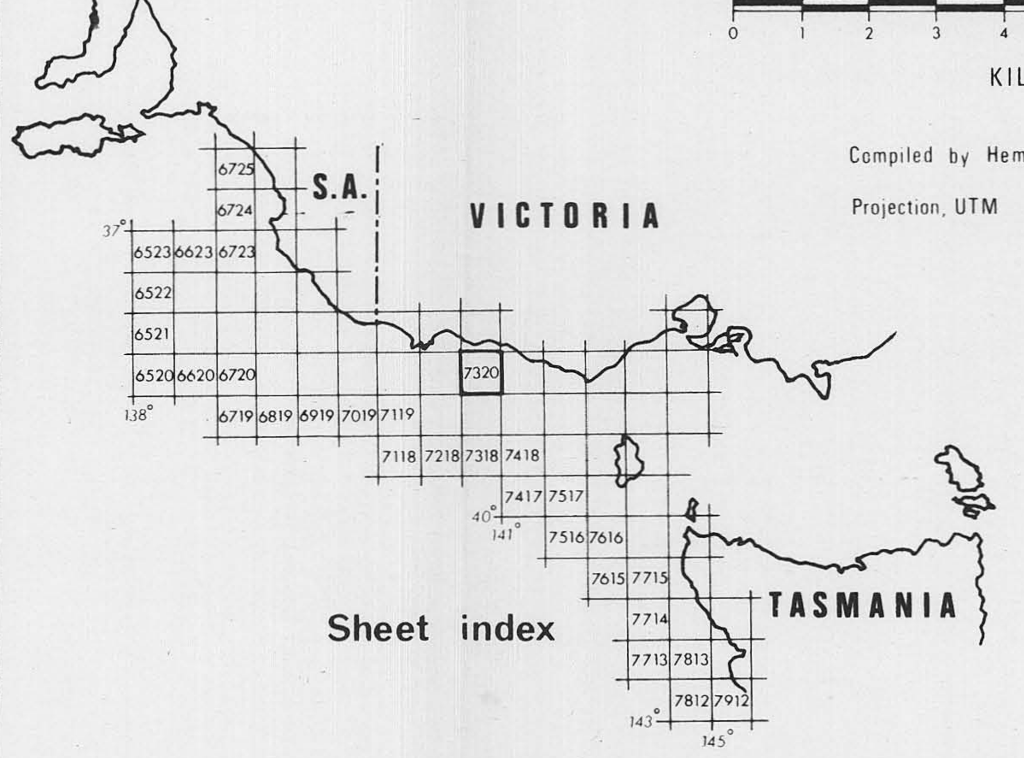
KILOMETERS

Compiled by Hematite Petroleum Pty Ltd

Projection UTM Zone 55 C.M. 147°E



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HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND - KING ISLAND SEISMIC SURVEY

HORIZON B

(Top of Upper Cretaceous)

Contour interval = 250 feet

Datum : Sea level

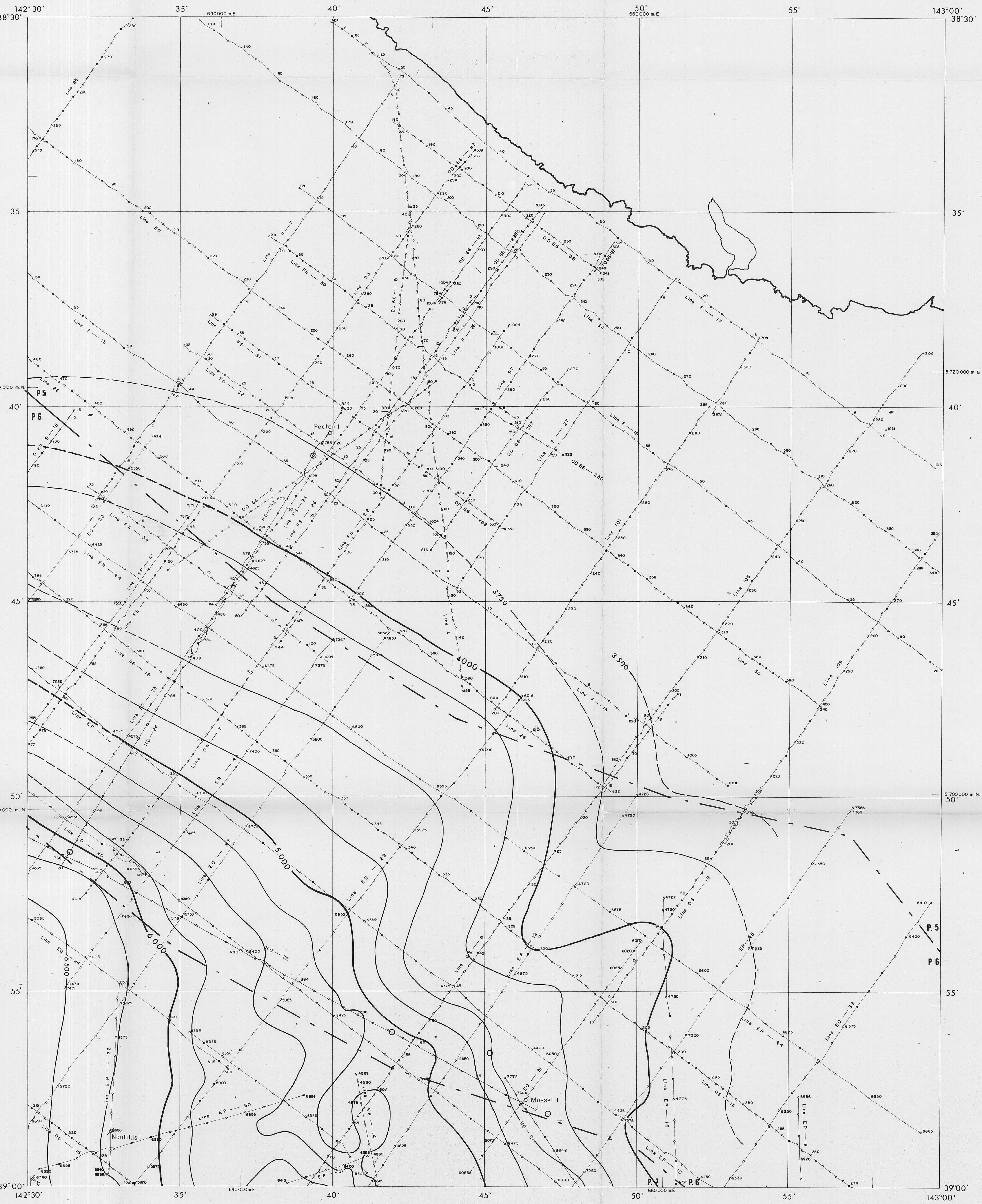
Author : E.G. Urschel

Date : March 1973

To accompany final subsidy report

5 cm

080124 **SHEET 7320** OR-C66 **Encl. 1c**



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MILES

0 1 2 3 4 5 6 7

0 1 2 3 4 5 6 7 8 9 10

KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection, UTM. Zone 54 C.M. 141°E

Sheet index

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND - KING ISLAND SEISMIC SURVEY

HORIZON B

(Top of Upper Cretaceous)

Contour interval: 250 feet | Datum: Sea level

Author: E.G. Urschel | Date: March 1973

5 cm

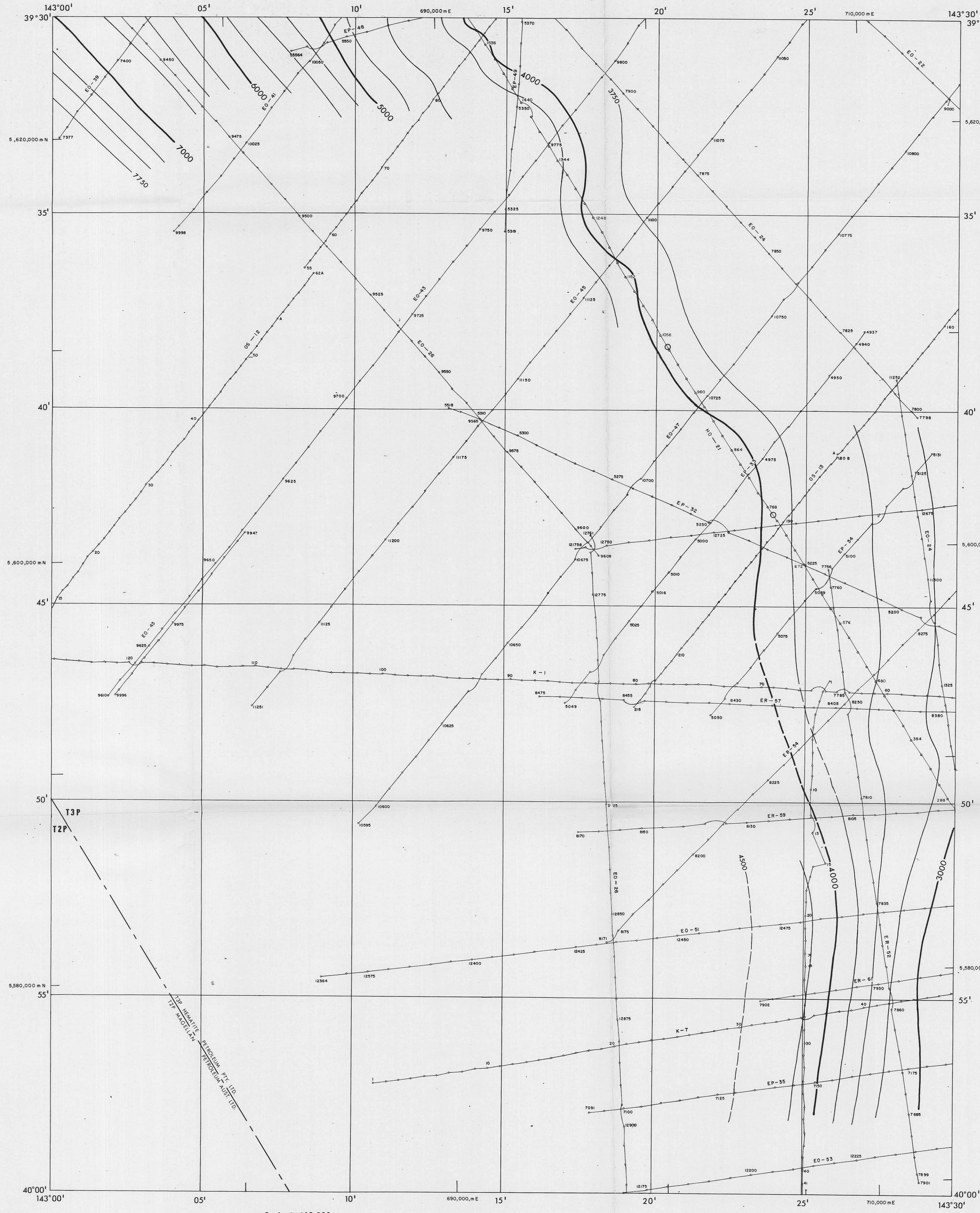
To accompany final subsidy report

080125

SHEET 7420 Encl. 1d

OR-066

OTWAY/KING PART-VII*



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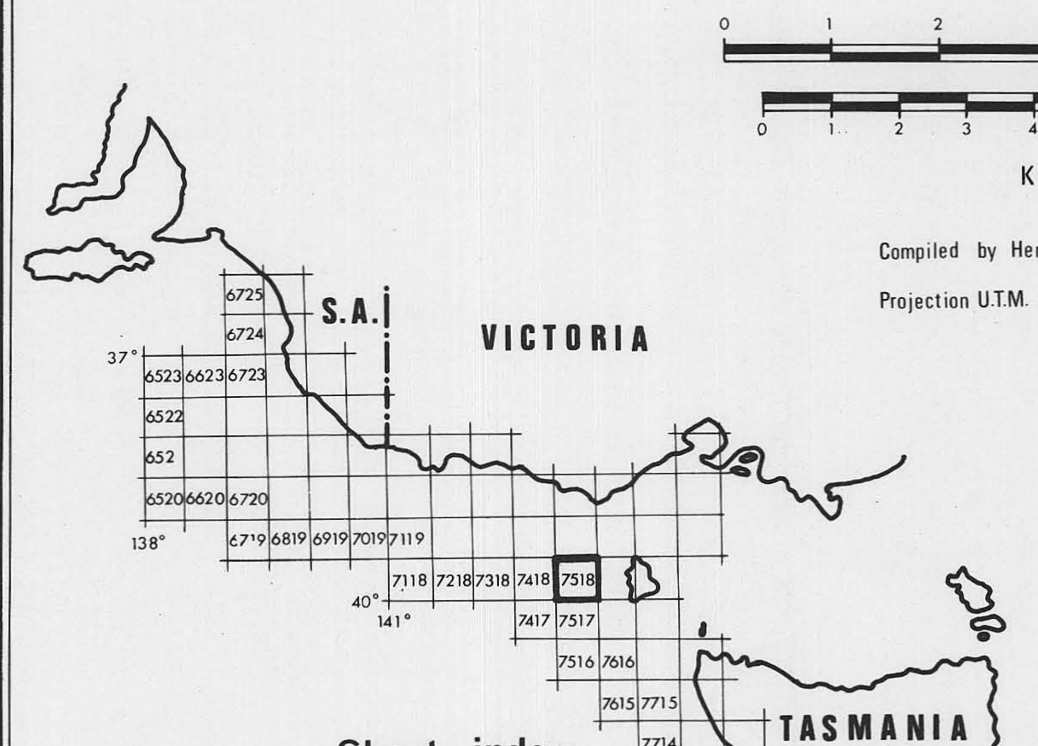
KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection U.T.M. Zone 54 C.M. 141°E



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HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

HORIZON B

(Top of Upper Cretaceous)

Contour interval = 250 feet

Datum : Sea level

Author : E.G. Urschel

Date : March 1973

To accompany final subsidy report

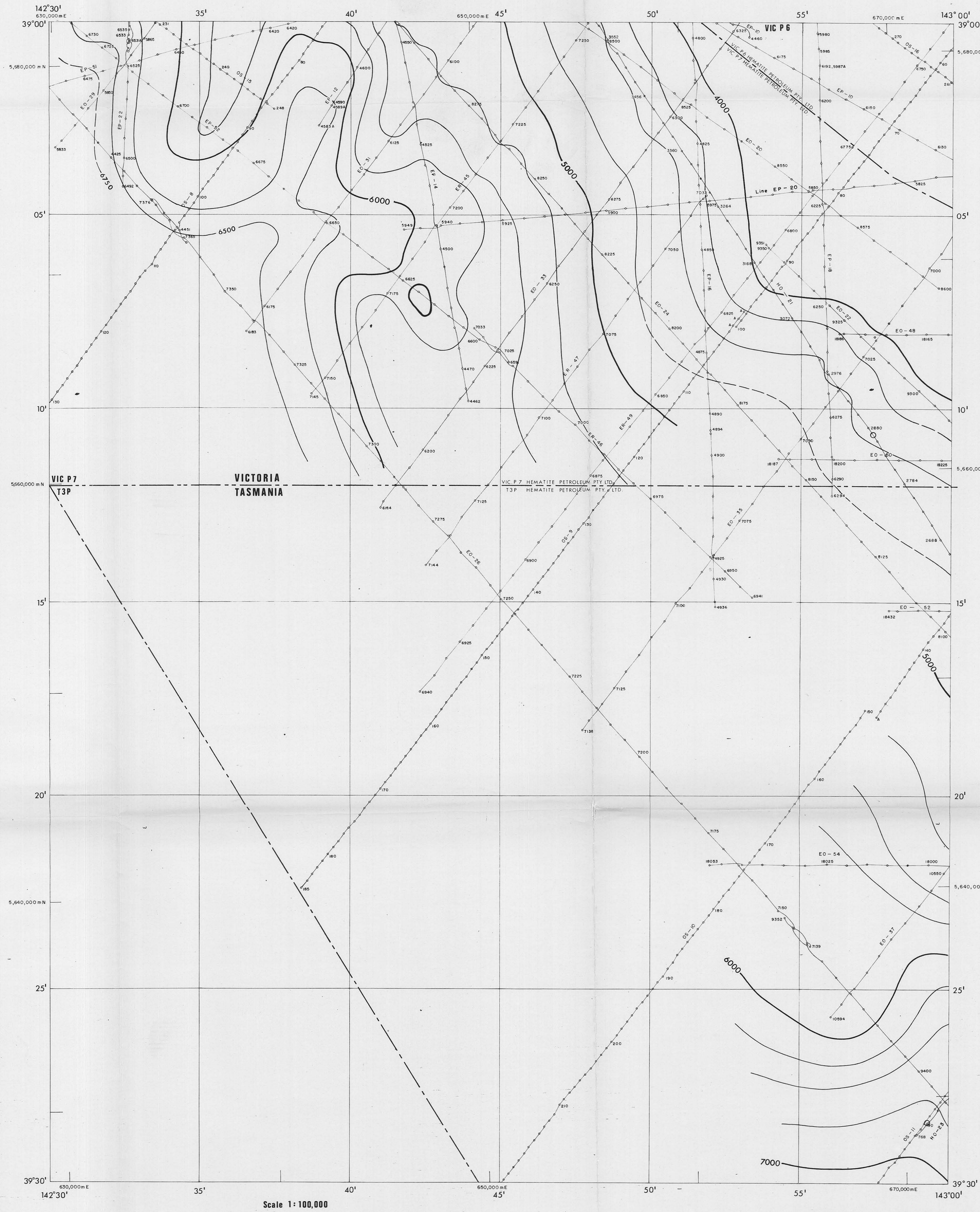
5 cm

030126

SHEET 7518 Encl. 1e

OR-066

OTWAY/KING PART-VII*



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KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

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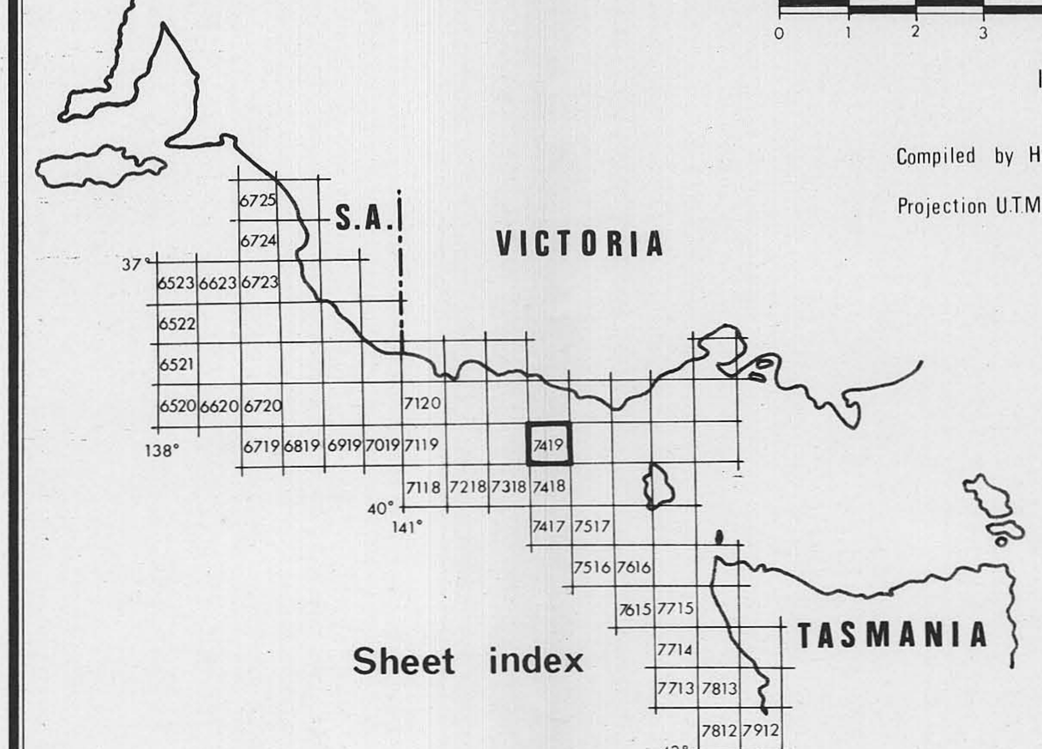

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HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

HORIZON B

(Top of Upper Cretaceous)

Contour interval : 250 feet

Datum : Sea level

Author : E.G. Urschel

Date : March 1973

5 cm

To accompany final subsidy report

C80127

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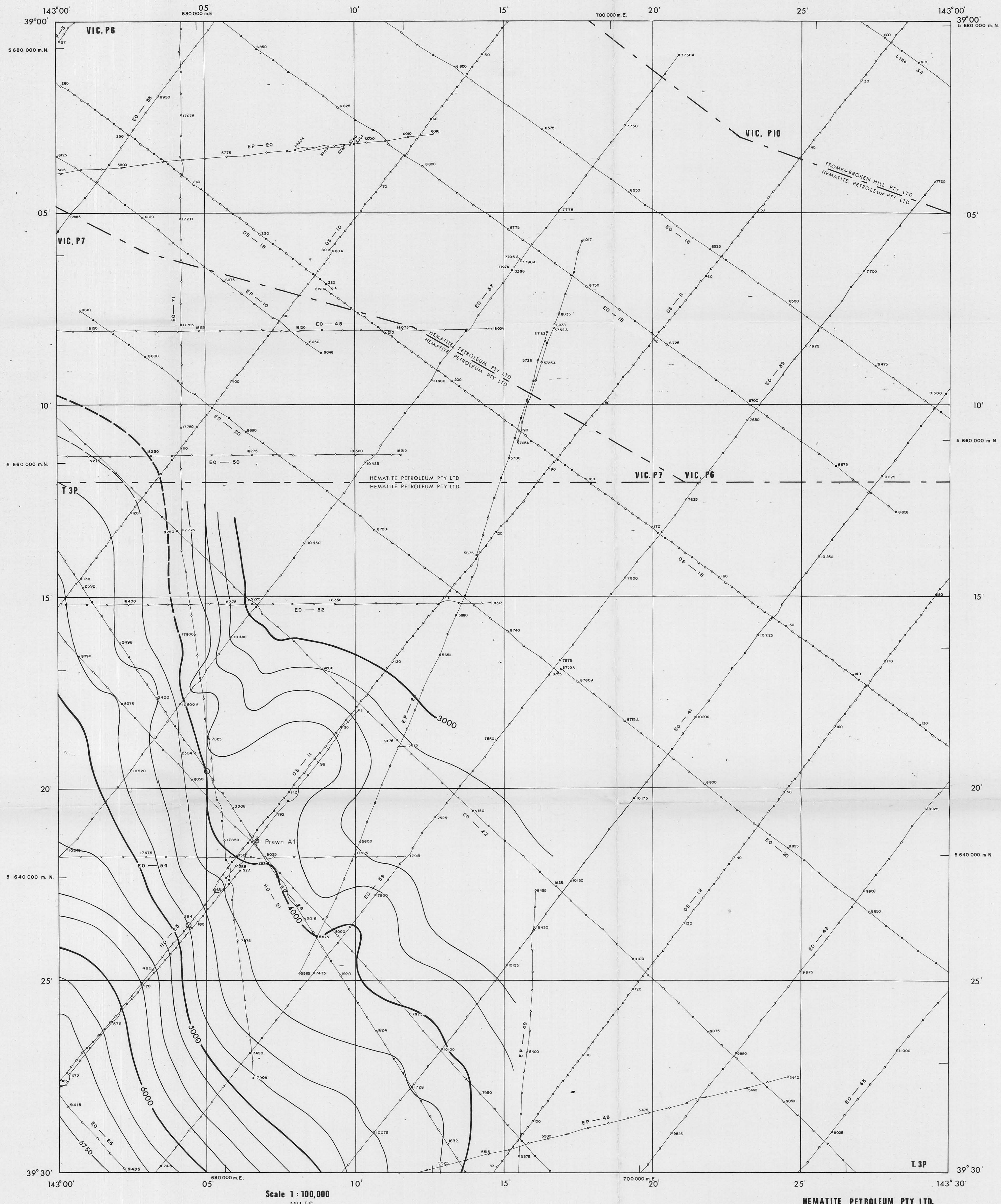

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KILOMETRES

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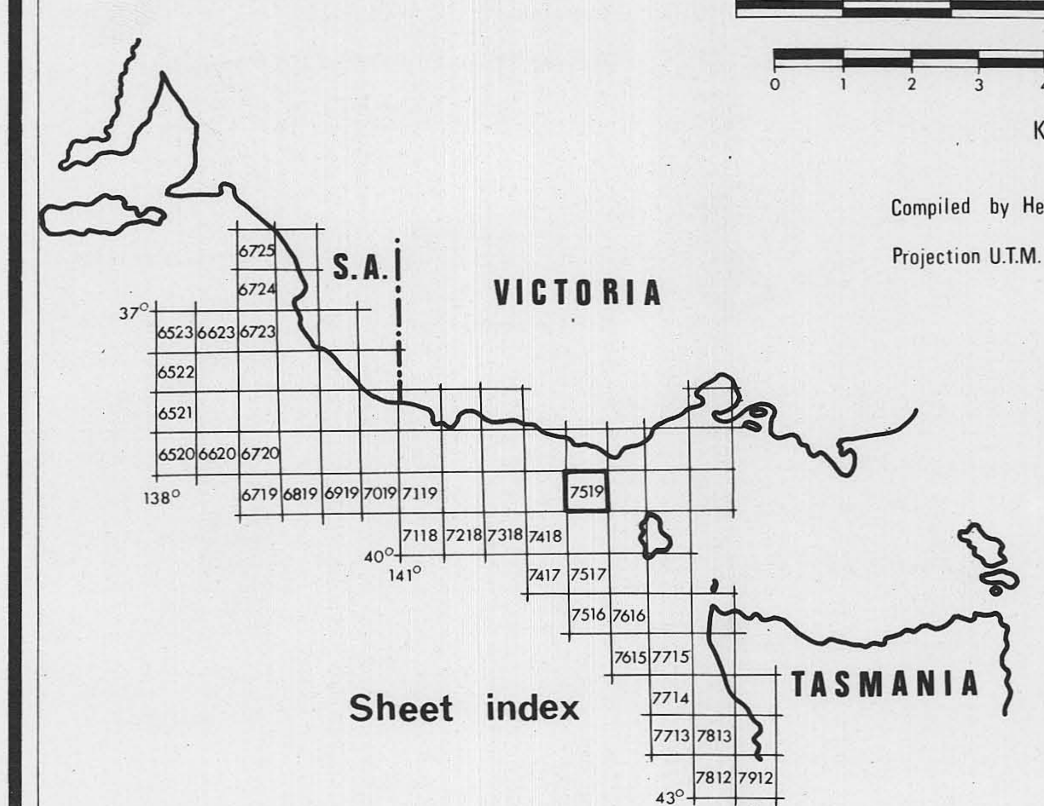


HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND KING ISLAND SEISMIC SURVEY

HORIZON B

(Top of Upper Cretaceous)

Contour interval : 250 feet

Datum: Sea level

Author : E.C. Urschel

Date: March-1973

5 cm

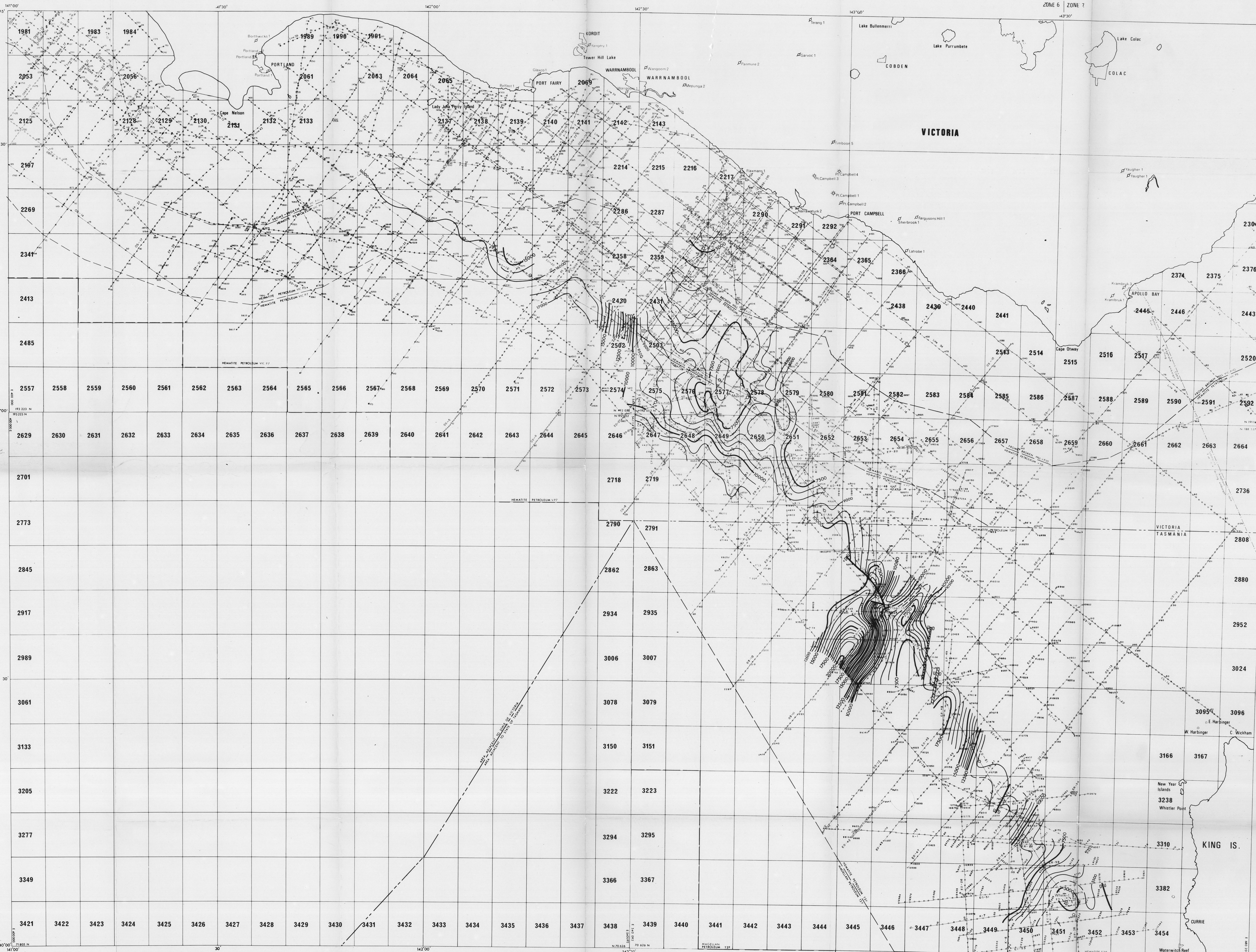
To accompany final subsidy report

080128

SHEET 7519 Encl. 1g

OR-066

OTWAY/KING PART-VII*



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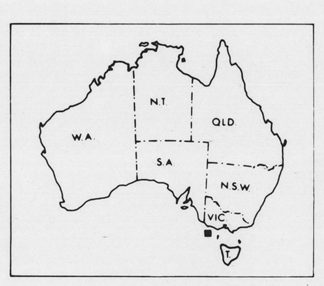

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Reference: Petroleum (Submerged Lands) Act 1967-68 of the Commonwealth of Australia.
Petroleum (Submerged Lands) Act 1967-68 of the State concerned.

LEGEND

- Oil
- Gas
- Oil & Gas
- Oil show
- Gas show
- Oil & Gas shows
- Drilling
- Dry hole (Abandoned)

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour interval: 500 ft. Datum: Sea level

Author: J. I. Denham Date: March 1973

To accompany final subsidy report

5 cm

OG 3030

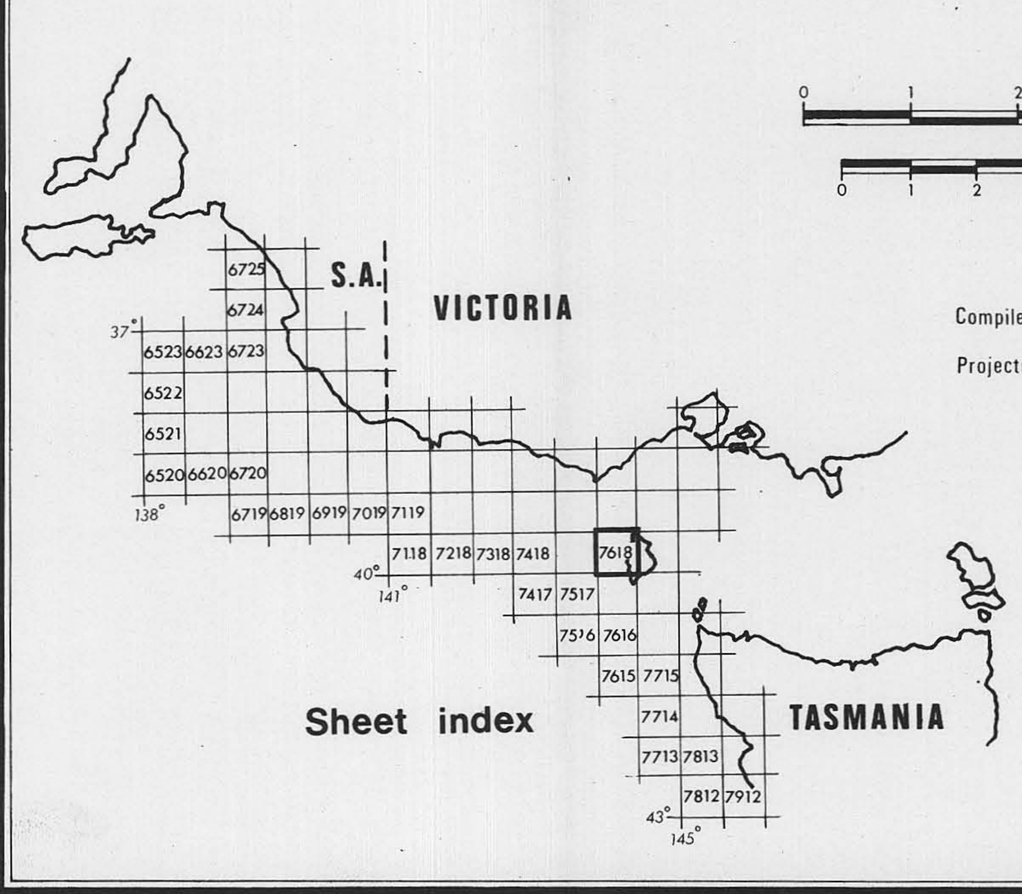
Scale 1: 100,000

MILES

KILOMETERS

Compiled by Hematite Petroleum Pty. Ltd.

Projection, UTM. Zone 54 C.M. 147°E



HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND-KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour interval-500feet

Datum: Sea level

Author: J.I. Denham

Date: March 1973

030130

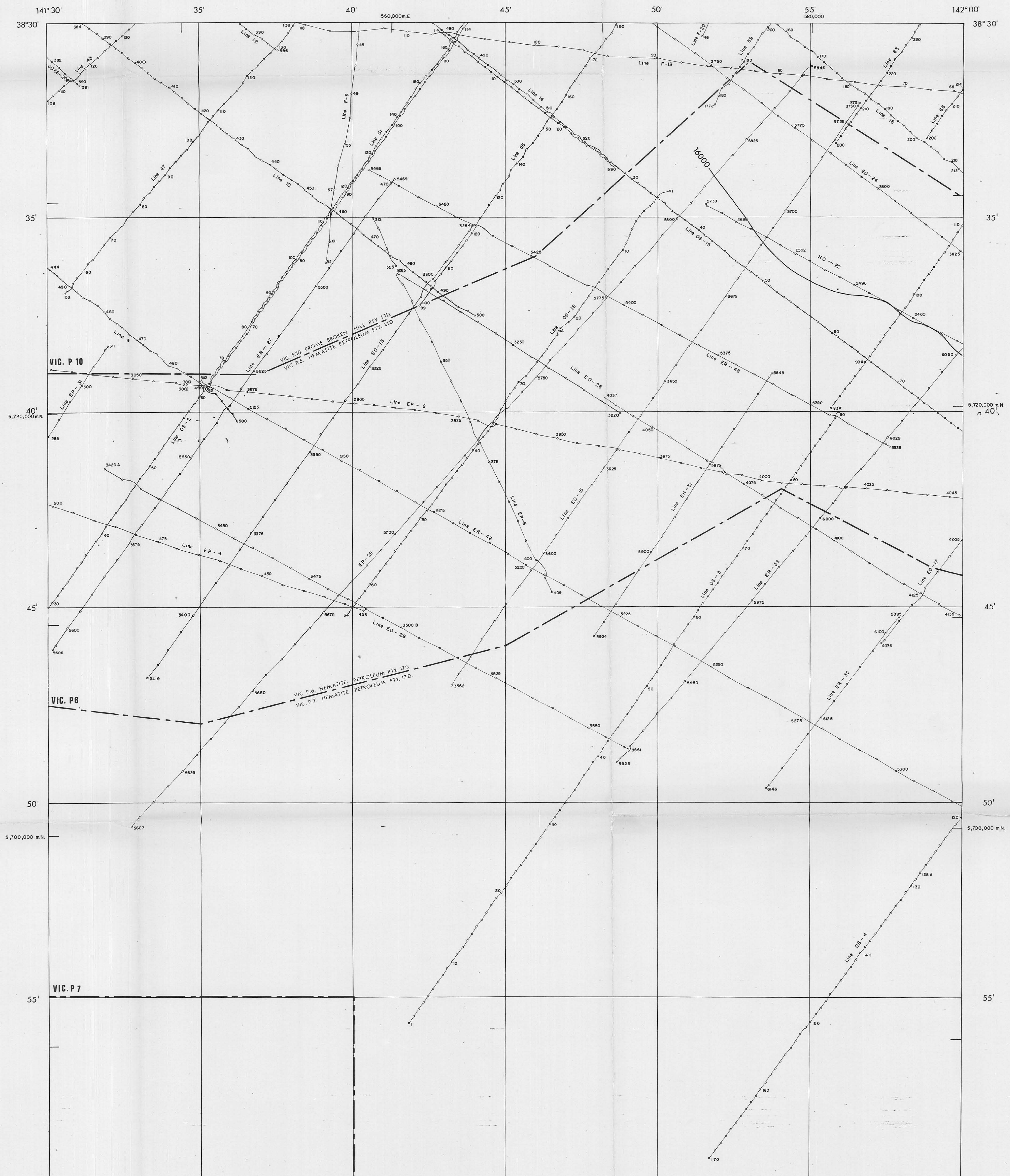
To accompany final subsidy report

5 cm

OR-066

SHEET 7618 Encl. 2a.

OTWAY/KING PART-VII*



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MILES

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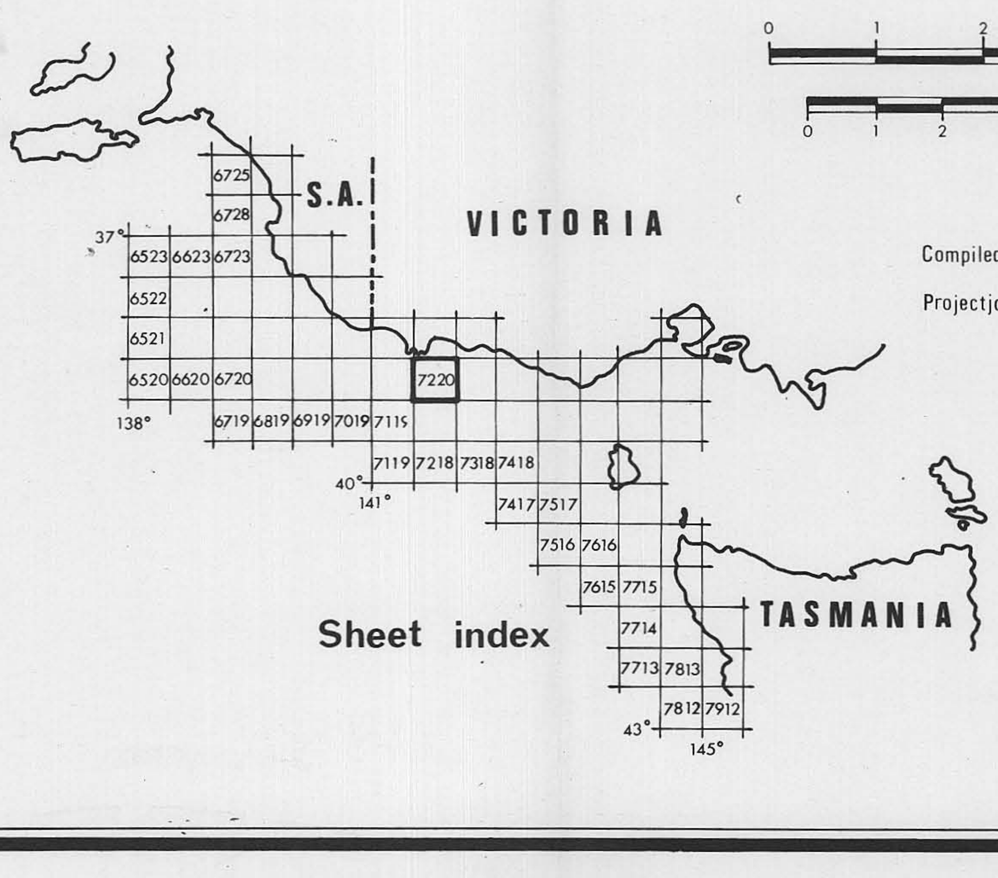
KILOMETRES

Compiled by Hematite Petroleum Pty Ltd.

Projection U.T.M. Zone 54 C.M. 141°E.



HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND-KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour interval 500 feet | Datum Sea level

Author J. J. Denham | Date March 1973

5 cm

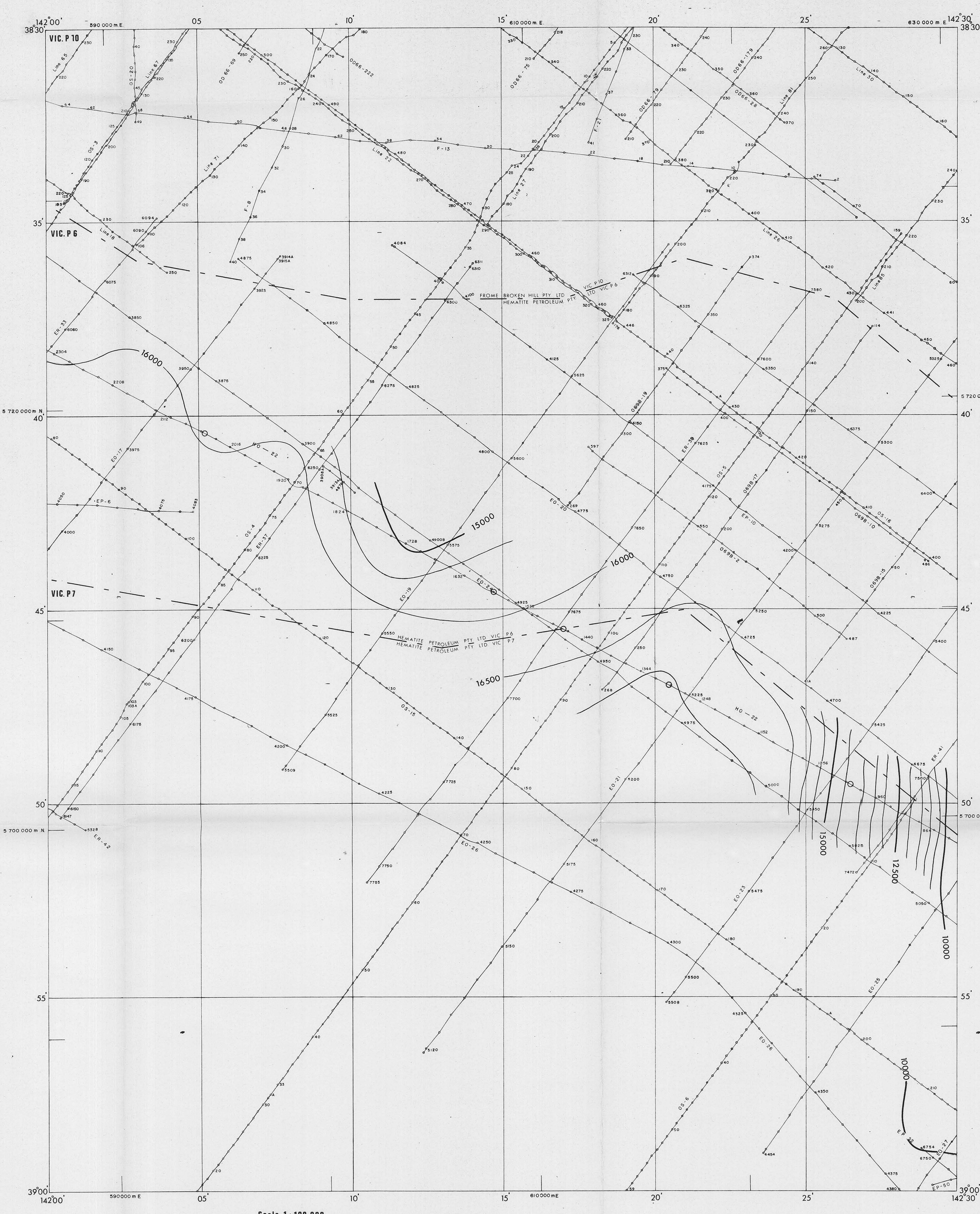
To accompany final subsidy report

080131

SHEET 7220 Encl. 2b

OR-066

OTWAY/KING PART-VII*



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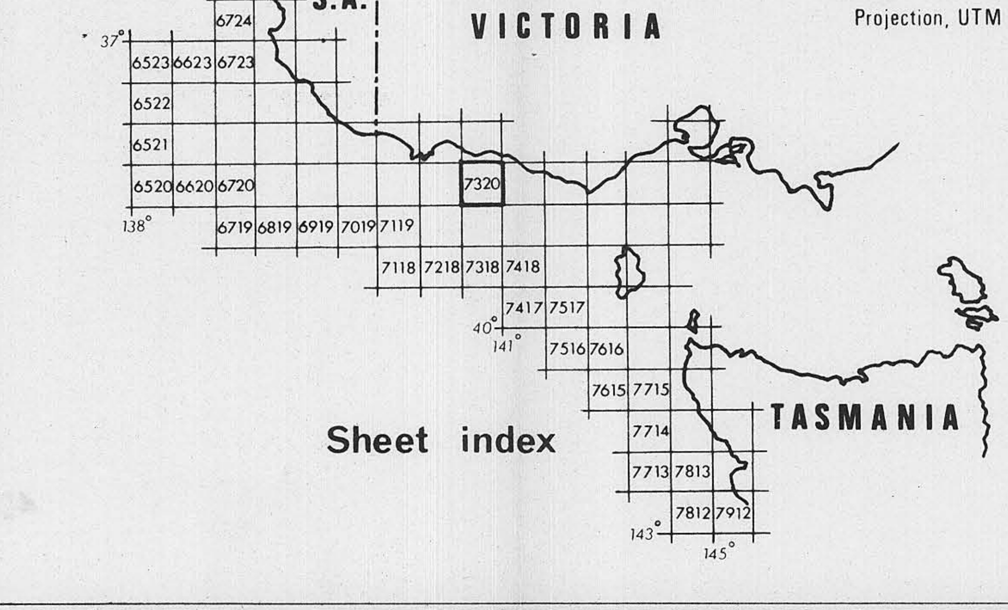
Compiled by Hematite Petroleum Pty Ltd.

Projection, UTM Zone 55 C.M. 147°E



Sheet index

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour Interval : 500 feet — Datum : Sea level

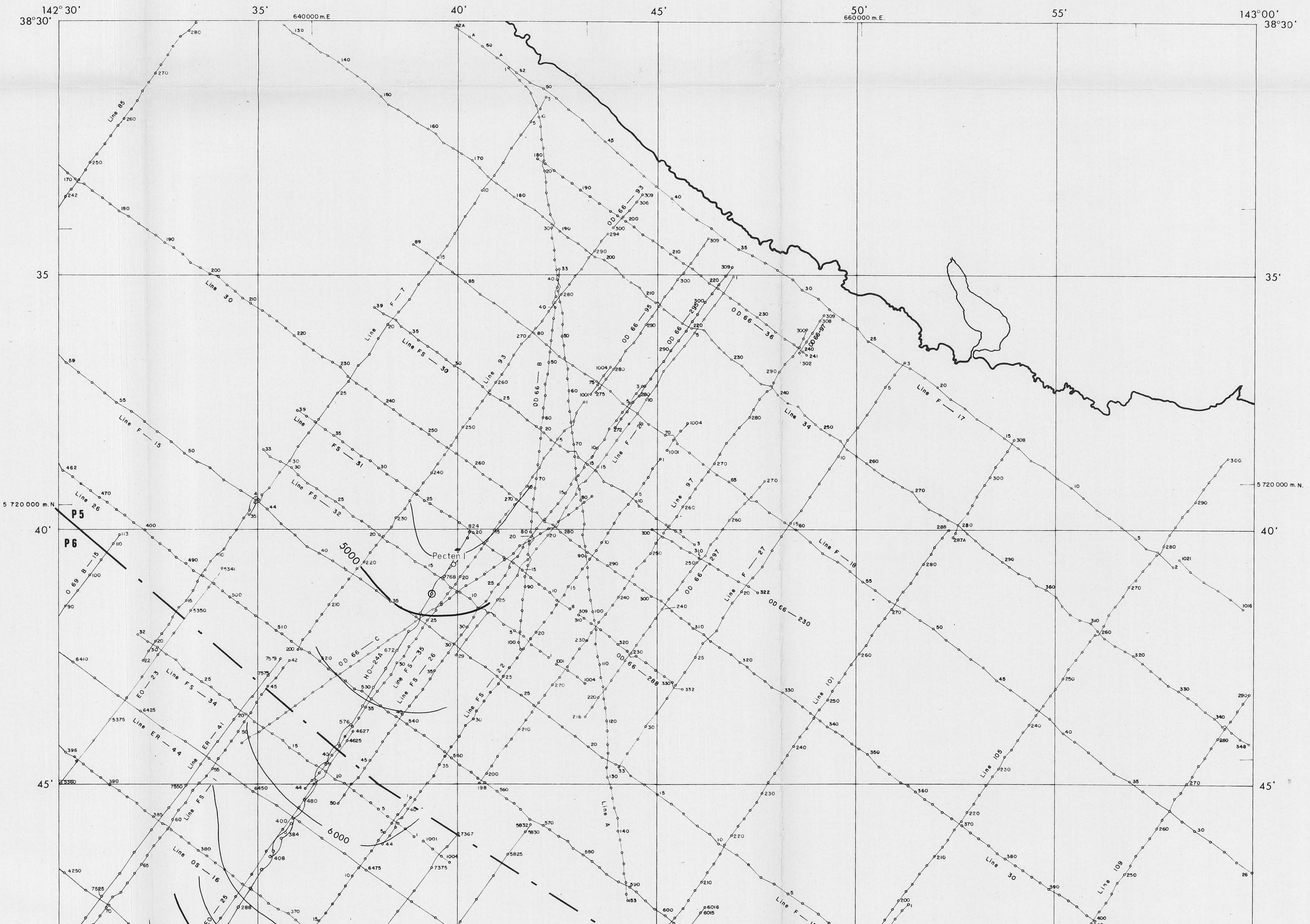
Author : J.I. Denham — Date : March, 1973

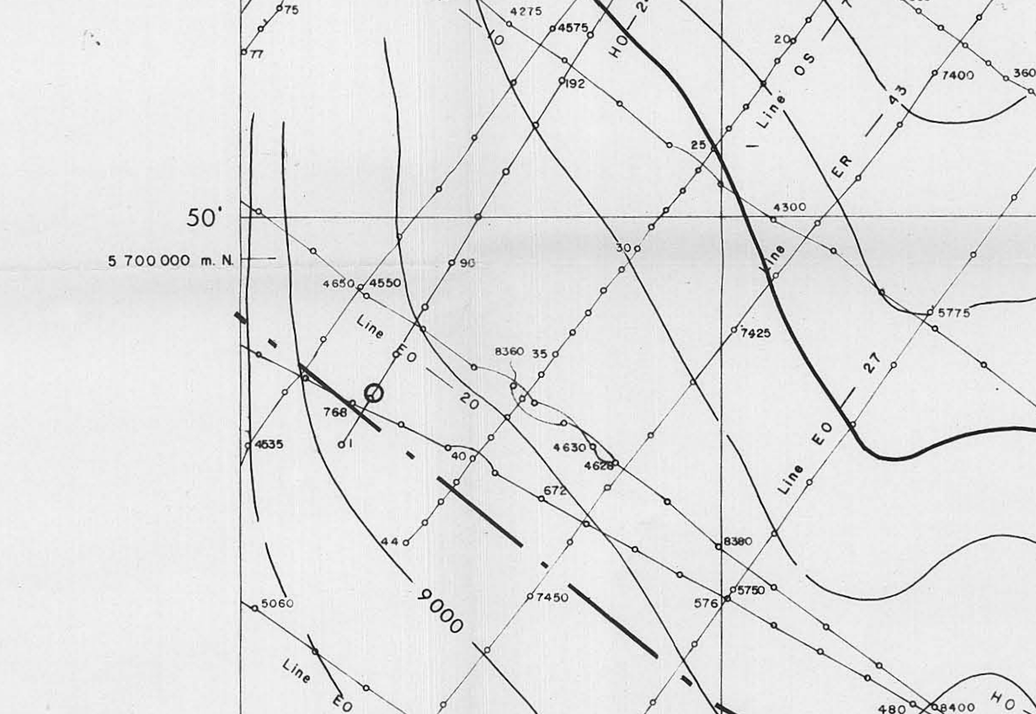
To accompany final subsidy report

5 cm

080132

SHEET 7320 Encl. 2c OR-066





Scale 1 : 100,000

MILES

KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection, UTM. Zone 54 C.M. 141°E

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour Interval : 500 feet

Datum : Sea level

Author : J. Denham

Date : March 1973

To accompany final subsidy report

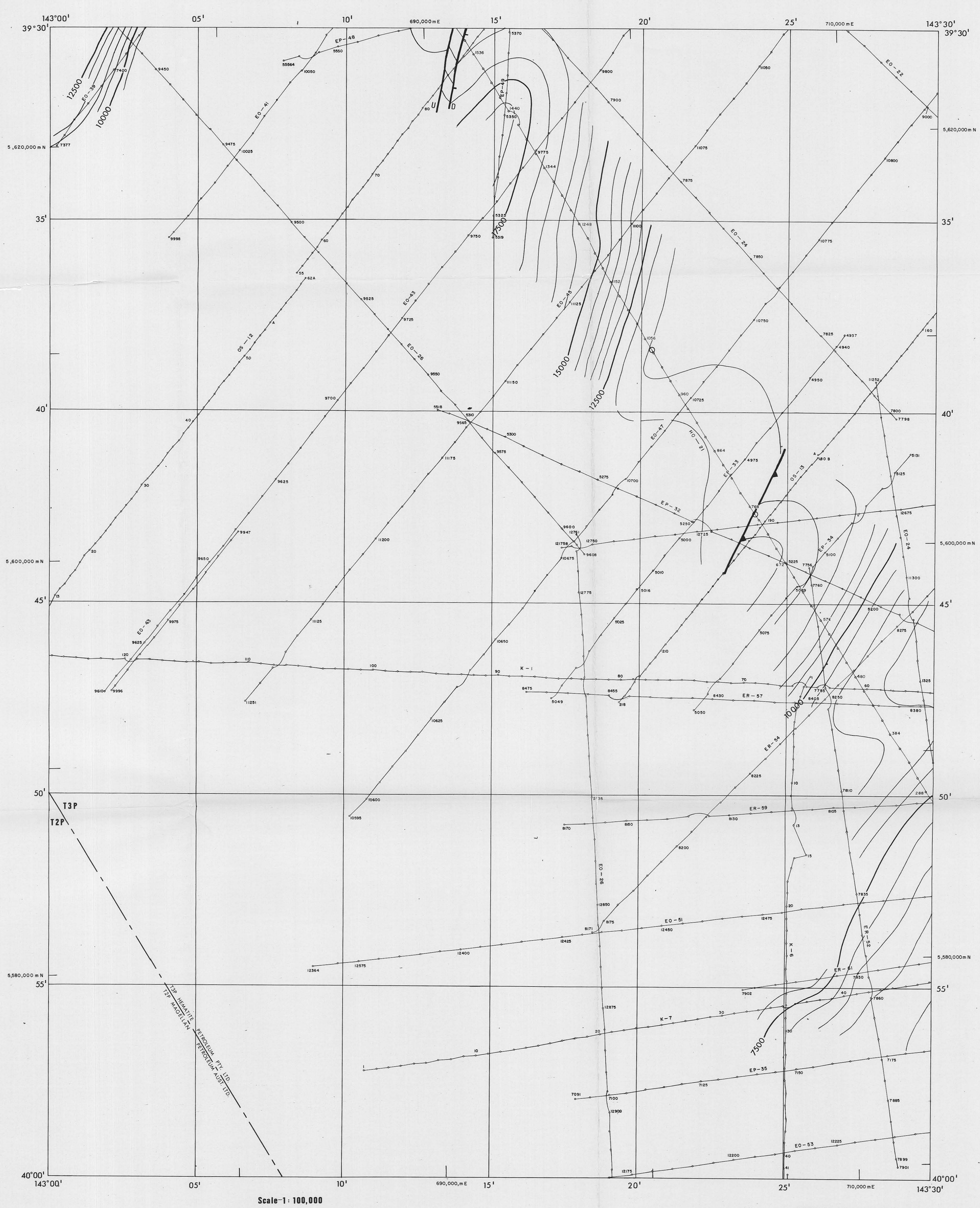
5 cm

080133

SHEET 7420 Encl. 2d.

OR-066

OTWAY/KING PART-VII*



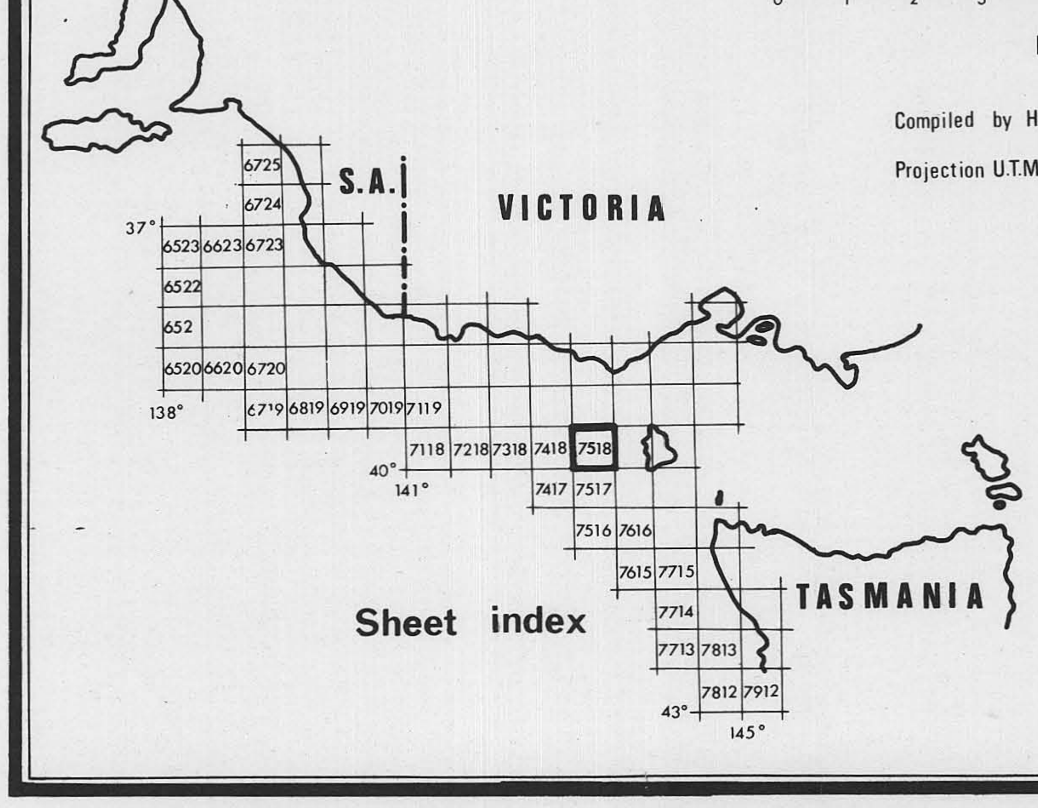
Scale 1: 100,000

MILES 0 1 2 3 4 5 6 7

KILOMETRES 0 1 2 3 4 5 6 7 8 9 10

Compiled by Hematite Petroleum Pty. Ltd.

Projection U.T.M. Zone 54 C.M. 141°E



Sheet index

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND-KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour interval: 500 feet | Datum: Sea level

Author: J. I. Denham | Date: March 1973

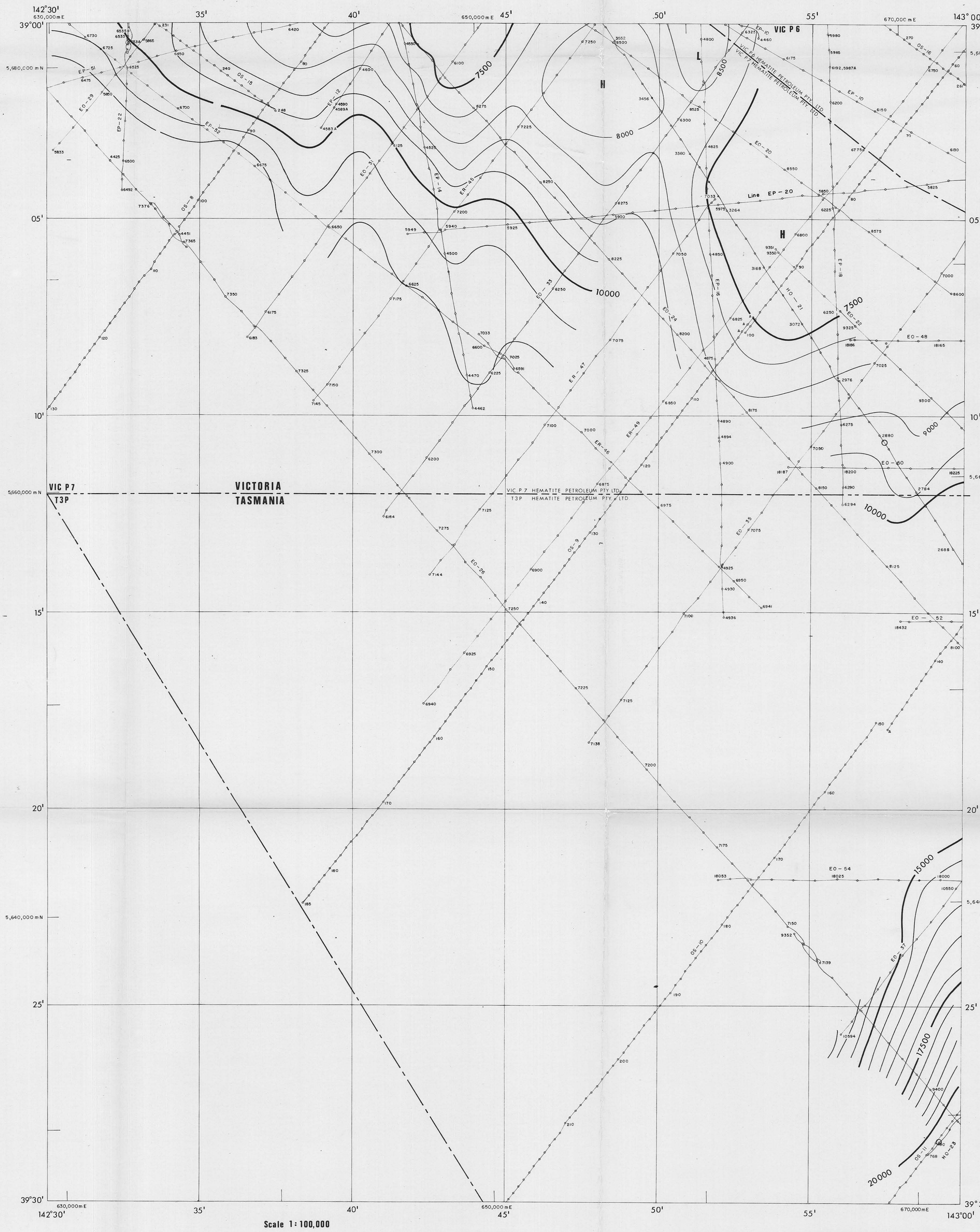
To accompany final subsidy report.

5 cm

090134

SHEET 7518 Encl. 2e

OR-066



Scale 1 : 100,000

MILES

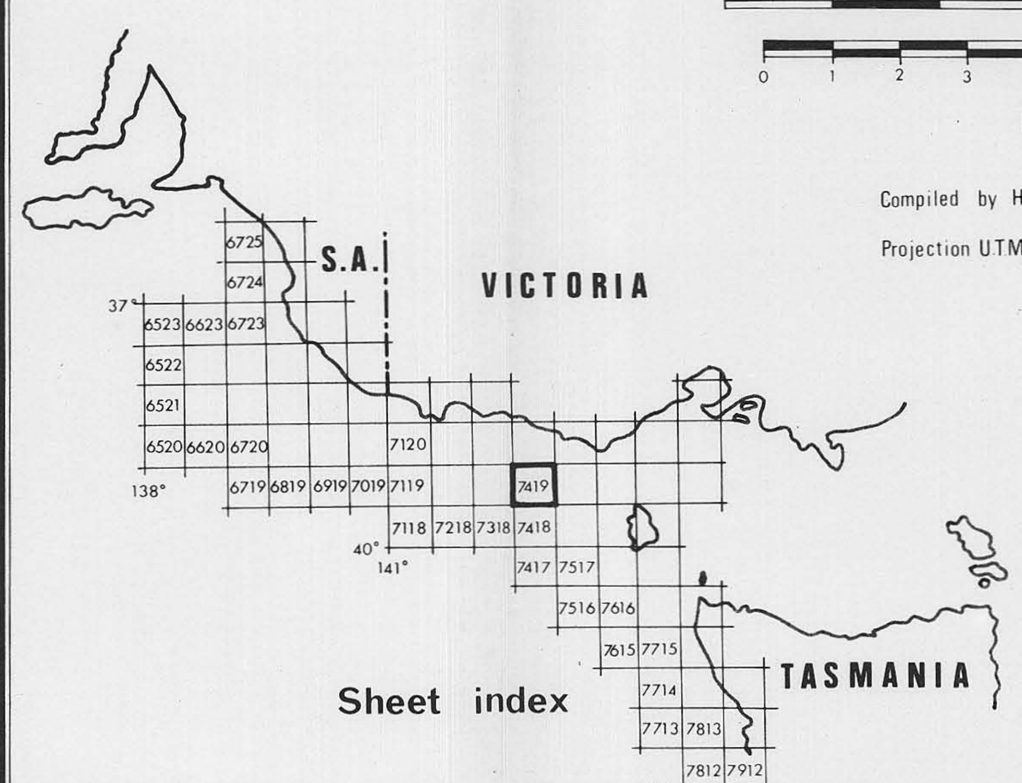
0 1 2 3 4 5 6 7

0 1 2 3 4 5 6 7 8 9 10

KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection U.T.M. Zone 54 C.M. 141 E



Sheet index

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour interval: 500 feet

Datum: Sea level

Author: J.I. Dunnam

Date: March 1973

To accompany final subsidy report

5 cm

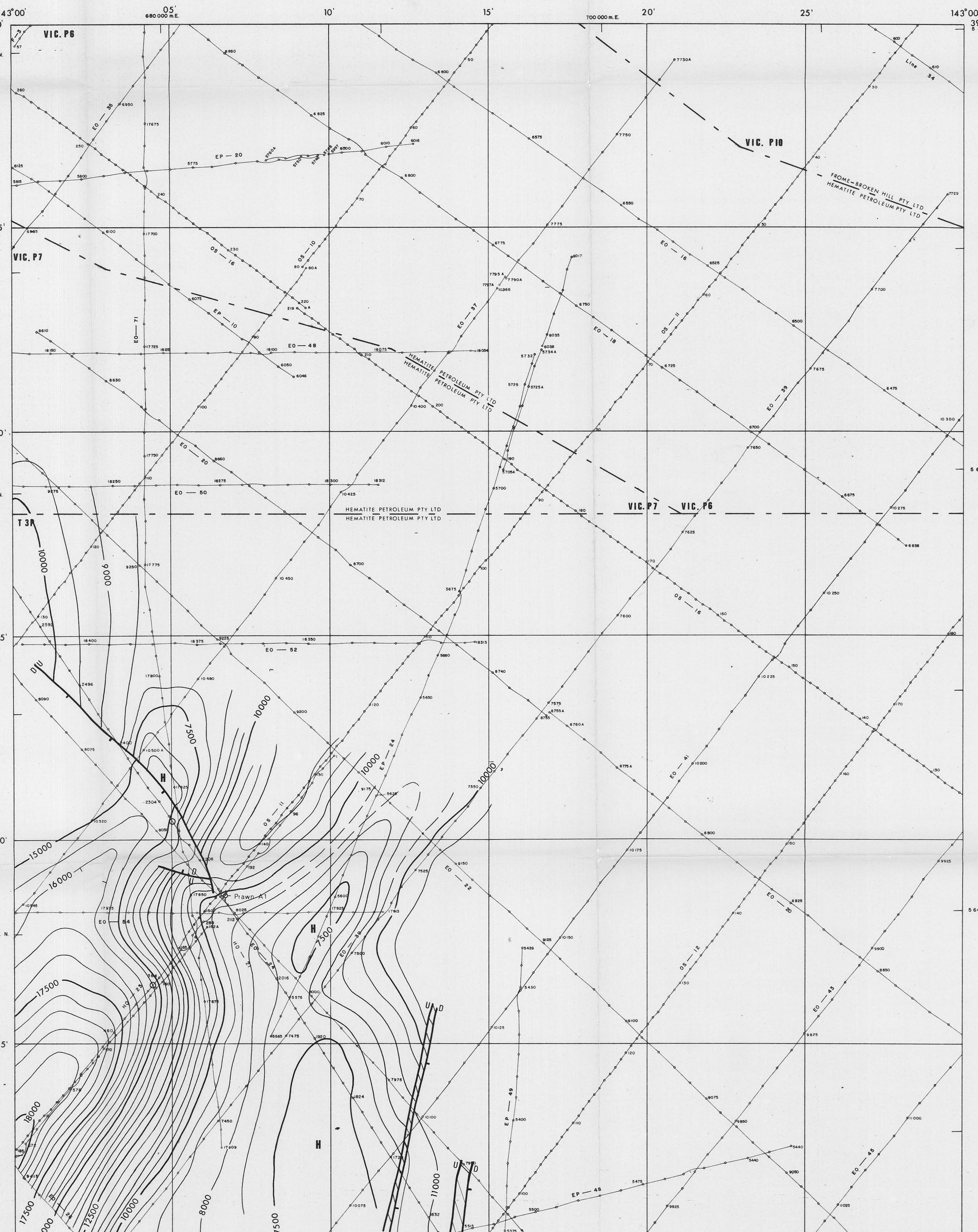
080135

OTWAY/KING PART-VII*

SHEET 7419 Encl. 2f.

OR-066

OTWAY/KING PART-VII*



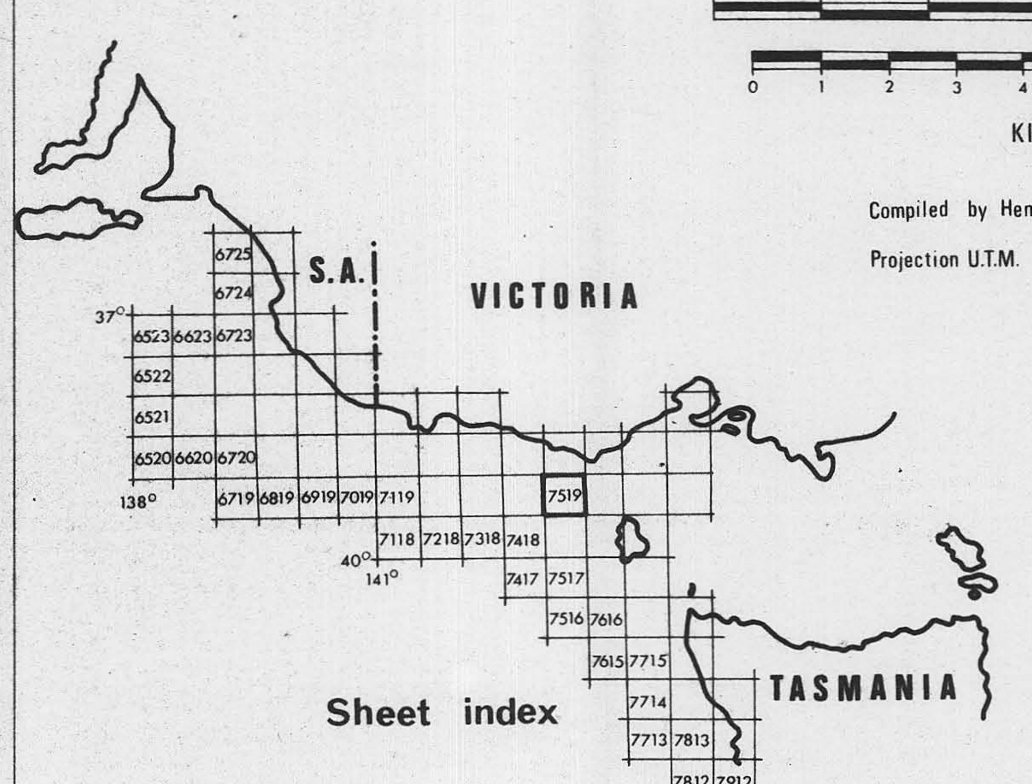
Scale 1 : 100,000

MILES

KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection U.T.M. Zone 54 CM 141 E.



Sheet index

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND-KING ISLAND SEISMIC SURVEY

HORIZON C

(Base of Upper Cretaceous)

Contour interval 500 feet

Datum Sea level

Author J.I. Denham

Date March 1973

To accompany final subsidy report

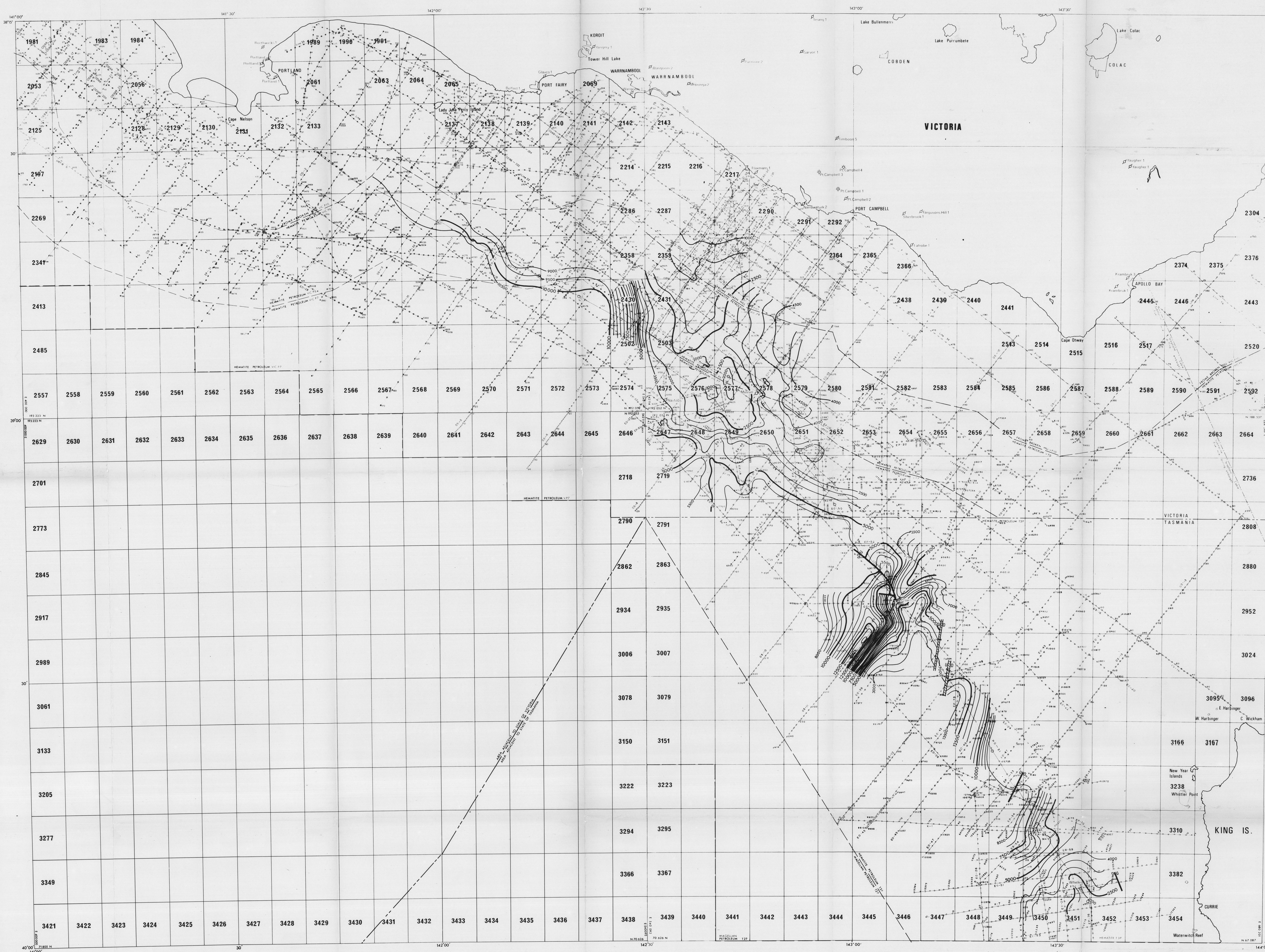
5 cm

080136

SHEET 7519 Encl. 2g

OR-066

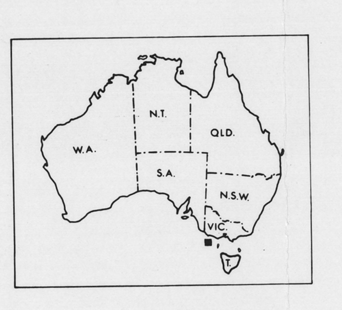
OTWAY/KING PART-VII*



Scale 1:250,000

MILES

KILOMETRES



INDEX
TO ADJOINING SHEETS

NORTHUMB ISLAND	PORTLAND	COLAC
	GRANT	WICKHAM
		STOKES

Compiled by the Exploration Drawing Office of Hematite Petroleum Pty. Ltd. in conformity with and as an extension to the topographic series prepared by the Royal Australian Survey Corps and the Division of National Mapping. This plan is drawn according to the zone numerical system and therefore disregards irregularly placed sheets. Transverse Mercator Projection.

The five minute Graticular Sections are shown thus [1777]

They are designated by:

1. The name of the Map Sheet 1:1,000,000 series.
2. The block number.
3. The Longitude and Latitude of the North West corner.

e.g. MELBOURNE 1777 Long. 148°00' E. Lat. 38°00' S.

Reference: Petroleum (Submerged Lands) Act 1967-68 of the Commonwealth of Australia.
Petroleum (Submerged Lands) Act 1967-68 of the State concerned.

LEGEND

- Oil
- Gas
- Oil & Gas
- Oil show
- Gas show
- Oil & Gas shows
- Drilling
- Dry hole (Abandoned)

ZONE 6 | ZONE 7

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B-C

Contour interval: 500 ft. Date: March 1973

Author: E G Urschel

To accompany final subsidy report

5 cm

080137

OR-066 Vol II

OG 3032

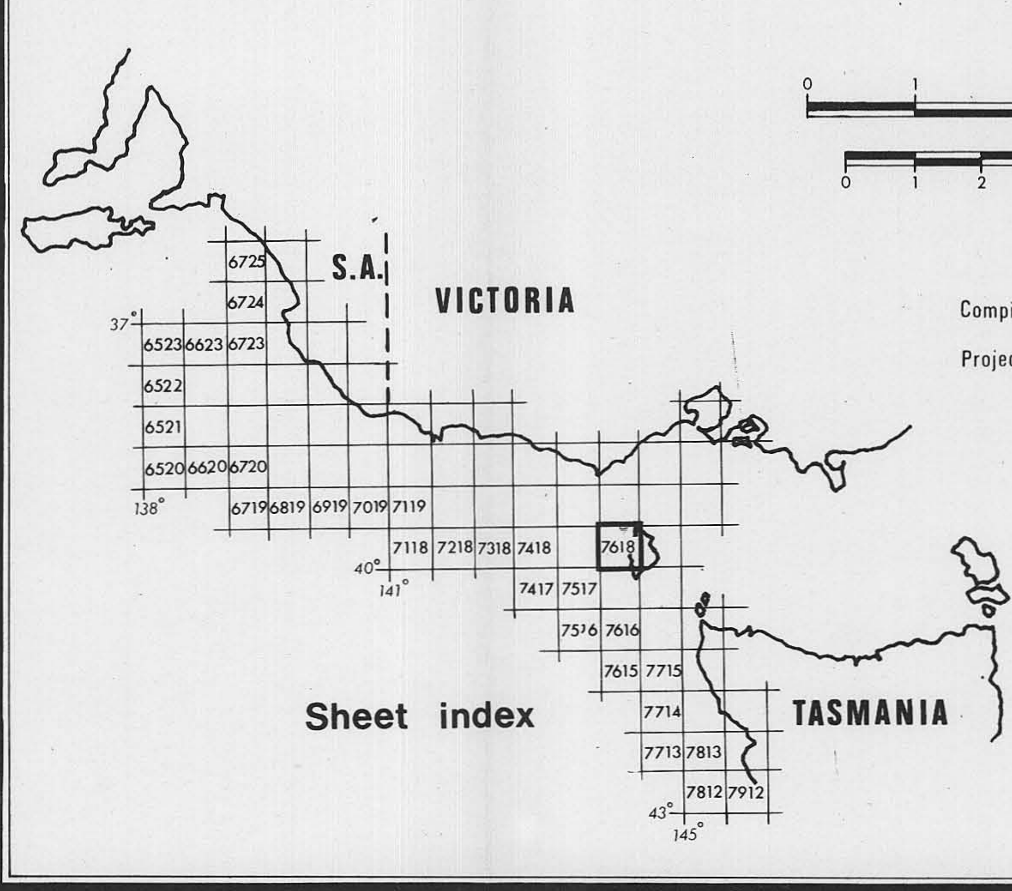
OTWAY/KING PART-VII*

Scale 1: 100,000

MILES

KILOMETERS

Compiled by Hematite Petroleum Pty. Ltd.
Projection, UTM. Zone 54 CM 147°E



HEMATITE PETROLEUM PTY. LTD.
OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B-C

Contour interval: 500 feet

Date: March 1973

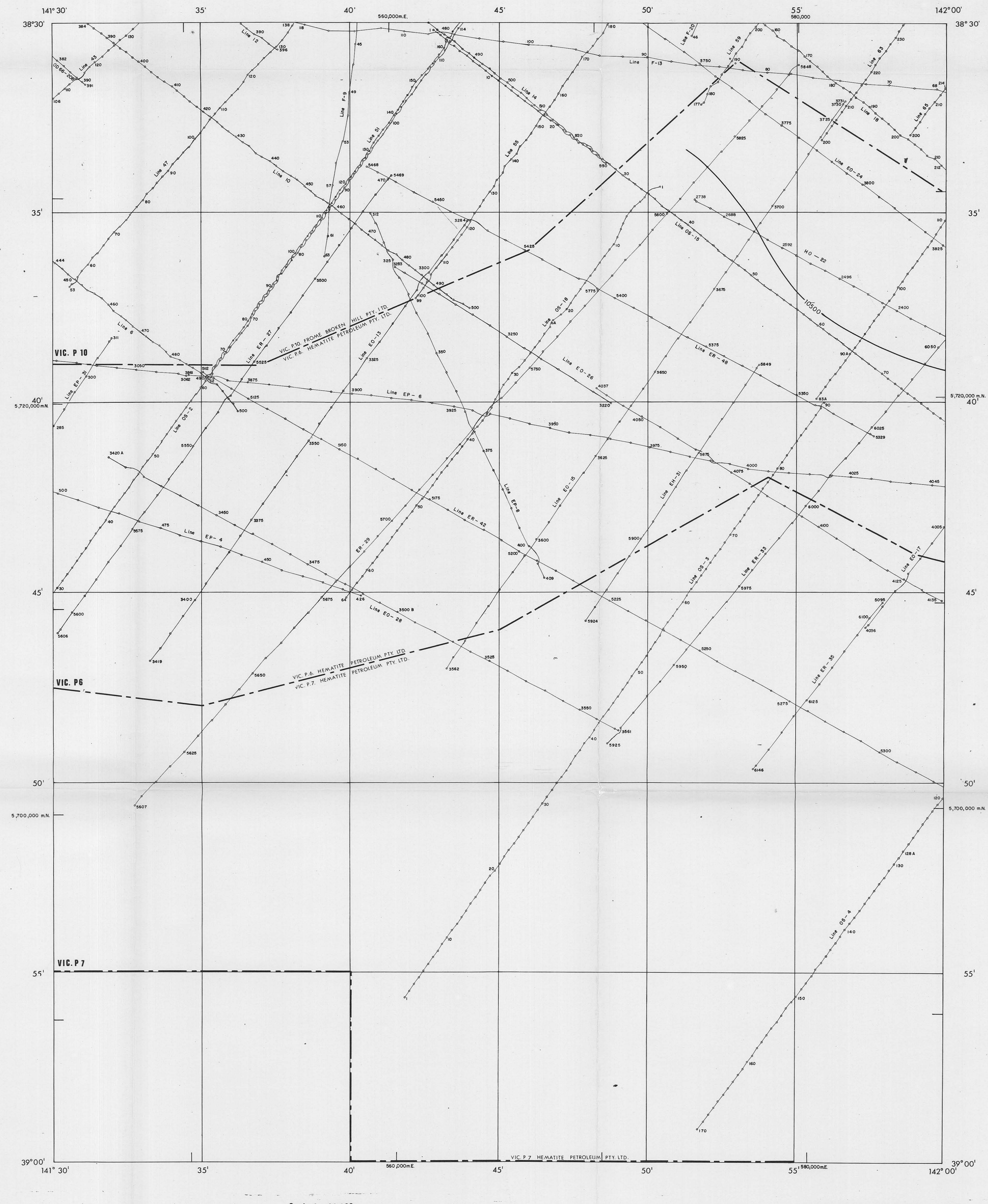
Author: E.G. Urschel

5 cm

To accompany final subsidy report

080138

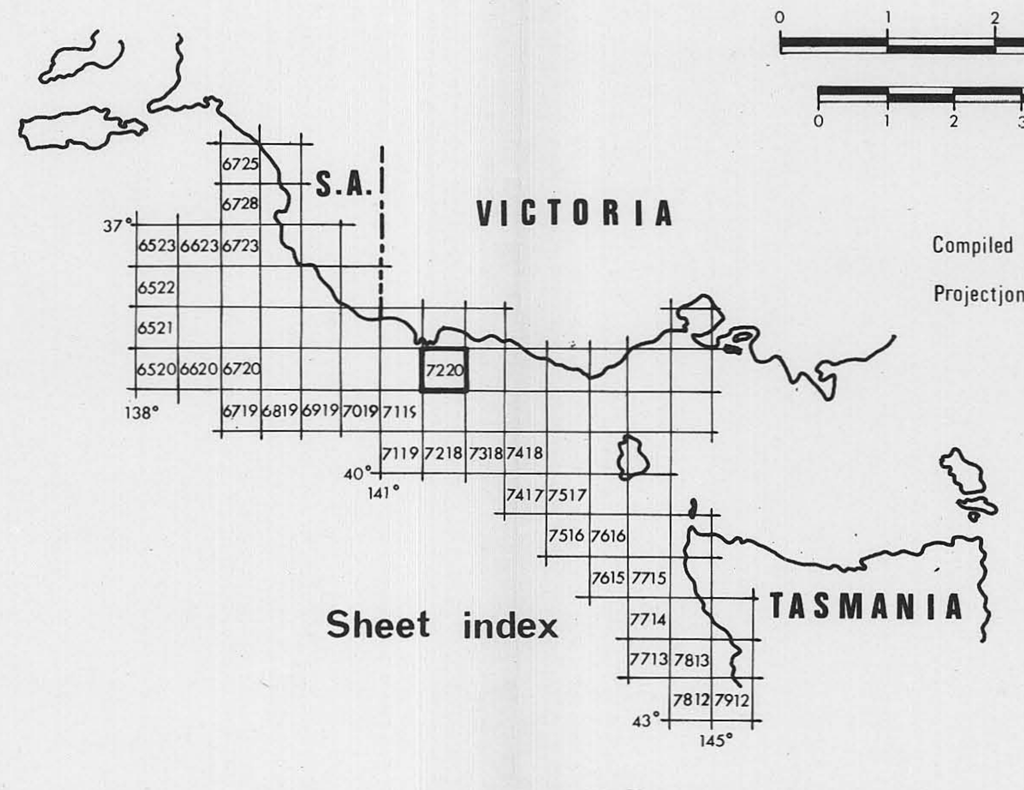
SHEET 7618 OR-066 Encl. 3a



Scale 1 : 100,000

MILES

KILOMETRES



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Compiled by Hematite Petroleum Pty Ltd.

Projection U.T.M. Zone 54 C.M. 141°E.

HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B-C

Contour interval: 500 feet

Date: March 1973

Author: E.G. Urschel

5 cm

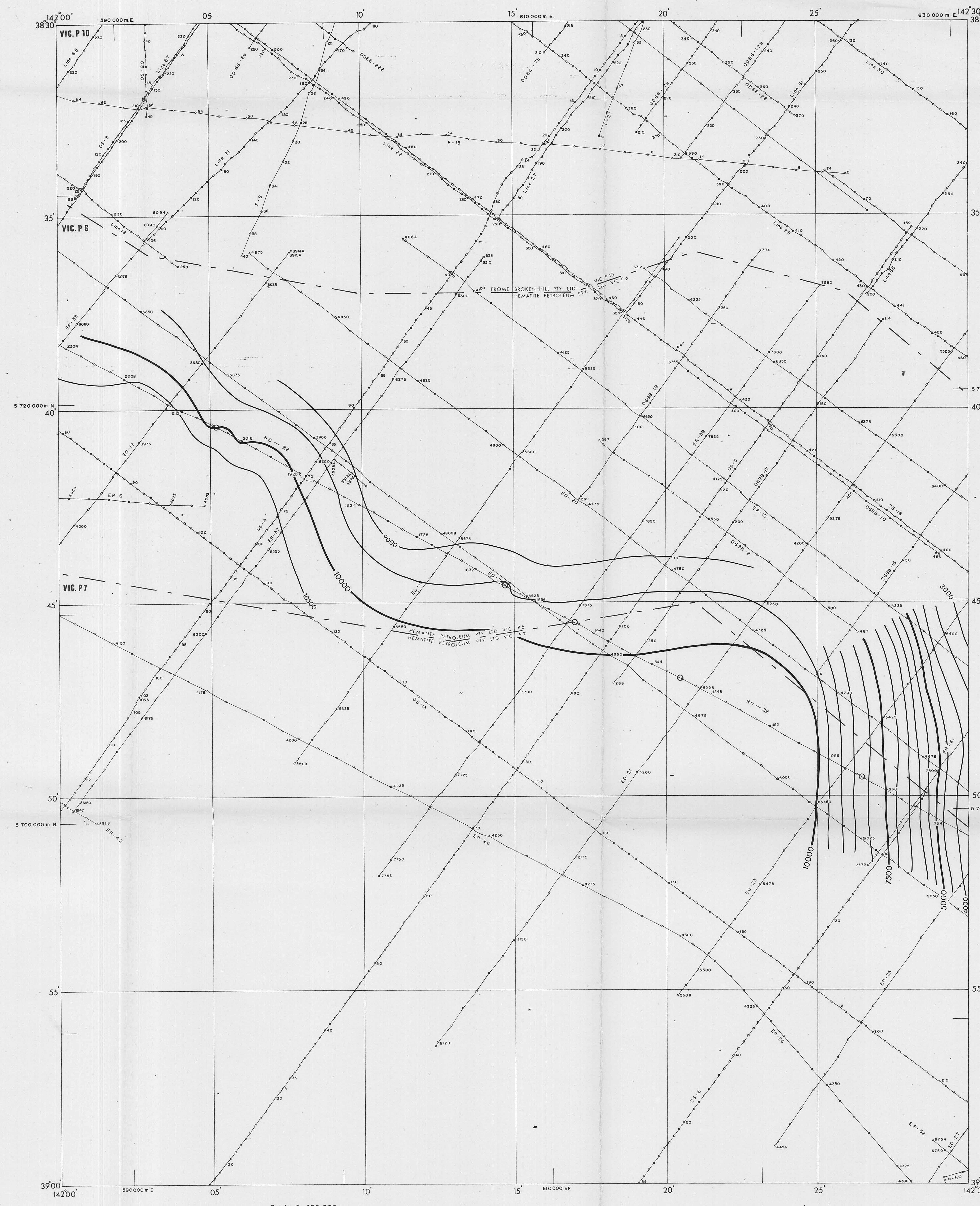
To accompany final subsidy report

080139

SHEET 7220 Encl. 3b

OR-066

OTWAY/KING PART-VII*



Scale 1 : 100,000

MILES

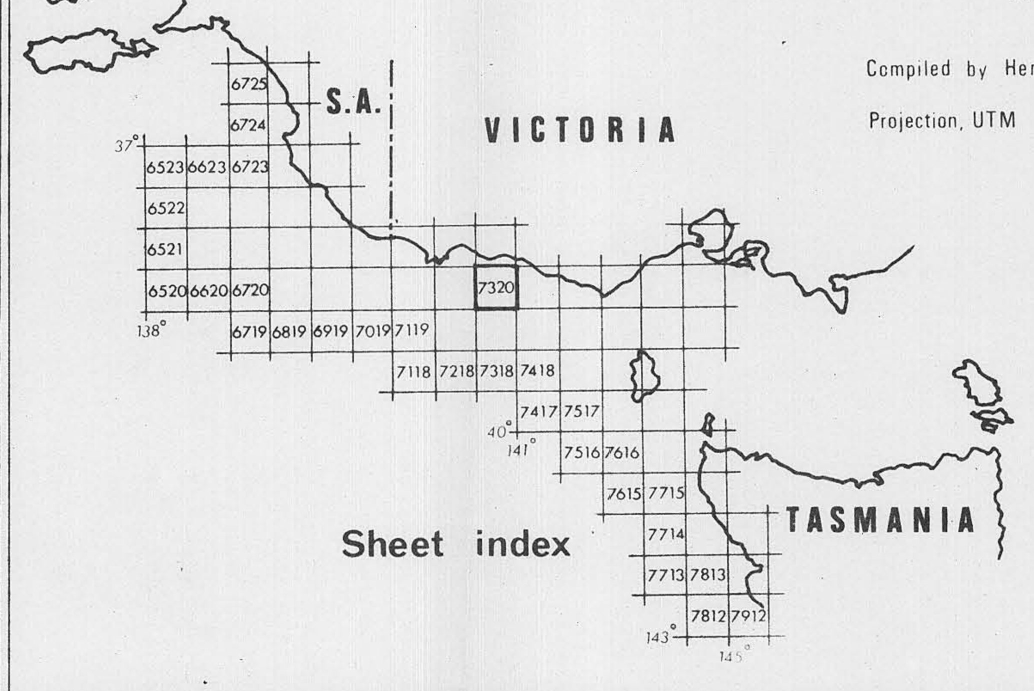
0 1 2 3 4 5 6 7

0 1 2 3 4 5 6 7 8 9 10

KILOMETERS

Compiled by Hematite Petroleum Pty Ltd.

Projection, UTM Zone 55 C.M. 147°E



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HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B-C

Contour interval: 500 feet

Date: March, 1973

Author: E.G. Urschel

5 cm

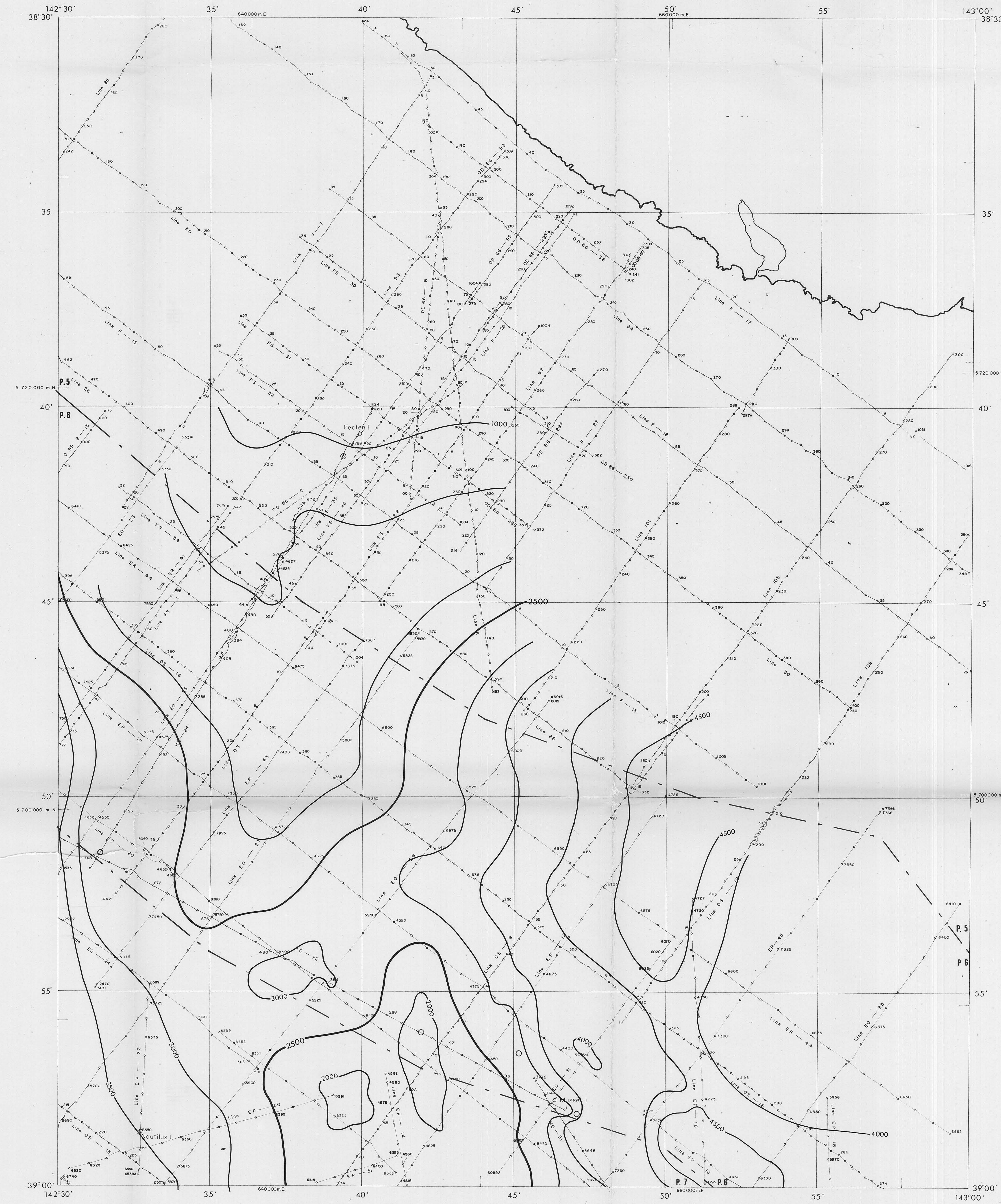
To accompany final subsidy report

080140

SHEET 7320 Encl. 3c

OTWAY/KING PART-VII*

OR-066



Scale 1:100,000

MILES

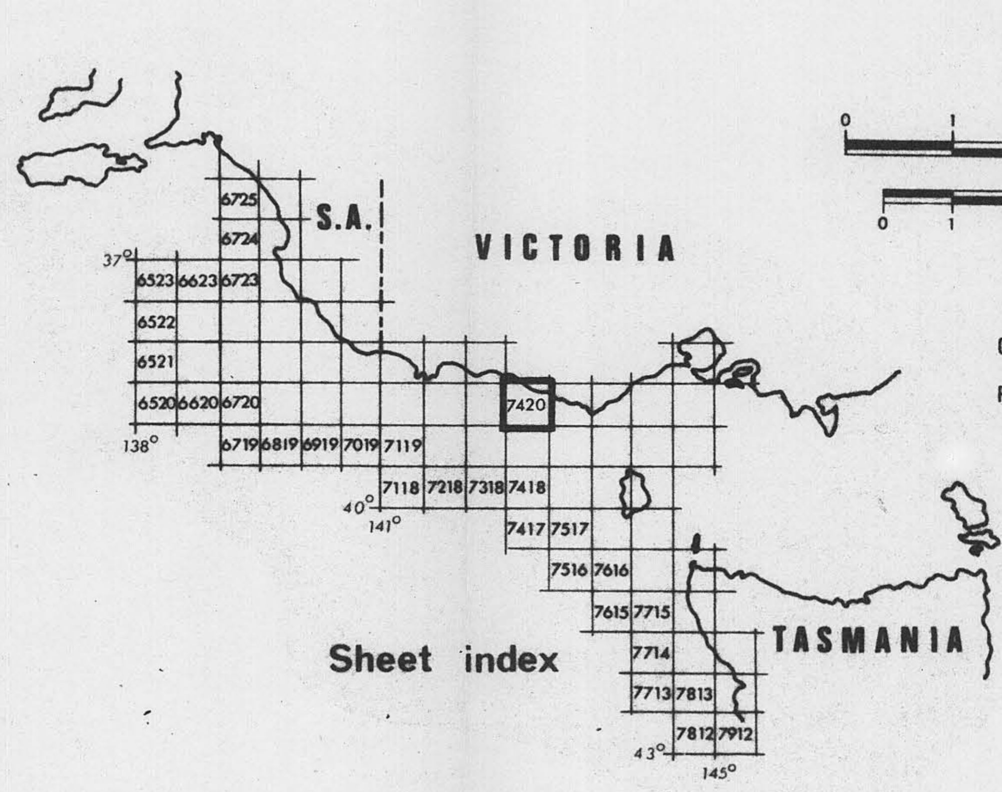
0 1 2 3 4 5 6 7

0 1 2 3 4 5 6 7 8 9 10

KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection, UTM. Zone 54 C.M. 141°E



HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B-C

Contour interval : 500 feet

Date : March 1973

Author : E.G. Urschel

5 cm

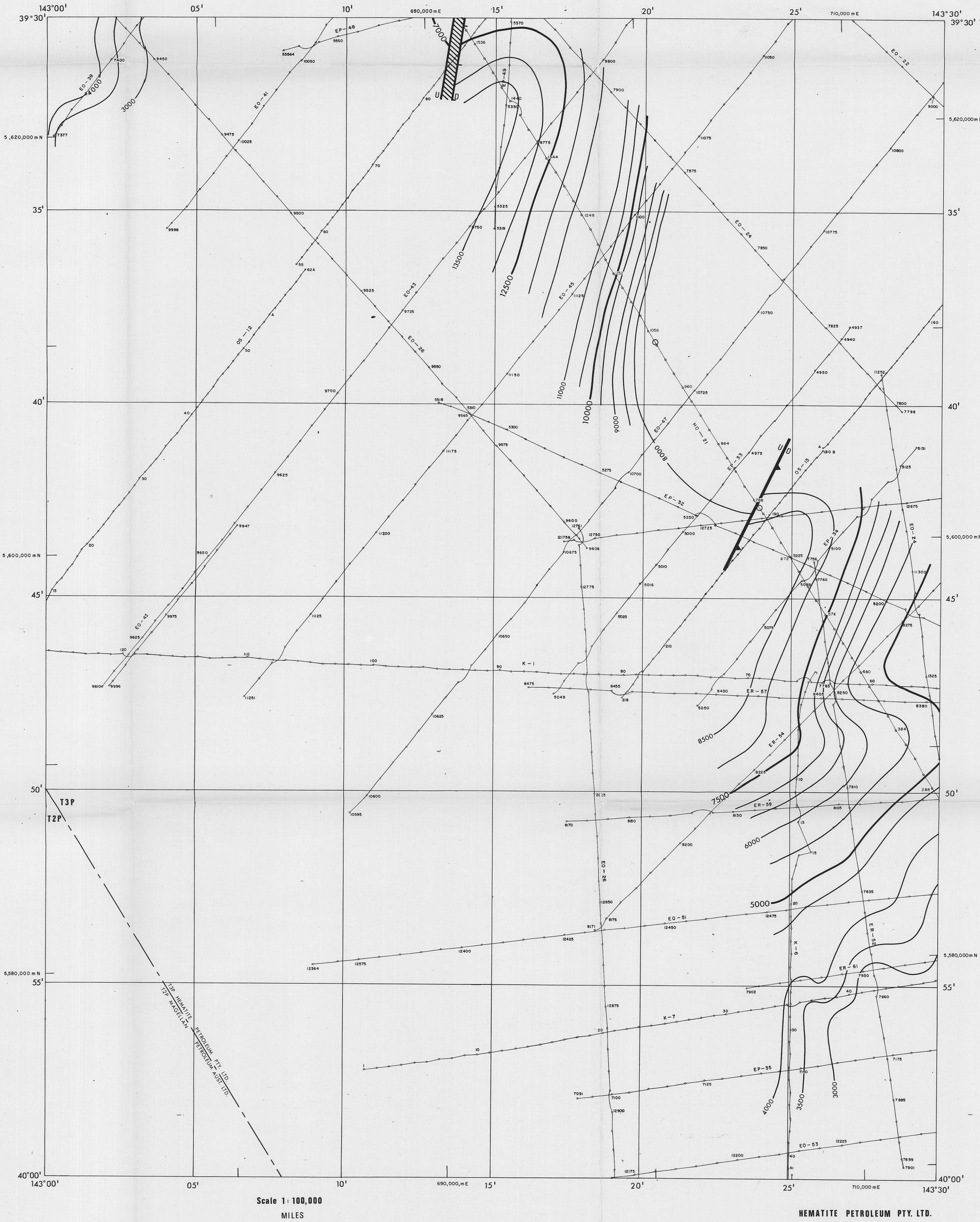
To accompany final subsidy report

080141

SHEET 7420 Encl. 3d

OR-066

OTWAY/KING PART-VII *



Scale 1 : 100,000

MILES

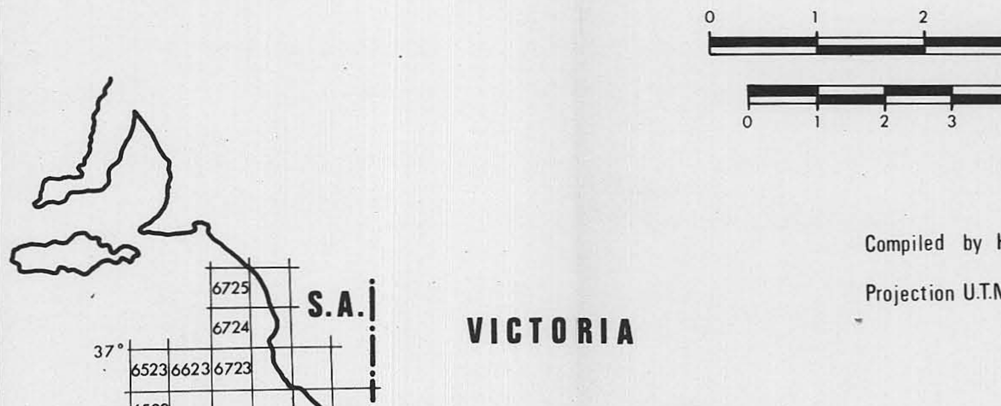
0 1 2 3 4 5 6 7

0 1 2 3 4 5 6 7 8 9 10

KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection U.T.M. Zone 54 C.M. 141°E



HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B - C

Contour interval: 500 feet

Date: March 1973

Author: E.G. Urschel

5 cm

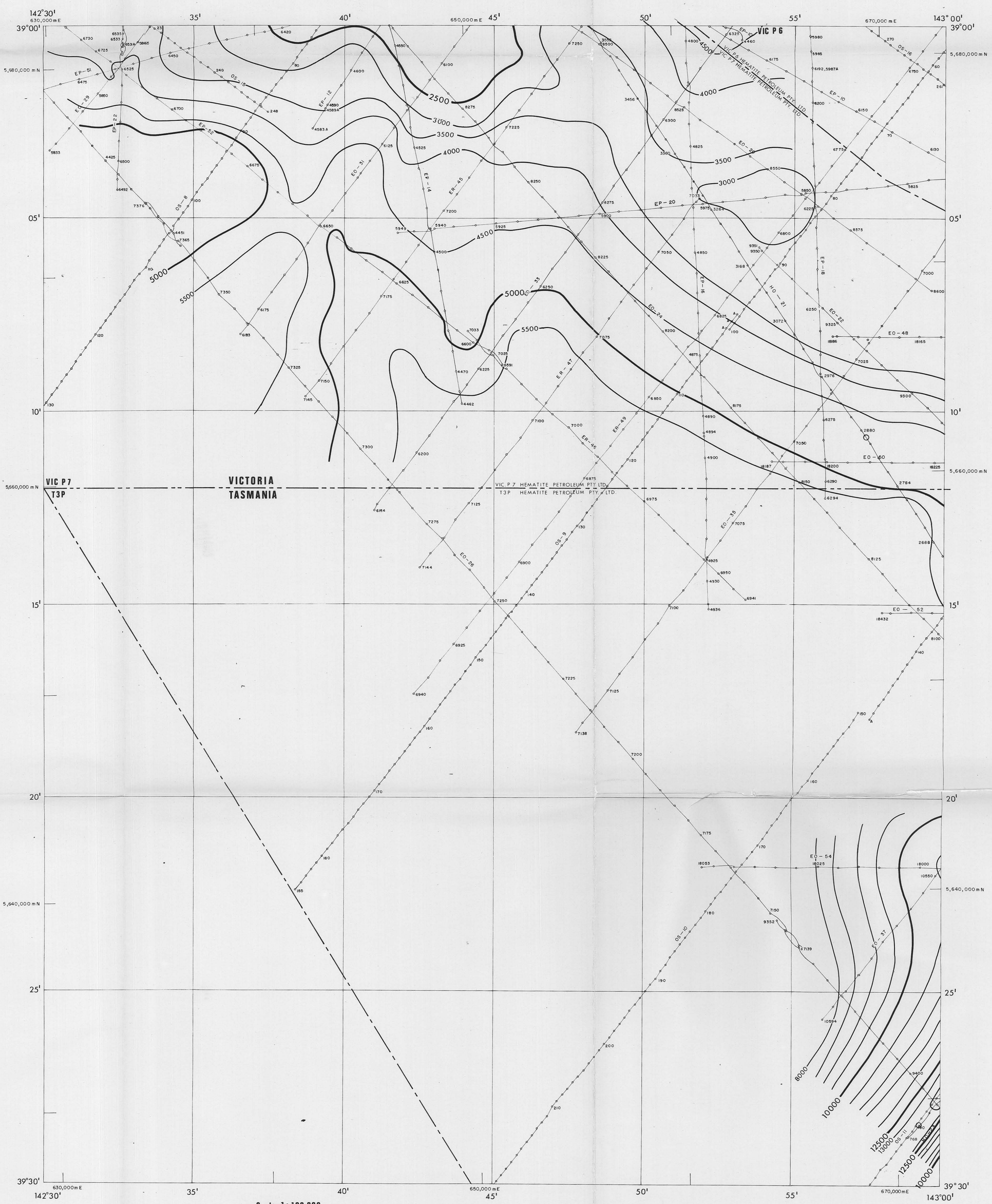
To accompany final subsidy report

080142

SHEET 7518 Encl. 3e

OR-C66

OTWAY/KING PART-VII*



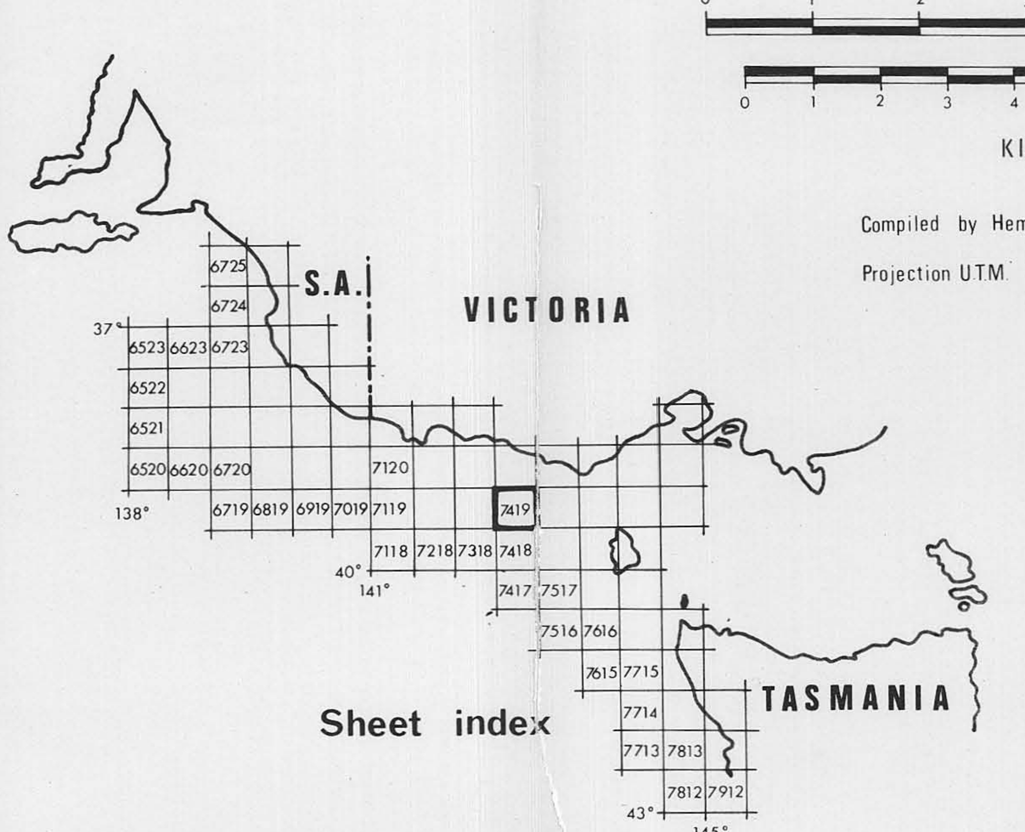
Scale 1 : 100,000

MILES 0 1 2 3 4 5 6 7

KILOMETRES 0 1 2 3 4 5 6 7 8 9 10

Compiled by Hematite Petroleum Pty. Ltd.

Projection UTM Zone 54 CM 141 E



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HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B-C

Contour interval 500 feet

Date: March 1973

Author: E.G. Urschel

5 cm

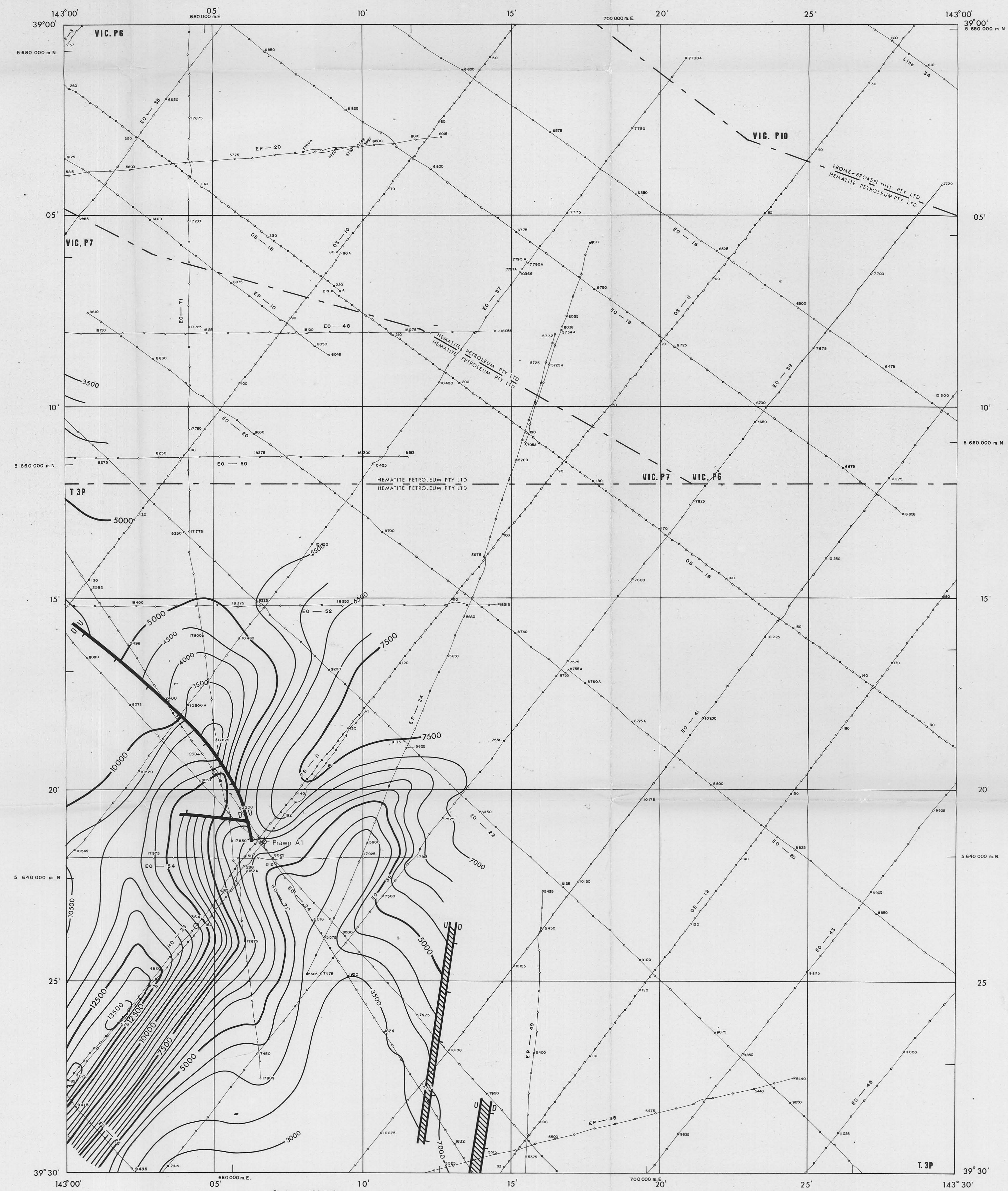
To accompany final subsidy report

080143

OTWAY/KING PART-VII*

SHEET 7419 Encl. 3f

OR-066



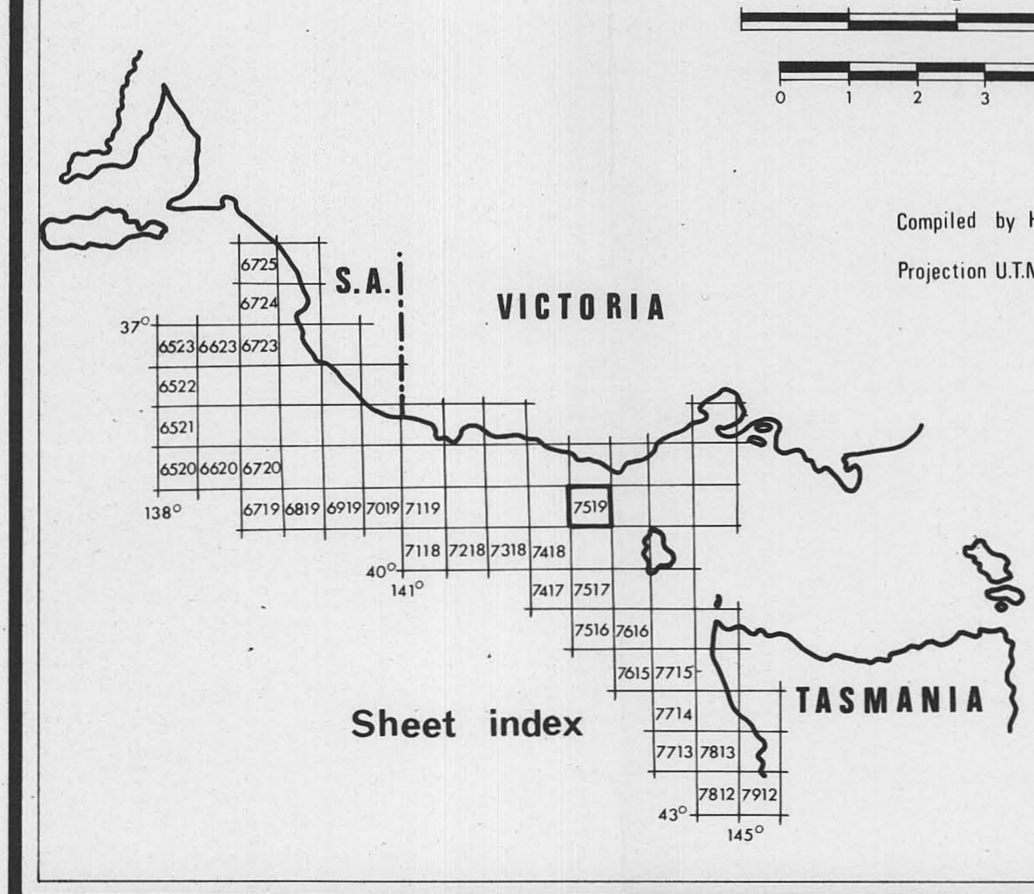
Scale 1 : 100,000

MILES

KILOMETRES

Compiled by Hematite Petroleum Pty. Ltd.

Projection U.T.M. Zone 54 CM 141 E.



HEMATITE PETROLEUM PTY. LTD.

OTWAY BASIN

PORTLAND – KING ISLAND SEISMIC SURVEY

ISOPACH B-C

Contour interval: 500 feet

Date: March 1973

Author: E.G. Urschel

5 cm

To accompany final subsidy report

080144

SHEET 7519 Encl. 3g

OR-066