Open File Envelope No. 1952

EPP 4

DENMAN BASIN

1972 DENMAN BASIN MARINE SEISMIC SURVEY FINAL REPORT

Submitted by

Outback Oil Company N.L.
1972

© 18/01/00

This report was supplied as part of the requirement to hold a mineral or petroleum exploration tenement in the State of South Australia. PIRSA accepts no responsibility for statements made, or conclusions drawn, in the report or for the quality of text or drawings. This report is subject to copyright. Apart from fair dealing for the purposes of study, research, criticism or review as permitted under the Copyright Act, no part may be reproduced without written permission of the Chief Executive of Primary Industries and Resources South Australia, GPO Box 1671, Adelaide, SA 5001.

Enquiries: Customer Services
Ground Floor
101 Grenfell Street, Adelaide 5000

Telephone: (08) 8463 3000
Facsimile: (08) 8204 1880

PRIMARY INDUSTRIES AND RESOURCES SA

CONTENTS ENVELOPE 1952

TENEMENT: E.P.P. 4 - Denman Basin.

TENEMENT HOLDER: Outback Oil Co. N.L.

REPORT:	Seismic Interpretation Of The Denman Basin Area, Offshore South Australia.	Pgs. 3-13
PLATES:	Outline Of Area. Plate 1.	Pg. 12
	Major Basins - South & West Australia. Plate 2.	Pg. 13
	Shallow Seismic Horizon(s). Plate 3.	1952(III)-23
	Seismic Horizon In Mesozoic(?) Plate 4.	1952(III)-24
	Isochron - Shallow In Mesozoic(?) Plate 5.	1952(III)-25
	Record Section Line 8. Plate 6.	1952(III)-26
	" " " 10. Plate 7.	1952(III)-27
	" " " 11. Plate 8.	1952(III)-28
	" " " 14. Plate 9.	1952(III)-29
	" " " 16. Plate 10.	1952(III)-30
	" " " G (Partial). Plate 11.	1952(III)-31
	" " " J " Plate 12.	1952(III)-32
	" " " 13. " Plate 13.	1952(III)-33
PLANS:	Water Depth (and Proposed Programme).	1952(I)-6,7,8
	Shallow Seismic Horizon(s).	1952(III)-1
	Seismic Horizon In Mesozoic(?).	1952(III)-3
	Isochron - Shallow Horizon(s) To Mesozoic(?).	1952(III)-2
REPORT:	Operations Report Marine Seismic Survey.	Pgs. 14-26
APPENDICIES:	Appendix A. Key Personnell.	Pg. 27-
	" B. Equipment - Recording & Vessel.	Pgs. 28-31
	" C. Operation Statistics.	Pg. 32
	" D. Field Tape Log & Production Statistics.	Pgs. 33-36
PLATES:	Location Of Prospect. Plate 1.	Pg. 38
	Cable & Spread Arrangement 1600 Meter Streamer. Plate 2.	Pg. 39
	Airgun Array. Plate 3.	Pg. 40
	Airgun Pulse And Spectrum. Plate 4.	Pg. 41
	Tape Format. Plate 5.	Pg. 42
REPORT:	Geonav Survey Of Denman Basin.	Pgs. 43-49
APPENDICIES:	Appendix A. Geonav Positioning System.	Pgs. 50-77

PLANS: Geonav System Block Diagram. Fig. 1. Pg. 57
Velocity Measurement Subsystem Block Diagram. Fig. 2. Pg. 59
Azimuth Measurement Subsystem Block Diagram. Fig. 3. Pg. 60
Instrument Accuracy. Table I. Pg. 61
Satellite Fix Distribution. Fig. 4. Pg. 67
" " Errors At Lat. 32°N, Due To Forced Dead Reckoning Errors. Fig. 5. Pg. 68
Satellite Fix Errors At Lat. 32°N, Due To Forced Dead Reckoning Errors. Fig. 6. Pg. 68
Standard Deviation Versus Satellite Elevation Angle. Fig. 7. Pg. 70
Satellite Position Fix Standard Deviation Estimate Far East. Fig. 8. Pg. 71
Differences Between Variance Estimate In Laboratory And Actual Position Error. Fig. 9. Pg. 72
Calibration Principle. Fig. 10. Pg. 73
Velocity - Heading Error Statistics. Table II. Pg. 77
Approximate Location Of Denman Basin. Fig. I. Pg. 45

REPORT: Seismic Interpretation Of The Denman Basin Area, Offshore South Australia. Pgs. 78-86

PLATES: Outline Of Area. Plate 1. Pg. 86
Shallow Seismic Horizon(s). Plate 2. 1952(III)-19
Seismic Horizon In Mesozoic(?). Plate 3. 1952(III)-21
Isochron-Shallow Horizon(s) To Mesozoic (?). Plate 4. 1952(III)-22
Record Section Line 107. Plate 5. 1952(III)-4
" " " 108. " 6. 1952(III)-5
" " " 116. " 7. 1952(III)-6
" " " 125. " 8. 1952(III)-7
" " " 127. " 9. 1952(III)-8
" " " 129. " 10. 1952(III)-9
" " " 135. " 11. 1952(III)-10

PLANS: Water Depth. 1952(III)-20
Shallow Seismic Horizon(s). 1952(III)-1
Seismic Horizon In Mesozoic(?). 1952(III)-2
Isochron-Shallow Horizon(s) To Mesozoic(?). 1952(III)-3
Seismic Horizon In Jurassic Sheet 1. 1952(I)-1
" " " " " 2. 1952(I)-2
Isochron Sheet 1. 1952(I)-3
" " 2. 1952(I)-4
" " 3. 1952(I)-5
Water Depth Map Sheet 1. 1952(I)-6

PLANS:	Water Depth Map Sheet 2.	1952(I)-7
	" " " " 3.	1952(I)-8
	Seismic Horizon In Cretaceous Sheet 1.	1952(I)-9
	" " " " " 2.	1952(I)-10
	" " " " " 3.	1952(I)-11
	Shallow Seismic Horizon.	1952(III)-1
	Isochron Shallow Horizon To Mesozoic.	1952(III)-2
	Seismic Horr. In Mesozoic.	1952(III)-3
	Record Section 107.	1952(III)-4
	" " 108.	1952(III)-5
	" " 116.	1952(III)-6
	" " 125.	1952(III)-7
	" " 127.	1952(III)-8
	" " 129.	1952(III)-9
	" " 135.	1952(III)-10
	" " 8.	1952(III)-11
	" " 10.	1952(III)-12
	" " 11.	1952(III)-13
	" " 14.	1952(III)-14
	" " 16.	1952(III)-15
	" " Line G.	1952(III)-16
	" " " J.	1952(III)-17
	" " " 13.	1952(III)-18
	Shallow Seismic Horizon.	1952(III)-19
	Water Depth Map.	1952(III)-20
	Seismic Horizon - Mesozoic.	1952(III)-21
	Isochron Shallow Borizon To Mesozoic.	1952(III)-22

27/3/25 ENV. -1952 Vol. II 003

FINAL REPORT

SEISMIC INTERPRETATION OF THE DENMAN BASIN AREA OFFSHORE SOUTH AUSTRALIA

for

OUTBACK OIL COMPANY

by

G. J. LONG & ASSOCIATES, INC.

HOUSTON, TEXAS

RECEIVED
1 AUG 1972
DEPT. OF MINES
SECURITY
1952-II

JULY, 1972

TABLE OF CONTENTS

	Page
INTRODUCTION	1
GEOLOGY	1
DATA ACQUISITION AND PROCESSING	2
INTERPRETIVE METHODS	2
DISCUSSION OF RESULTS	3
CONCLUSIONS	7

PLATES:

1. Outline of Area
2. Major Basins - South and West Australia
3. Shallow Seismic Horizon(s)
4. Seismic Horizon in Mesozoic(?)
5. Isochron - Shallow Horizon(s) to Mesozoic(?)
6. Record Section, Line 8
7. Record Section, Line 10
8. Record Section, Line 11
9. Record Section, Line 14
10. Record Section, Line 16
11. Record Section, Line G (Partial)
12. Record Section, Line J (Partial)
13. Record Section, Line 13 (Partial)

MAPS:

1. Water Depth (and Proposed Program)
2. Shallow Seismic Horizon(s)
3. Seismic Horiz on in Mesozoic(?)
4. Isochron - Shallow Horizon(s) to Mesozoic(?)

INTRODUCTION

The Denman Basin Area (~~O.E.L. 33~~ EPP4, South Australia) covers an area of approximately four million acres off the southern coast of Australia, centering approximately at Latitude 131° East, Longitude 32° South. Water depths over the Tenement area range from 160 to 275 feet.

The seismic data available in the area consist of 839 miles of coverage by Geophysical Service, Inc., obtained in early 1972 and 380+ miles by Western Geophysical Company during 1966.

The seismic traverse is laid out on approximately an eight mile square grid. This is sufficient to indicate the potential of the area, but does not provide control necessary to adequately delineate structural features other than broad regional trends.

The interpretation was begun on May 10, 1972, as processed data from the current survey became available. A preliminary final report was made at a meeting on June 20, 1972, in Houston.

Available published materials relating to the geologic background of the area were examined and have been incorporated into this report and its conclusions.

GEOLOGY

The Denman Basin, an offshore extension of the Eucla Basin, covers an area of approximately 70,000 square miles onshore in Western Australia and South Australia and extends offshore to cover an additional 70,000 square miles.

Onshore, Miocene limestones outcropping at the surface create a flat, treeless, arid plain. Available information from shallow wells along the coast indicate that this Miocene Limestone is underlain by Eocene limes, sands and clays which rest upon a thin veneer (700+) of "Marine" Cretaceous shales with suggestions of Paleozoic rocks.

The only deep test in the area is the Outback Oil-Pickrell Drilling Company, Mallabie #1 (31° 32' 14" S, 130° 36' 06" E) which was abandoned in granite at a T.D. of 4901. This test appears to have been located near a porphyry intrusive of undetermined age (similar to others noted in the Adelaide Basin) as most of the sediments encountered from 2900' to 4901' show evidence of having been affected by this intrusion. A velocity survey was run in this test,

but due to the porphyry intrusive is not regarded as normal to the area of interpretation.

Regional geological studies combined with the seismic results suggest that the Offshore Denman Basin, located on the shelf area of the South Australia Basin, lies on trend with the Canning Basin*, and is probably its southeast counterpart (Plate 2).

DATA ACQUISITION AND PROCESSING

Commencing on February 19, 1972, the Geophysical Service, Inc. M/V R. C. Dunlap, Party 909, began recording reconnaissance lines in the Offshore Denman Basin. Continuous operations continued until February 24, 1972, resulting in a completed survey totaling 839 miles.

Field recordings were obtained using an air gun array totaling 1300 cubic inches, a digital sample rate of four milliseconds, spread length of 8644 feet, pop interval of 164 feet, cable depth of 60 feet, twenty-four fold multiple subsurface coverage and a group interval of 328 feet. Data were processed in the GSI data processing center, Houston, Texas. Data were recorded to five seconds and processed to three seconds. Approximately 380+ miles of control by Western Geophysical Company was also available. Although this coverage was obtained in 1966 and is only threefold multiple subsurface coverage, the record quality is comparable.

INTERPRETIVE METHODS

Base Maps for the area at a scale of 1:100,000 were furnished by GSI. This map has been revised for the final report to include the area of the survey on one map. Line identification is provided by designating Western lines with letters and GSI lines with numbers.

The Horizons mapped were taken directly from the record sections and the maps submitted with this report have been contoured in time. Depth values based on local velocity determinations have been shown at selected locations.

Structure maps are based on continuous reflected data where available. Where character correlations define throw across faults,

* AAPG, Volune 43, No. 2, February, 1959, Page 399, P. E. Playford and M. H. Johnstone.

the throw has been determined in this fashion. In the absence of correlations, throw has been estimated. Datum changes have been necessary in order to maintain horizons at a suitable level or to provide adequate data for mapping. Wherever possible, these datum changes have been made along faults or areas of major geologic change. They have been indicated by a serrate line and appropriate notations.

DISCUSSION OF RESULTS

General:

Record quality in the Denman Basin ranges from good to poor and is directly related to the geologic setting. Geologically the area is complex, being divided into a high platform area (see Line 11, Plate 8) in the southwestern part of the Tenement, a NW-SE trending graben (see Lines 8 and 14, Plates 6 and 9) in the central part of the area, and a large, high, truncated area (see Line 16, Plate 10) in the east part of the area.

The southwest portion of O.E.L. #33 has been interpreted as a large, high, platform area containing numerous small faults, and much local crenulation. Gradual Tertiary (?) onlap is noted in this area, suggesting a "Strand Flat Area", but density of the reconnaissance control is not adequate to define local features.

The NW-SE trending graben appears to be of major geologic interest. Favorable anticlinal reversal has been interpreted within the graben with unusual thickening being noted within the Mesozoic(?) section at the intersection of Lines 8 and 14 (Plates 6 and 9).

The demonstrated thickness of the sedimentary section at this position approximates 5500 feet, but scattered deeper reflectors are noted, suggesting a thicker sedimentary section. (Western Line "G", Plate 11, indicates this deeper sedimentary section by such deeper data.)

The truncated area found on Lines 1 through 5, 15 and 16 (Plate 10) is of somewhat lesser interest, but definitive geologic data are not available. Apparently this high "Massif" indicates older tectonics, with lesser Cretaceous and recent movement being noted. Anomalous deep reflectors have been noted on Lines 1, 2, 3 and 13. The repetitive appearance on these lines suggests a major geologic change differentiating this area from the NW-SE trending graben area.

Interpretational problems are due mainly to the complex geology, the large reconnaissance loops (average 8 miles) and numerous smaller anomalies which interrupt major regional trends.

Western Lines J and K appear to be out of position with the new GSI grid rendering the interpretation subject to question in their locality.

The most significant of the anomalies observed have been tabulated on Table 1, which indicates their geologic province, as well as their presence (or absence) at the mapping horizons and on the isochron.

TABLE 1

MAPS INDICATING ANOMALY

Area*	Feature	Line	Near Station	Shallow	Mesozoic	Isochron
P	A	8	23956	X	X	Thin
P&G	B	J	370		X	Thin
P	C	7	23151	X	X	Thin-Datum Change
P&G	D	13	19909	X	X	Thin
G&TM	E	J	435		X	Thin
G	F	L	210	X	X	Faulted
G	G	13	20581	X	X	Thin
G	H	7	22623		X	Thin
G	I	8&14	10135	X	X	Thick
G	J	G	590		X	Thick
TM	K	14	8743	X	X	Thin - Intrusive?
TM	L	15	12236		X	Thin-Truncation
G	M	G	325	X	X	Thick
TM	N	16	14573		X	Thick
TM	O	16	14909	X	X	Thin
TM	P	15	11372	?	X	Thick
G&TM	Q	15	10940		X	Thick?
P	R	10	17726	X	X	Thick

* Area: P = Platform
G = Graben
TM = Truncated "Massif"

Seismic Horizon in Mesozoic(?):

Anomaly R reveals a possible Tertiary hinge area. Rapid sedimentary onlap to the west is noted (Plate A, Line 10 near Station 17726; Plate 5, Line 11).

Anomalies A and B establish a northwest-southeast trend across the "High Platform Area" previously mentioned. All observed

sedimentary horizons appear to onlap over this "Strand Flat Area". Numerous crenulations occur on this high platform.

Anomalies C, D and E align to show a northwest-southeast trend similar to the A-B trend. This axis is somewhat deeper as a result of the down-dropping in the central graben area. Additional onlap of shallow horizons is indicated with anomaly "D" now being located on the wedge edge of the Mesozoic(?) horizon (note major datum change on the Shallow horizon map.)

The anomalous area at the intersection of Lines 7 and 13 - Station 20293 appears to be an erosional escarpment created by cross faulting or shearing.

Anomalies F, G, H, I and J lie along a major structural axis in the graben area. Major sedimentary changes are observed in this area as compared to the east and west parts of the Tenement.

The structural trend H-I-J exhibits not only structure, but areas of growth both older and younger than the mapped structure.

Anomaly I, located at the intersection of Lines 8 and 14 (Plates 6 and 9) is a thickening above the Mesozoic(?) Horizon (note dotted outline on map). This anomalous thickening may be interpreted as a large sand buildup or a reef-knoll (bioherm). The local positioning, high on a plunging anticlinal axis, suggests "reefing". Anomalous thickening is noted near Station 10087 on Line 14 (Plate 9). Additional "fill" is noted between Stations 10183 and 10303 above the mapped Mesozoic(?) Horizon. This "pan shape" fill suggests continuing growth after Mesozoic(?) sedimentation. Major cross faulting or shearing is indicated by the shift of structural axes between the "Shallow Seismic Horizon(s)" and the deeper Mesozoic(?) horizon. Additional sedimentary section below the Mesozoic(?) Horizon is suggested by deeper reflections in this locality.

Anomaly I is considered the most favorable feature observed in the area.

Anomaly J, located some 15 miles southeast of I, demonstrates Mesozoic(?) closure as well as excellent deeper events. These deeper events not only indicate growth of this anomaly (divergence to the north and south) but a gradual northward crestal shift (Plate 11, Line G) (Plate 12, Line J).

Anomaly J, the second most favorable feature, exhibits growth and is probably an older feature than I. Deep divergence, representing

the northwest-southeast Denman Basin re-entrant, is noted on Line G (Plate 11). This re-entrant has been interpreted as the southward extension of the Pre-Penn trough connecting the Canning Basin to the Denman Basin re-entrant (Plate 2).

Anomaly H demonstrates good E-W reversal but is speculative since complex NE-SW cross faulting is encountered (Plate 9, Line 14 - Station 9847). The Isochron map demonstrates much less section over this feature than over "I" or "J".

Anomaly K is based on a limited amount of data of poor quality. This feature appears to be an intrusive mass in a locality of relatively thin section (Plate 9, Line 14 - Station 8743).

Anomalies L, N and O, typify the truncation, complex faulting and thin sedimentary column observed along the flank of the "Massif" in the eastern part of the Tenement. Structural trends are not clear in this locality.

Anomaly M is based on north-south trending structural axis of limited extent located on west flank of the "Massif" displaying a thin section with a highly undulating surface (Plate 6, Line 8 - Station 25300).

Anomaly Q, which is similar to Anomaly M, demonstrates abrupt thickening of section and is probably a downthrown remnant of the "Massif".

Shallow Seismic Horizon(s):

This map consists of three parts, individually designated as Tertiary(?), Cretaceous (?) and Upper Tertiary(?). The limits of these zones have been set along geologic boundaries and are indicated by major datum changes.

Data in the vicinity of Anomaly R (Plate 7, Line 10) show a rapid westward thickening in the Tertiary(?) section although no structural closure is observed.

Anomalies A and B are extremely weak at this level, representing little more than leads.

Anomalies F, G, H and I indicate a general axial shift to the north, probably indicating greater southward subsidence as the Tertiary and Cretaceous seas transgressed.

Anomaly K appears as a low relief feature complicated by faulting at this level. A relatively thin section appears to be present over a possible intrusive mass.

Anomaly M is based on north-south reversal along Line G with possible fault closure to the east.

Anomalies N, O and P appear to have been subjected to re-adjustment due to a deep uplift located immediately south of anomaly "P" (see Isochron Map).

Anomaly Q is expressed only at the deeper horizon, although a substantially thicker section than that in the vicinity of Anomalies N, O and P is observed as a result of major faulting.

CONCLUSIONS

The major area of interest is the central graben area. The most favorable features, Anomalies I and J, demonstrate structural growth and closure and are located within this graben. Additionally, the reef-like anomaly suggests further potential that has not been delineated by present control.

Seismic data, although not definitive, strongly suggest the presence of sediments below the Mesozoic(?) Horizon to an undetermined depth.

Additional seismic program will probably not contribute significantly to the certainty of the postulated reef. However, it will reasonably establish its potential magnitude and more adequate delineation of the structural anomalies. With the control now available over the possible reef anomaly, we could speculate that it covers approximately 15,000 acres reaching a thickness of 200 to 300 feet. At this point it is not possible to predict that the proposed additional seismic program will provide the support necessary for a drillable location. However, the southern half of the Tenement area is sufficiently attractive to be of further interest.

Respectfully submitted,

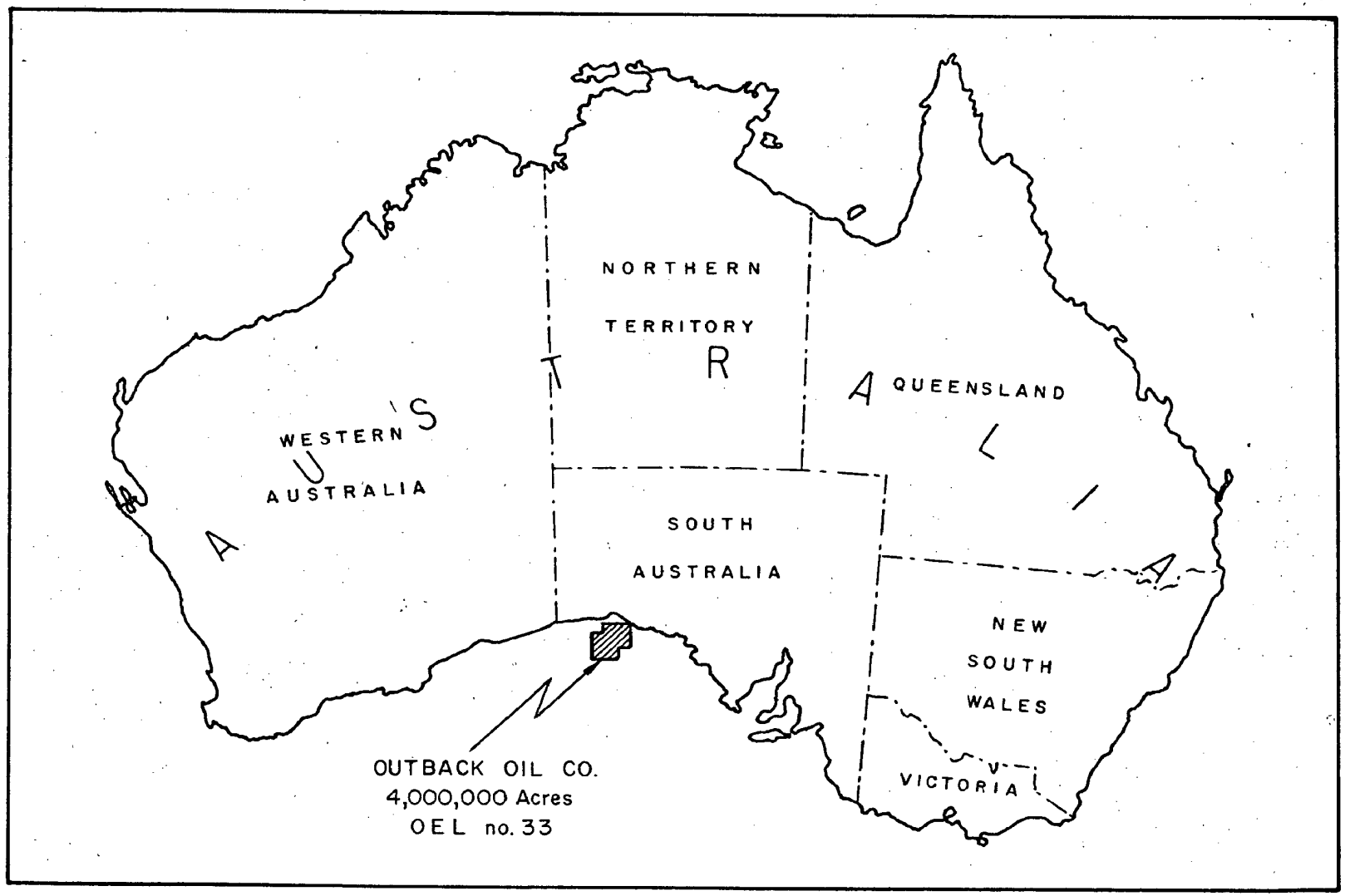
G. J. LONG & ASSOCIATES, INC.

By G. W. Fenner
G. W. Fenner

Approved:

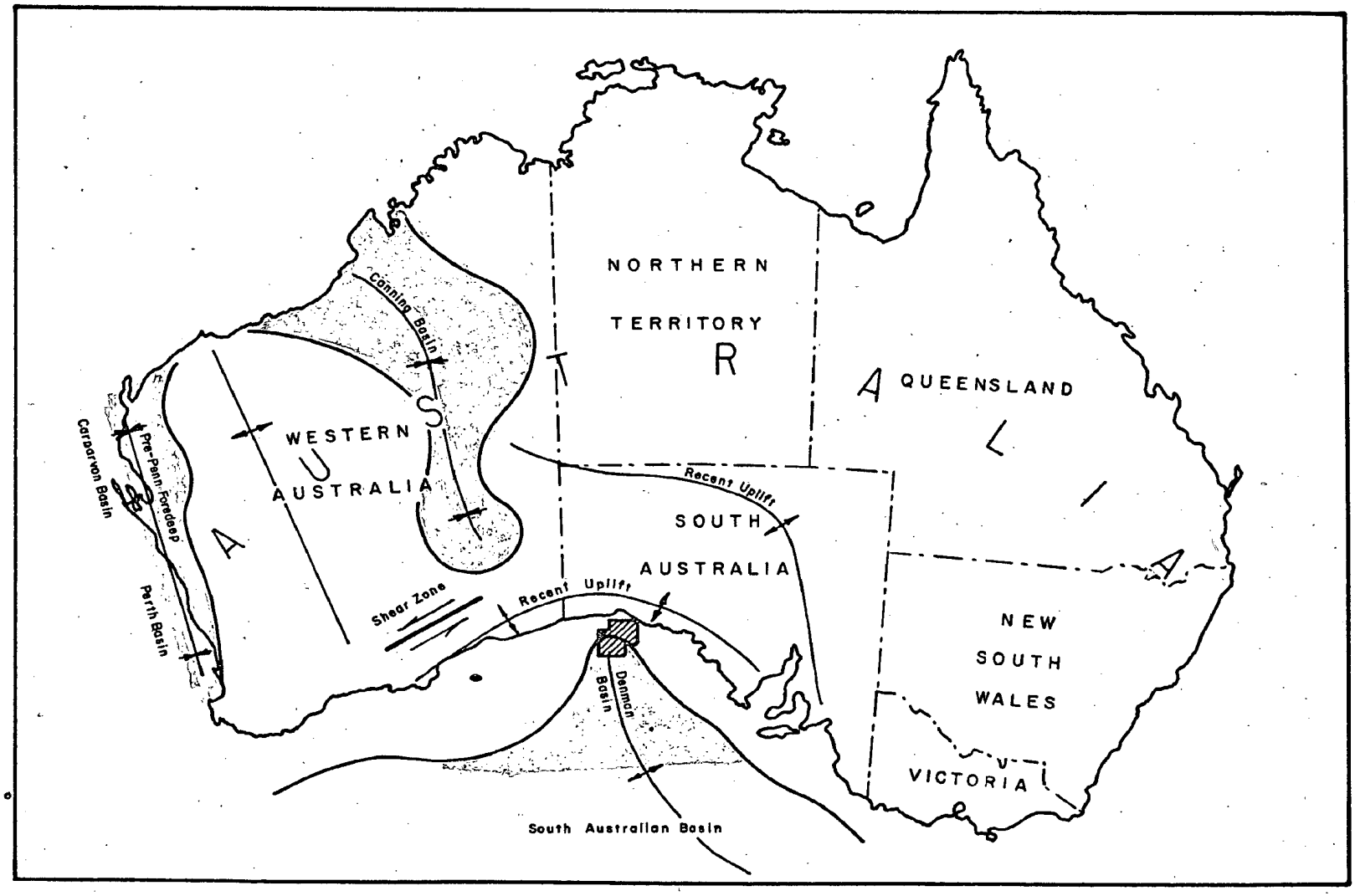
L. K. Buller

012

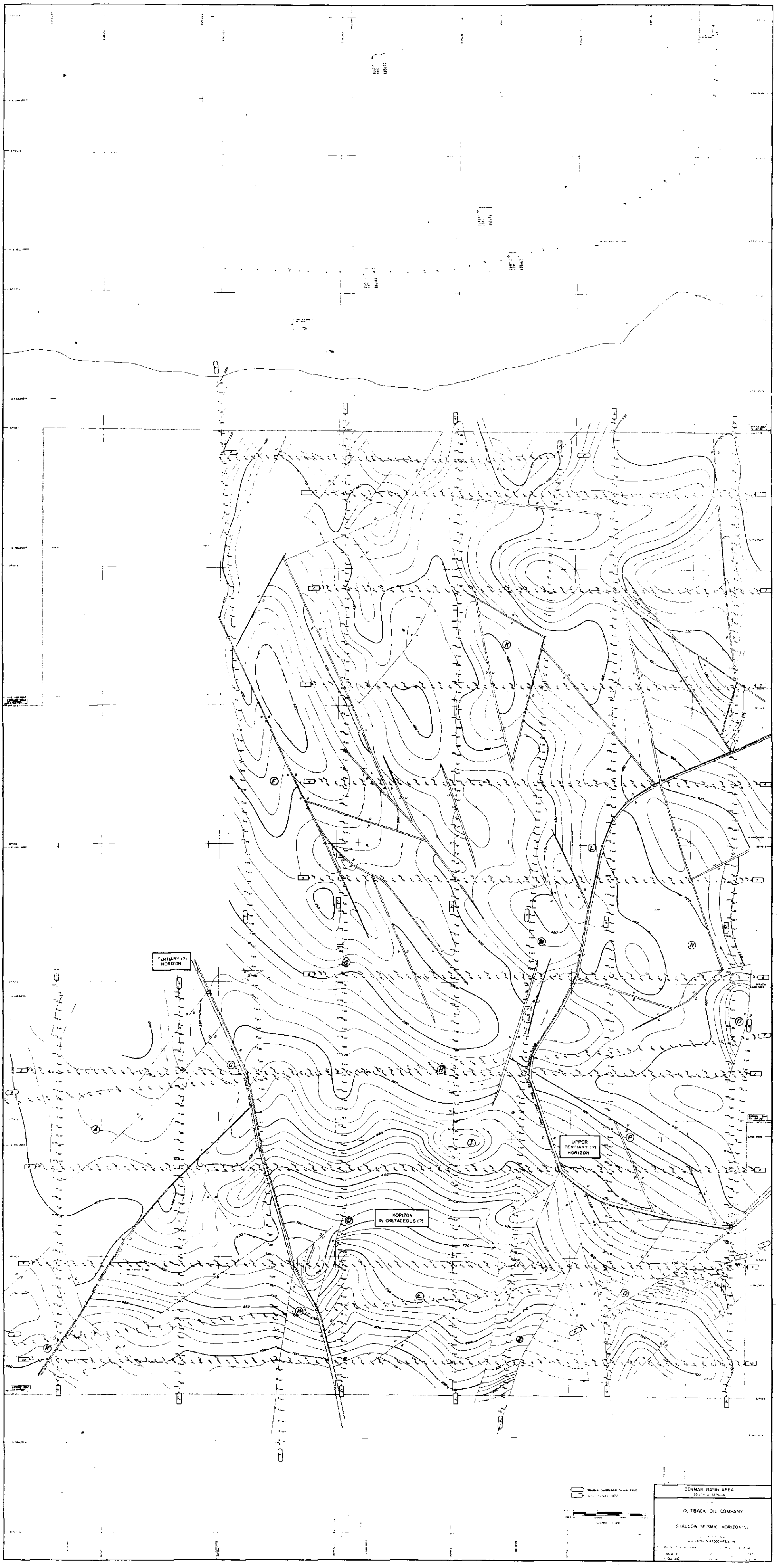


OUTLINE OF AREA

PLATE I



MAJOR BASINS
SOUTH and WEST AUSTRALIA

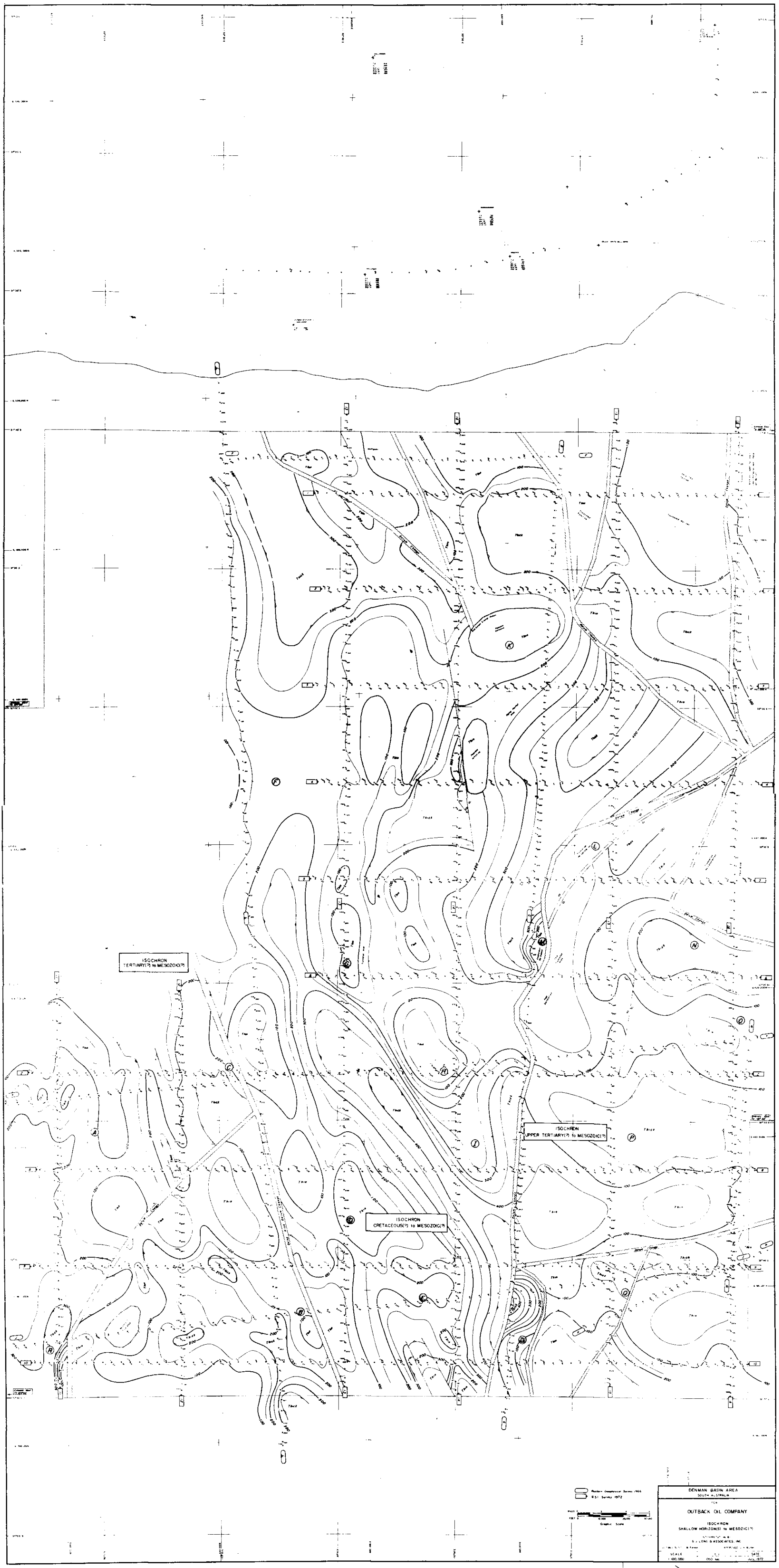


1952(III)23

Plate 3

1952(III)-24

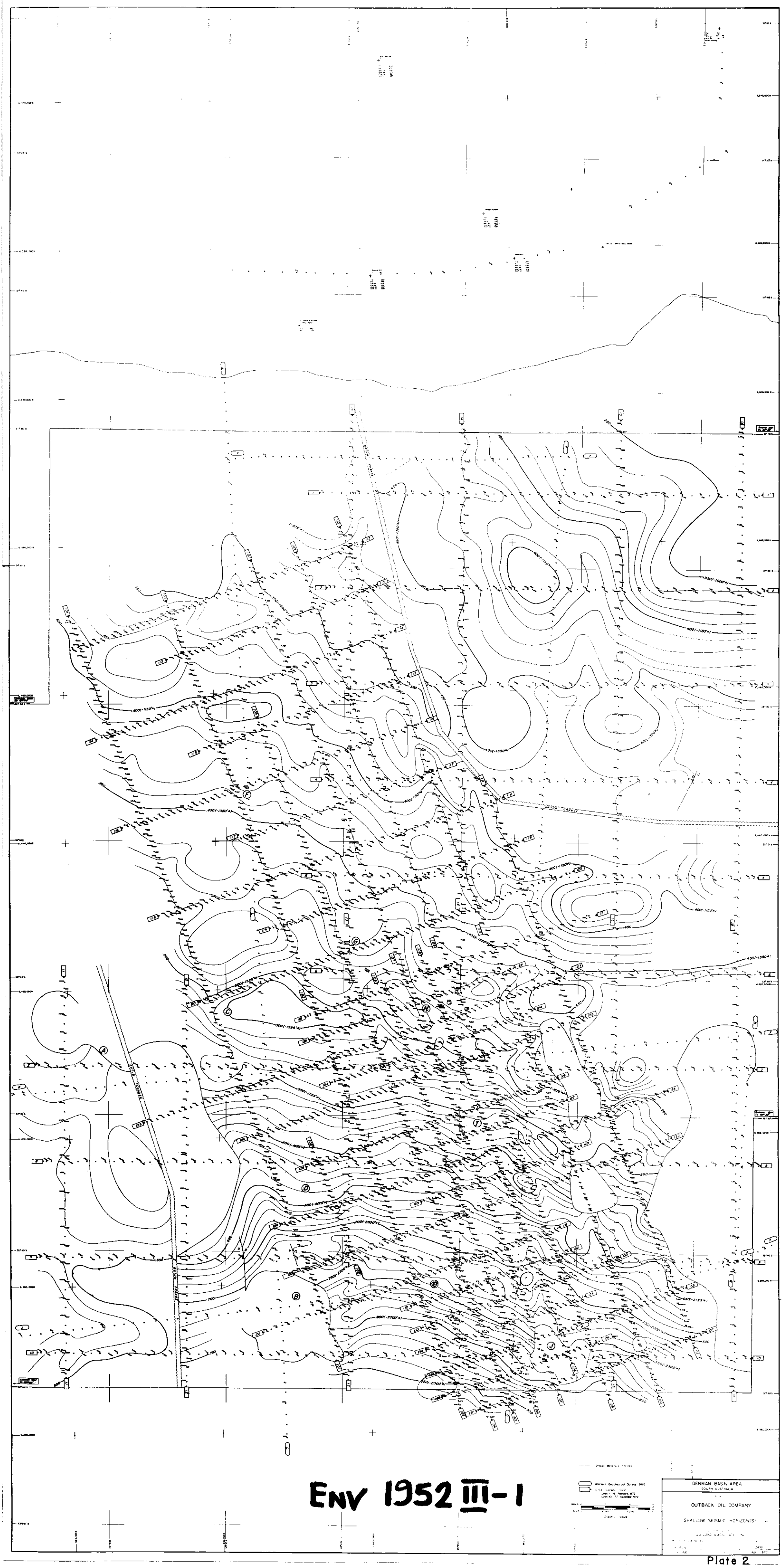
Plate 4



1952 (III) 25

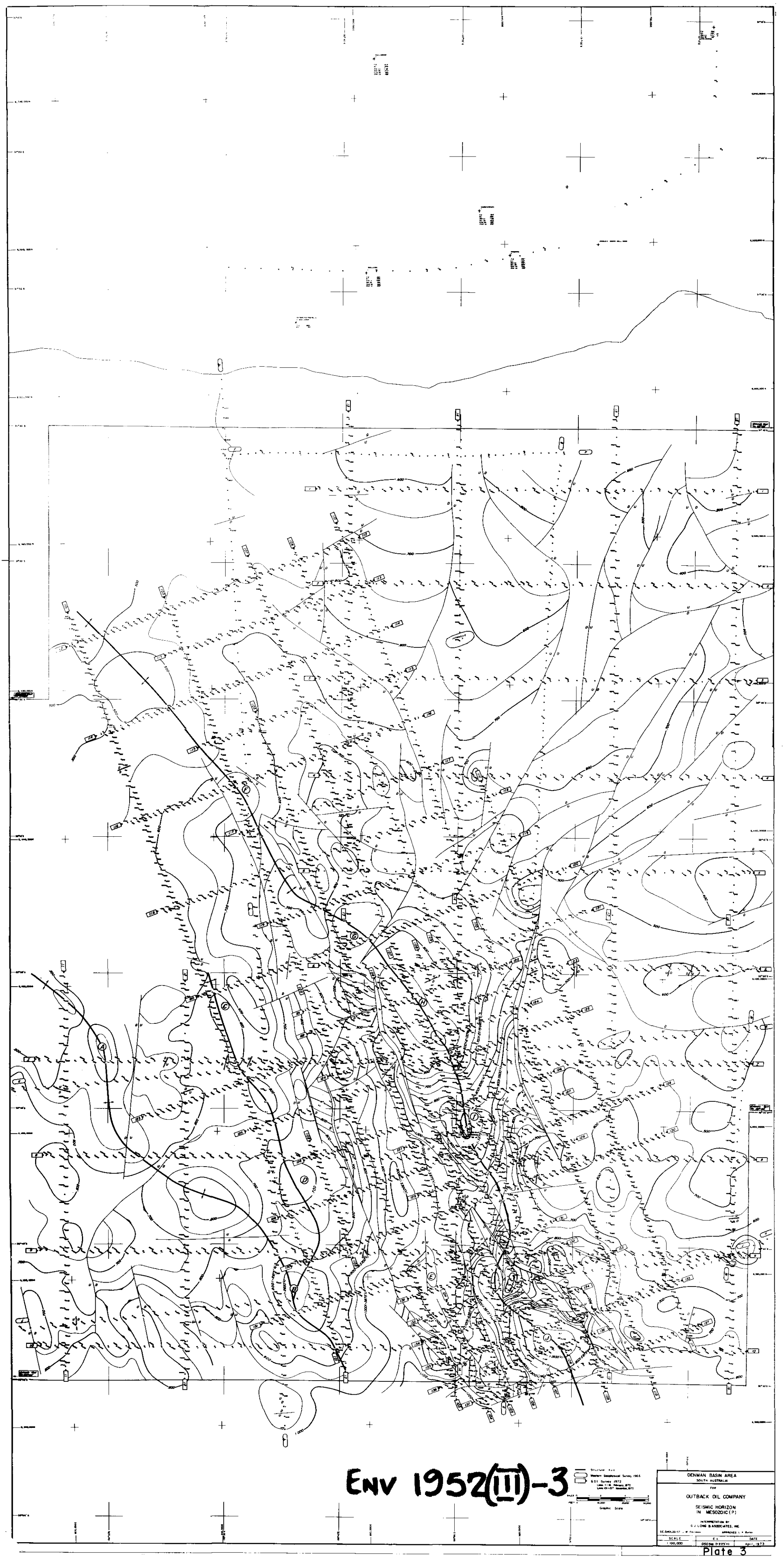
Plate 5

Western Geophysical Survey 1966
G.S.I. Survey 1972
Line 01-127 Number 970
Line 01-137 Number 970
Graphic Scale
DENMAN BASIN AREA
SOUTH AUSTRALIA
FOR
OUTBACK OIL COMPANY
WATER DEPTH MAP
INTERPRETATION BY
G J LONG & ASSOCIATES, INC.
SCALE
1:100,000
C.I.
25 Feet
DATE
April, 1973
ENV/152 (III)-20



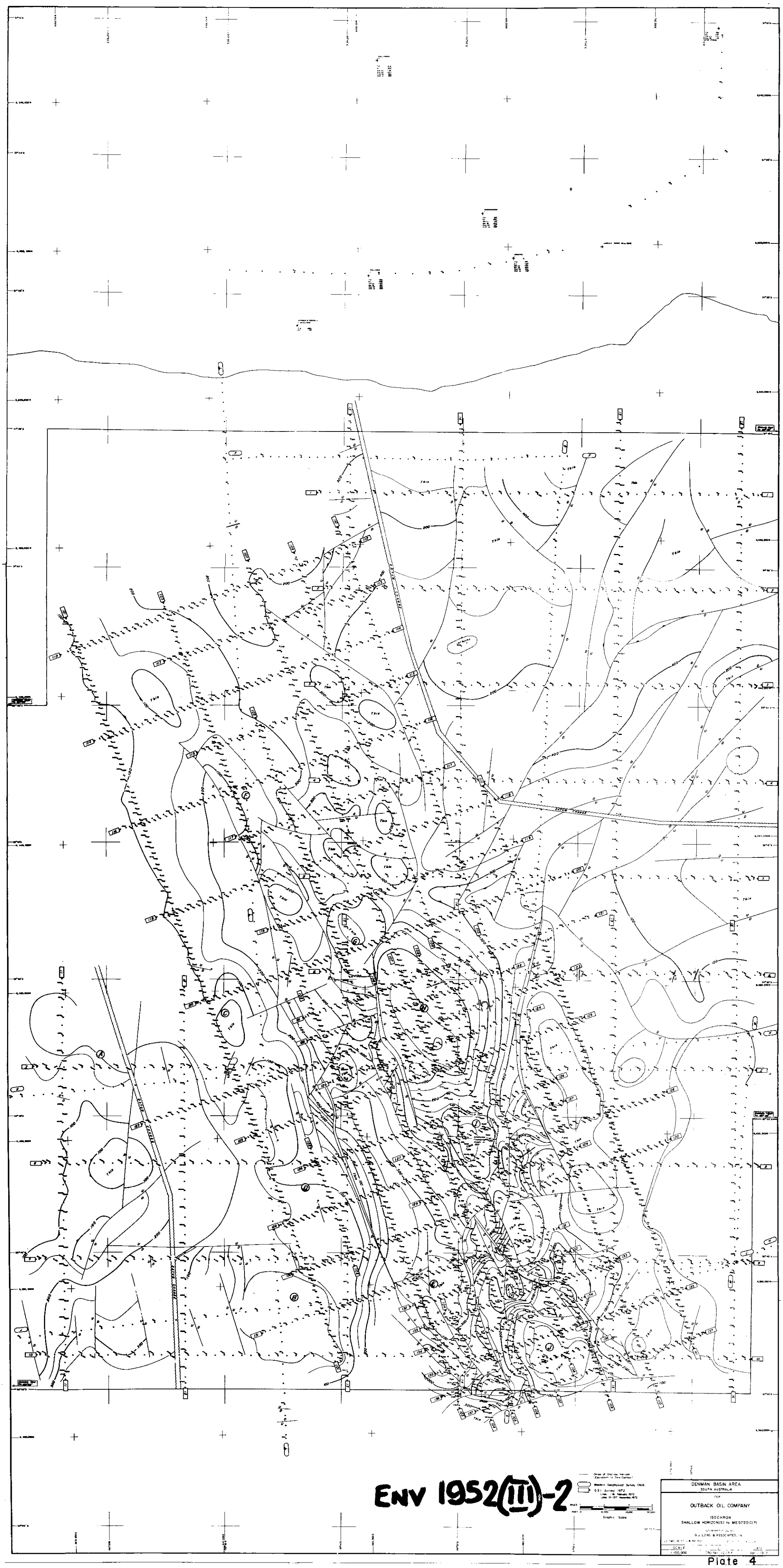
ENV 1952 III-1

Plate 2



ENV 1952(III)-3

Plate 3


DENMAN BASIN AREA
SOUTH AUSTRALIA
FOR
OUTBACK OIL COMPANY
ISOCHRON
SHALLOW HORIZONISI to MESOZOIC(?)
G.J. LONG & ASSOCIATES, LTD
SCALE
1:100,000
Graphic Scale
Western Geophysical Survey 1966
G.S.I. Survey 1972
Line 14 February 1972
Line 24-127 November 1972
Trip
Trip
Trip

EN1952

014

OPERATIONS REPORT

MARINE SEISMIC SURVEY

DENMAN BASIN

SOUTH AUSTRALIA

For

OUTBACK OIL COMPANY N.L.
G.P.O. BOX 1849, ADELAIDE, S.A. 5001

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 Seismologists : P. Keegan, P. Chernoff

NOVEMBER, 1972.

GSI-709

TABLE OF CONTENTS

SECTION	TITLE	PAGE
I	INTRODUCTION	1
II	OPERATION PROCEDURES	
	A. RECORDING	2
	B. STREAMER	2
	C. ENERGY SOURCE (AIRGUNS)	3
	D. INSTRUMENT AND NOISE TESTS	6
	E. FATHOMETER	7
	F. SURVEY	8
III	OPERATIONS	9

LIST OF APPENDICES

APPENDIX	TITLE
A	KEY PERSONNEL
B	EQUIPMENT i) Recording ii) Vessel
C	OPERATION STATISTICS
D	FIELD TAPE LOG AND PRODUCTION STATISTICS.

LIST OF PLATES

PLATE	DESCRIPTION
1	LOCATION OF PROSPECT
2	CABLE AND SPREAD ARRANGEMENT 1600 METER STREAMER
3	AIRGUN ARRAY
4	AIRGUN PULSE AND SPECTRUM
5	TAPE FORMAT

SECTION I

INTRODUCTION

A marine seismic reflection survey was conducted by the M.V. "Eugene McDermott II" in the Denman Basin, South Australia, for Outback Oil Company N.L. between 1st November and 11th November, 1972.

1146.03 miles of 24-fold reflection coverage were shot utilizing a 1600 meter streamer under continuous tow in conjunction with a Pneumatic Acoustic Energy Source (Airguns), generally operating 24 hours per day.

Recordings were made using one set of 24 trace DFS III's, with 2 tape transports, recording on 1" magnetic tape in 21 track 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*.

* Trademarks of Texas Instruments Inc.

GSI-709

SECTION II

OPERATION PROCEDURES

A. RECORDING :

A Texas Instruments Digital Field System III (DFS III) with 2 tape transports was used for all recording. A Servo-Writer Profiler was utilized 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 30 shotpoints for quality control purposes.

B. STREAMER :

The 1600 meter, neutrally buoyant, continuous tow streamer consisted of 24 Live sections (L) each 50 meters in length; 24 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 24 and between groups 20 L and 20 D, 15 L and 15 D, 10 L and 10 D, 5 L and 5 D, 1 L and 1 D.

Five nylon stretch sections were placed between group 24 and the recording vessel to attenuate ship generated noise. Five Condep** cable depth controllers were placed between the depth transducers on the streamer at the centre of live section 24 and at the centre of dead sections 20, 13, 6 and 2.

Three nylon stretch sections followed group 1 and were joined to the tailbuoy by 400 feet of nylon rope. Tailbuoy bearings were taken by radar every 45 'pops' (weather permitting) to ensure that maximum feathering angle was not exceeded.

The average streamer depth was 44 feet, with the front end running at about 60 feet. This was due to large swells, resulting in high noise on the near traces and a resultant slow shooting speed of under 4 knots.

C. ENERGY SOURCE (AIRGUNS) :

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

** Trademark of Continental Oil Company

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 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 to 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.

GSI-709

Using different guns of various chamber sizes broadens and flattens the frequency spectrum of the pulse (Plate 4).

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 yields a flat frequency spectrum. (Plate 4.)

G61-709

The time co-ordinator unit triggered the Digital Field System which in turn discharged the Texas Instruments 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 24-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. INSTRUMENT AND NOISE TESTS :

Instrument tests were carried out prior to each day's operations and the results were examined in an analogue 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 abovementioned tests.

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

GSI-709

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 and an Elac Deneb Model LAZ 17DDL fathometer were used.

The Ross fathometer operates on a frequency of 100 KHz, with a range of 0 to 400 fathoms. Depths are recorded in fathoms and decimals of a fathom.

The Elac Deneb fathometer operates on a frequency of 20 KHz with a range of 0 to 2000 fathoms. Depths are recorded in meters.

Each fathogram was identified by line number, direction shot, time and date of first shotpoint and scale. The zero line was not corrected for ship's draught.

Although the water depth never dropped below 285 feet, both fathometers were used because of large swells and air getting into the transducers.

GSI-709

F. SURVEY :

The ship's position at every 'pop' was determined by Geonav II, supplied and operated by Texas Instruments Inc. of Dallas, Texas, U.S.A.

A separate report will be supplied.

SECTION III

OPERATIONS

The general quality of the data was fair. Large swells were encountered, resulting in slow shooting speeds to reduce noise on the near traces. The slow shooting speed made it difficult to control the front end of the cable, resulting in it running deep for the major part of the prospect.

Respectfully submitted,
GEOPHYSICAL SERVICE INTERNATIONAL

Charlie A. Martin

Charlie Martin,
Operations Manager.

G61-709

APPENDICES

APPENDIX A

KEY PERSONNEL

C. Rowell	Supervisor
T. Kerlin	Party Manager
B. Pettigrew	Administrator
P. Keegan P. Chernoff	Quality Control Seismologists
D. Lanyon M. McLean	Instrument Engineers
T. Morgan	Instrument Engineer Trainee
P. Stark A. Denny P. Reichle J. Trever	Airgun Mechanics
J. Fjaeride	Captain
J. Gilbert	Survey Supervisor
P. Godwin J. Jesske	Survey Operators

GSI-709

APPENDIX B

EQUIPMENT

a) Recording

i) 1600 Meter Streamer (Plate 2)

Type Cable	: 24 live, 24 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 24 (centres)	: 1533 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

GSI-709

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	: 36 - 24 db
Upper Set Limit	: 62.5%
Lower Set Limit	: 18%
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	: 24 milliseconds

GSI-709

30

iii) Data Channel Allocations

Function	Monitor Trace No.	Tape Channel
Timing	-	0
Streamer Groups 1 - 24	1 - 24	1 - 24
Water Break 1 (between groups 1 L & 1 D)	25	31
Water Break 2 (between groups 5 L & 5 D)	24	28
Water Break 3 (between groups 10 L & 10 D)	26	29
Water Break 4 (between groups 15 L & 15 D)	25	31
Water Break 5 (between groups 20 L & 20 D)	26	27
Water Break 6 (in front of group 24)	24	28
Field Time Break	4	-
DFS Synthetic Time Break	8	-

GSI-709

b) Survey Vessel

M.V. "EUGENE McDERMOTT II"

Flag	: Bahamas
Homeport	: Nassau
Trade	: Foreign going
Owners	: Worldwide Surveys Ltd.
Call Sign	: ZQA 2012
Length	: 171' L.O.A.
Breadth	: 39'
Depth	: 14'
Draught	: 10' - 11'
Official Number	: 343728
Gross Tonnage	: 911
Net Tonnage	: 244
Engine Horsepower	: 2 engines of 1150 H.P. each.

GSI-709

APPENDIX C

OPERATION STATISTICS

Prospect	:	Denman Basin
Operational period	:	1st to 11th November, 1972.
Time spent on recording	:	146 hours
Line Changes	:	63 hours
Time lost due to bad weather	:	32 hours
Waiting for Satellite Fixes	:	10 hours
Time lost due to other reasons, (cable and compressor work)	:	14 hours
Field tapes used	:	130
Water depth range	:	175 - 270 feet
Total production mileage	:	1146.03
Production shotpoints	:	55331
Autofires	:	17

GSI-709

APPENDIX D

FIELD TAPE LOG AND PRODUCTION STATISTICS

Date	Line	Shotpoints	Field Tapes	Mileage
1/11/72	110	001-3673	OB1, OB2, OB3, OB4, OB5, OB6, OB7, OB8, OB9.	76.08
2/11/72	109	001-3589	OB9, OB10, OB11, OB12, OB13, OB14, OB15, OB16, OB17.	74.34
	108	001-1725	OB17, OB18, OB19, OB20, OB21.	35.73
	106	001-1817	OB21, OB22, OB23, OB24, OB25.	37.63
3/11/72	107	001-3533	OB25, OB26, OB27, OB28, OB29, OB30, OB31, OB32, OB33.	73.18
	103	001-3462	OB33, OB34, OB35, OB36, OB37, OB38, OB39, OB40, OB41, OB42, OB43.	71.71
	135	001-1041	OB43, OB44, OB45.	21.56

GSI-709

Date	Line	Shotpoints	Field Tapes	Mileage
4/11/72	101	001-3186	0B46, 0B47, 0B48, 0B49, 0B50, 0B51, 0B52, 0B53.	65.99
	112	001-1224	0B53, 0B54, 0B55, 0B56.	25.35
	113	001-849	0B56, 0B57.	17.59
	114	001-1231	0B58, 0B59, 0B60.	25.50
	115	001-846	0B60, 0B61, 0B62.	17.52
5/11/72	105	001-2965	0B62, 0B63, 0B64, 0B65, 0B66, 0B67, 0B68, 0B69.	61.41
	137	001-959	0B69, 0B70, 0B71.	19.86
6/11/72	111	001-2405	0B71, 0B72, 0B73, 0B74, 0B75, 0B76, 0B77.	49.81
	116	001-1252	0B77, 0B78, 0B79, 0B80.	25.93
	117	001-848	0B80, 0B81	17.56
	118	001-1426	0B82, 0B83, 0B84, 0B85.	29.54
	119	001-1040	0B85, 0B86, 0B87	21.54

Date	Line	Shotpoints	Field Tapes	Mileage
7/11/72	120	001-1583	OB87, OB88, OB89 OB90, OB91.	32.79
	121	001-1200	OB91, OB92, OB93.	24.85
	122	001-853	OB94, OB95.	17.67
	124	001-848	OB96, OB97.	17.56
8/11/72	123	001-1781	OB97, OB98, OB99, OB100, OB101.	36.88
	125	001-1415	OB102, OB103, OB104, OB105.	29.31
	126	001-1055	OB105, OB106, OB107.	21.85
	127	001-654	OB107, OB108, OB109.	13.55
	129	001-660	OB109, OB110.	13.67
9/11/72	102	001-465	OB110, OB111.	9.61
	128	001-1631	OB111, OB112, OB113, OB114, OB115.	33.78
	130	001-1584	OB115, OB116, OB117, OB118, OB119.	32.81

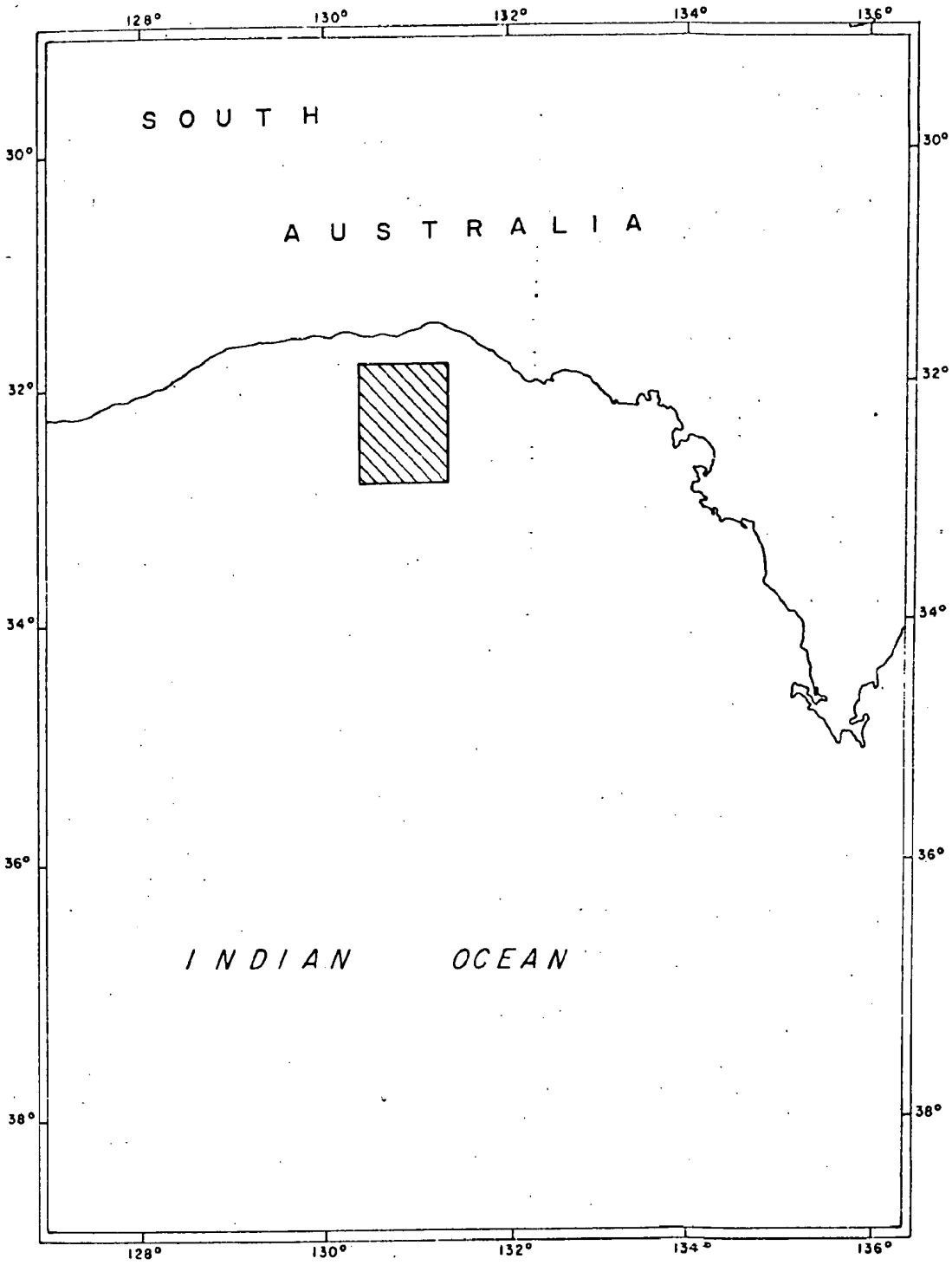
GSI-709

Date	Line	Shotpoints	Field Tapes	Mileage
10/11/72	104	001-464	OB119, OB120.	9.61
	136	001-235	OB120.	RESHOT
	136	001-659	OB120, OB121, OB122.	13.65
11/11/72	134	001-657	OB122, OB123.	13.61
	133	001-841	OB123, OB124, OB125.	17.42
	131	001-1254	OB125, OB126, OB127, OB128.	25.97
12/11/72	132	001-657	OB128, OB129, OB130.	13.61

TOTAL PRODUCTION MILEAGE : 1146.03

G61-709

PLATES



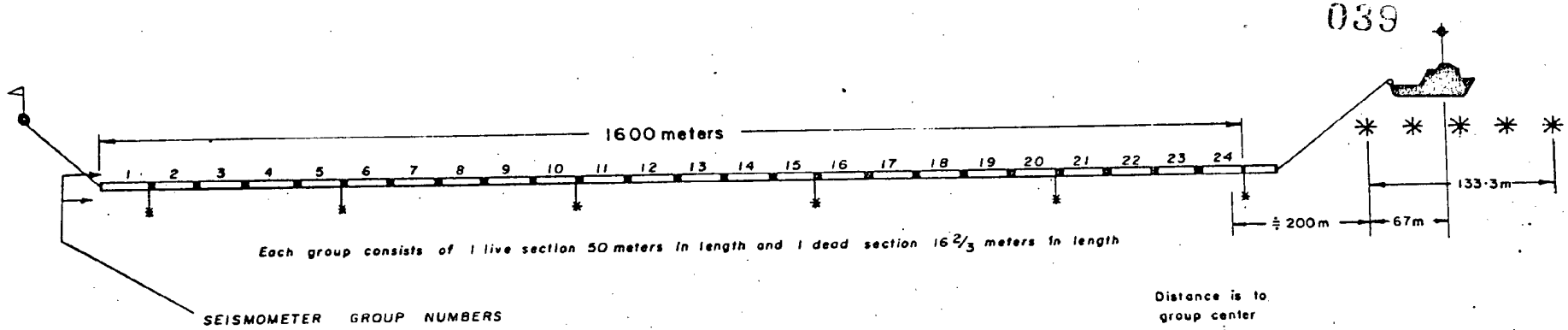
OUTBACK OIL COMPANY N.L.

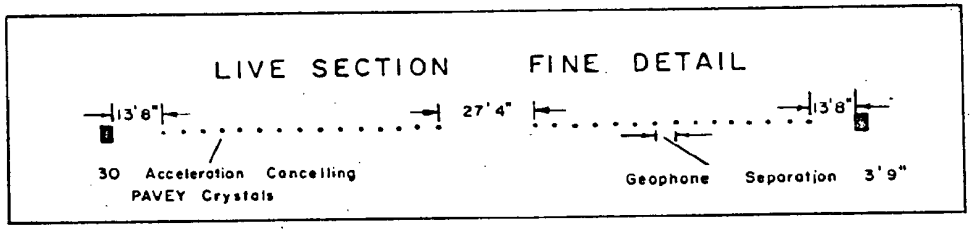
LOCATION OF PROSPECT

GEOPHYSICAL SERVICE INTERNATIONAL PARTY 931

PLATE I

039





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

MARINE CABLE DIAGRAM
1600 METER
(OFF END SPREAD – 24 GROUPS)

G.S.I. Party 931
Ship M/V Eugene Mc Dermott II
Client OUTBACK OIL CO. N.L.
Area Denman Basin S.A.
Date November 1972

PLATE II

35 ft.

60 ft. to stern

N°	GUN	SIZE	Distances,		N°	GUN	SIZE
1	●	10 cu. in.	0 ft.		17	●	10 cu. in.
2	●	10	4		18	●	10
3	●	20	9		19	●	20
4	●	20	14		20	●	20
5	●	20	19		21	●	20
6	●	40	24		22	●	40
7	●	40	29		23	●	40
8	●	40	34		24	●	40
9	●	80	39				
10	●	80	40·5	40·5	25	●	100
11	●	80	42	42	26	●	100
12	●	80	43·5	43·5	27	●	100
				45	28	●	100
13	●	100	48·5				
14	●	100	50	50·5	29	●	100
				52	30	●	100
15	●	80	56				
16	●	80	57·5	58	31	●	80
				59·5	32	●	80
	PORT					STARBOARD	

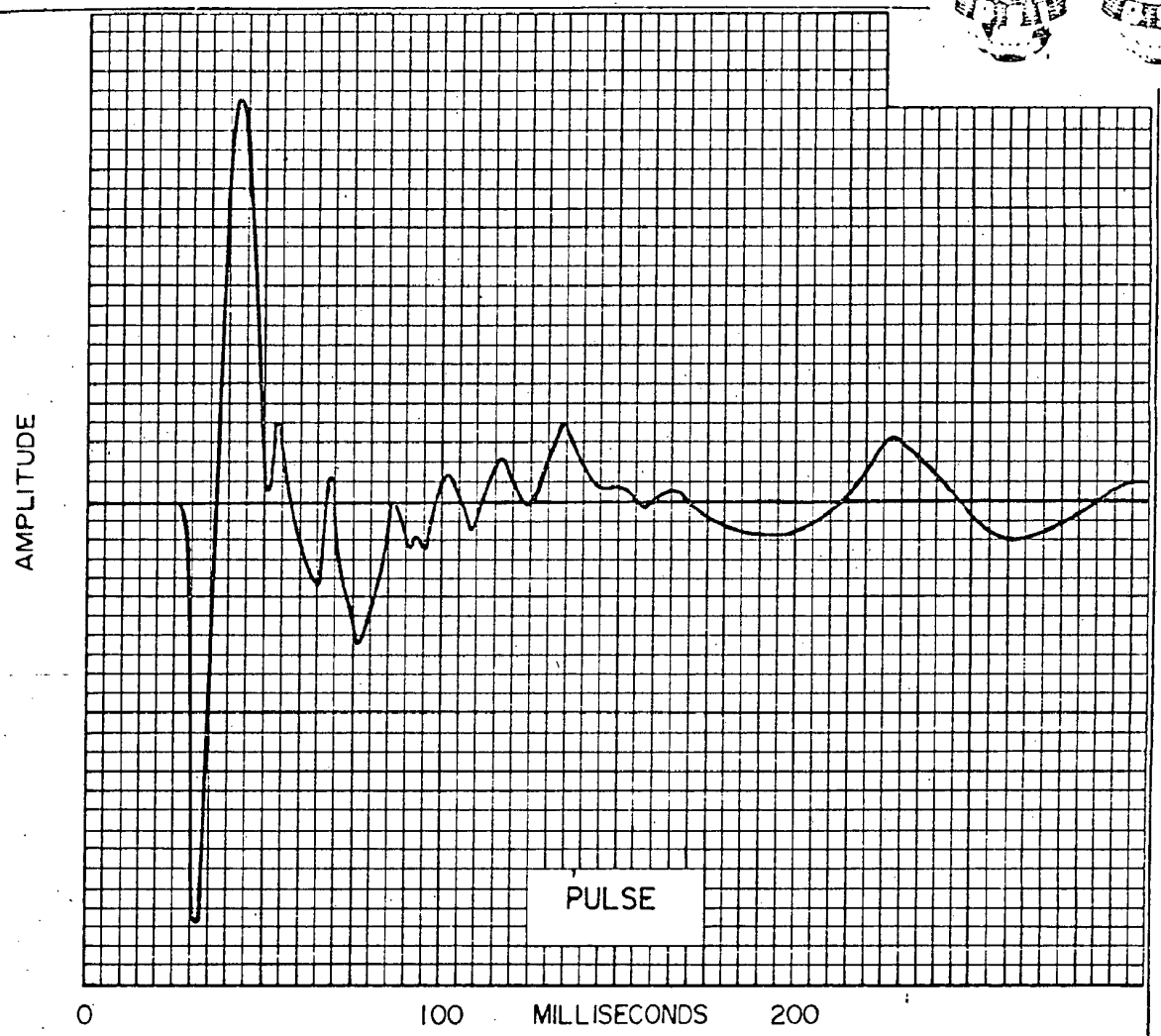
m/v EUGENE Mc DERMOTT II

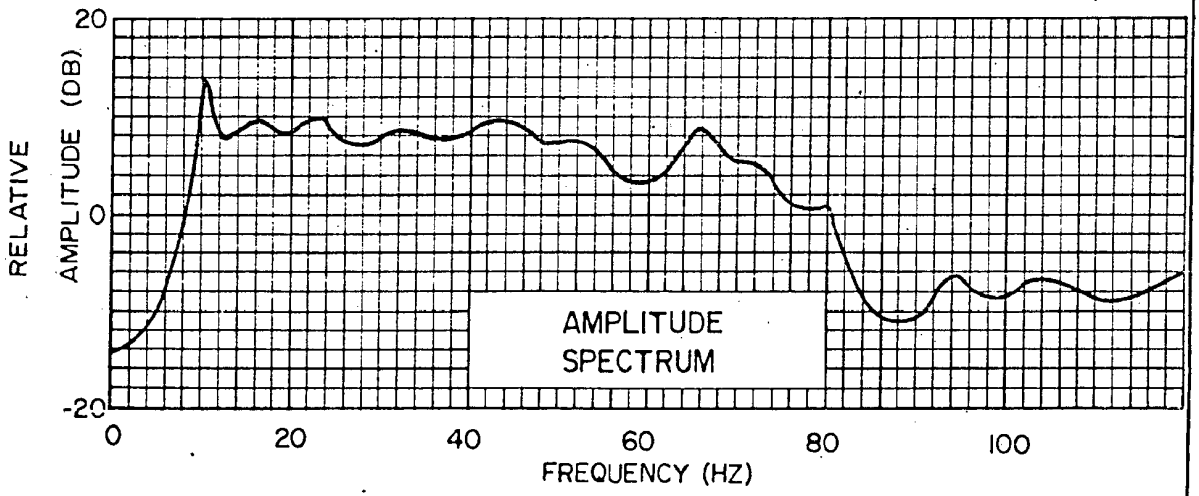
AIR GUN ARRAY

0 5 feet

APRIL 1972

PLATE III





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

PLATE IV

042

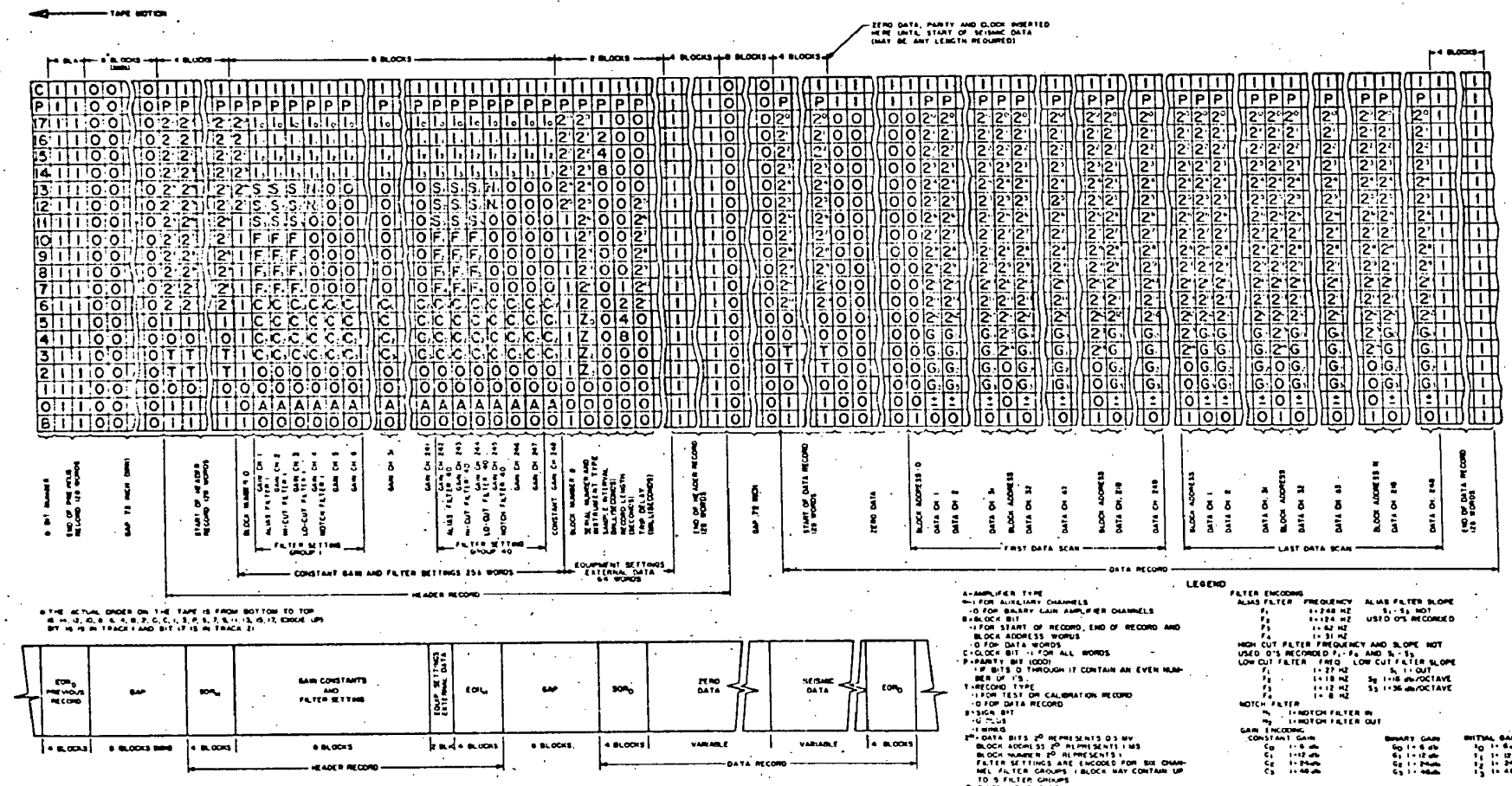

TAPE MOTION
ZERO DATA, PARITY AND CLOCK INSERTED HERE UNTIL START OF SEISMIC DATA (MAY BE ANY LENGTH REQUIRED)
CONSTANT GAIN AND FILTER SETTINGS 256 WORDS
HEADER RECORD
FIRST DATA SCAN
LAST DATA SCAN
DATA RECORD
EQUIPMENT SETTINGS EXTERNAL DATA 64 WORDS
LEGEND
A-AMPLIFIER TYPE
B-BLOCK BIT
C-CLOCK BIT
P-PARITY BIT (ODD)
T-RECORD TYPE
S-SIGN BIT
Z-INSTRUMENT TYPE
FILTER ENCODING
GAIN ENCODING
LIST OF MATERIALS
TEXAS INSTRUMENTS
21 TRACK TAPE FORMAT
SDFS III
225461

PLATE V

046

GEONAV SURVEY
OF
DENMAN BASIN

Prepared for

OUTBACK OIL COMPANY

Prepared by

GEOPHYSICAL SERVICE INTERNATIONAL

March 1973

GSI-709

044

TABLE OF CONTENTS

Title	Page
INTRODUCTION	2
SUMMARY OF OPERATIONS	2
APPENDIX A — GEONAV POSITIONING SYSTEM	
FIGURE 1 — Approximate Location of Denman Basin	1
TABLE 1 — Line No., First and Last Shotpoints, and Direction Shot	4

GSI-709

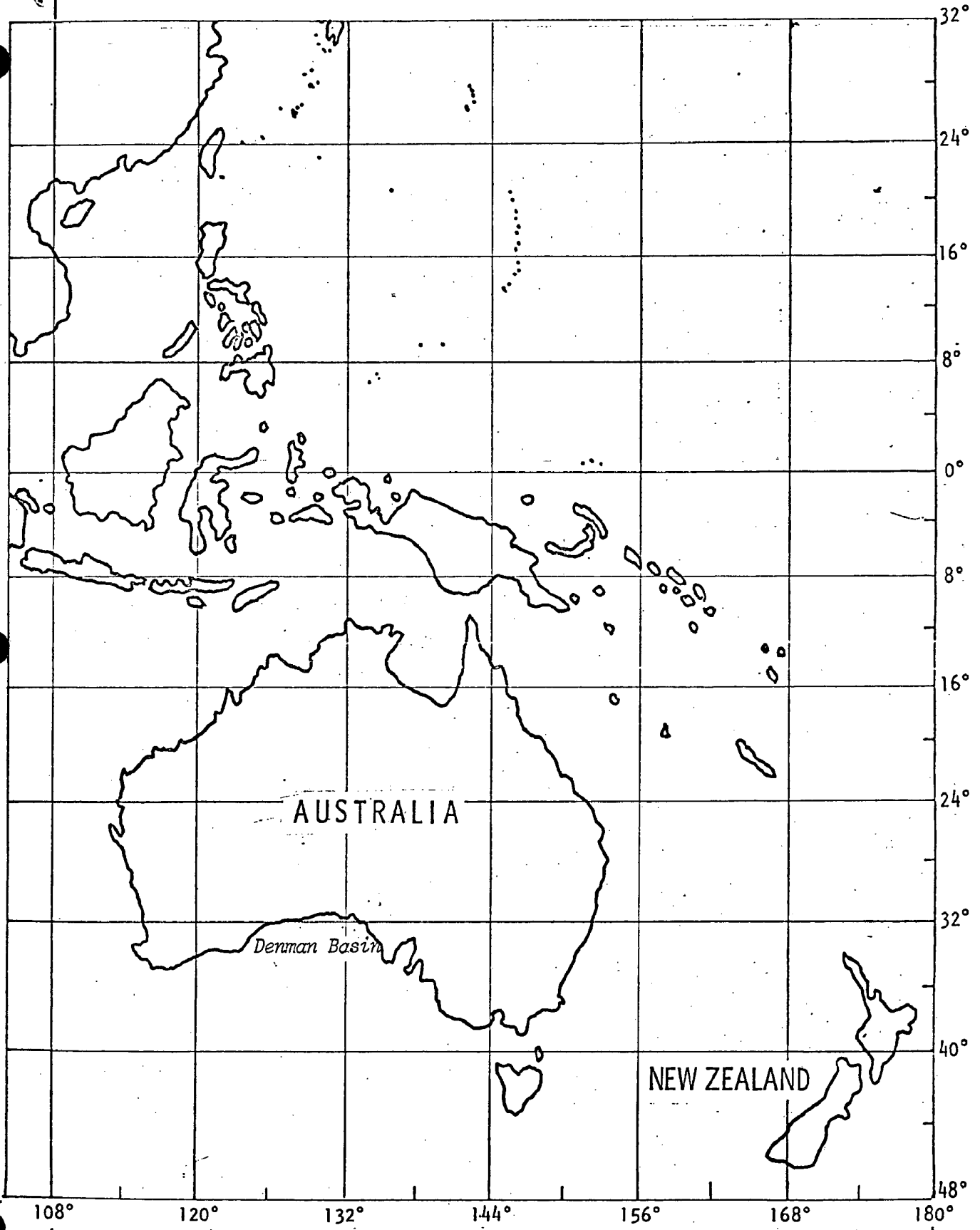


Figure 1. Approximate Location of Denman Basin

GSI-709

INTRODUCTION

From 1 November to 12 November 1972, Geophysical Service International, Party 931, aboard the M/V McDERMOTT II, conducted a marine geophysical survey for Outback Oil Company in the Denman Basin. The area surveyed is near 32° 30'S latitude 130° 40'E longitude (See Figure 1).

GEONAV, an integrated satellite positioning system (described in Appendix A), was the onboard navigation system and provided horizontal survey positioning and shotpoint spacing control. No secondary system was employed during the shooting of the lines.

Base maps of the survey area were provided by the client. These maps were scaled 1:100,000 and employed a transverse Mercator projection based on standard U.T.M. parameters. The shotpoint and satellite positions on the map are referenced to the Australian National Spheroid and the Australian Geodetic Datum. The posted maps and grid and graticule listings have been submitted prior to this report.

SUMMARY OF OPERATIONS

The seismic survey was conducted with an airgun energy source and a 1600-m, 24-group streamer. A 33-1/3-m shotpoint interval was controlled by the GEONAV system and the position of each was recorded on magnetic tape. This shotpoint interval yielded 24-fold seismic data. The shotpoint locations mapped represents the CDP. The plot frequency for mapping is every sixth (6) shotpoint, although the listings give the positions of all shotpoints. The first and last shotpoints of a line are also plotted. Only online satellites, to include the fix immediately before the beginning of a line and the first fix after line termination, are plotted, although many more fixes are used for navigation and processing.

The lines, together with the first and last shotpoints and the direction of shooting, are identified in Table 1. They are listed in the order shot, and any peculiarities occurring on line are annotated.

The GEONAV system gave no major problems during the shooting of the prospect. Where practicable, fixes were taken prior to starting any line and after line termination. During the prospect more than 10 hours was spent waiting for satellite fixes. Most of the satellite updates during the survey were well within 200 m. The largest update was 700 m along track and zero meters across track, but since this occurred after about 50 km of navigation without another fix, the update was accepted.

The weather was fair for most of the survey, although near the end the seas and wind picked up and necessitated a very slow shooting speed. This was a particular problem in shooting lines 131 and 132.

Shotpoint and satellite positions were transformed from the APL global datum, to which all GEONAV determinations are made, to the Australian Regional Datum. This is done by using weighted mean shifts of the origin of one datum with respect to the other. This produces nonconstant corrections to be applied to the latitude and longitude of points in the area. The 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 shift the datums in GEONAV processing are values published by the Smithsonian Astrophysical Observatory in Special Report 200. The values used to transform the APL Datum to the Australian Geodetic Datum 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. Representative values of these corrections are, for a point at 30°S latitude and 130°E longitude, -2.92" latitude and -3.36" longitude. These values are added to the APL coordinates to produce coordinates on the Australian Geodetic Datum.

After the datum shift, U.T.M. coordinates, using the Australian National Spheroid and Zone-52 parameters, were computed and used for final mapping.

The defining parameters for this spheroid are

Semimajor axis: 6,378,160.0 m

Flattening: 1/298.25

U.T.M. Zone 52 is based on a central meridian of 129°E longitude and a 0.9996 scale factor at this origin.

Table 1

LINE NUMBER, FIRST AND LAST SHOTPOINTS, AND DIRECTION SHOT

Line Number	First Shotpoint	Last Shotpoint	Direction Shot
110	1	3673	SE - NW
109	1	3589	NW - SE
108	1	1725	SE - NW
106	1	1817	NW - SE
107	1	3533(1)	SE - NW
103	1	3462	NW - SE
135	1	1041	SW - NE
101	1	3186	SE - NW
112	1	1224	SW - NE
113	1	849	NE - SW
114	1	1231	SW - NE
115	1	846	NE - SW
105	1	2965	NW - SE
137	1	959	SW - NE
111	1	2405	SE - NW

Table 1 (Contd)

Line Number	First Shotpoint	Last Shotpoint	Direction Shot
116	1	1252	NE - SW
117	1	848	SW - NE
118	1	1426	NE - SW
119	1	1040	SW - NE
120	1	1583	NE - SW
121	1	1200	SW - NE
122	1	853	NE - SW
124	1	848	SW - NE
123	1	1781	NE - SW
125	1	1415	SW - NE
126	1	1055	NE - SW
127	1	1654	SW - NE
129	1	660	NE - SW
102	1	465	SE - NW
128	1	1631	SW - NE
130	1	1584	NE - SW
104	1	464	NW - SE
136	1	235	NE - SW
136	1	659	NE - SW
134	1	657	NE - SW
133	1	841	SW - NE
131(2)	1	1254	NE - SW
132(2)	1	657	SW - NE

(1) High wind and tides caused line deviation (140 m) near shotpoint 3076.
(2) Trouble keeping boat on line due to high winds and sea

APPENDIX A

GEONAV POSITIONING SYSTEM

051

APPENDIX A

TABLE OF CONTENTS

Section	Title	Page
A.	INTRODUCTION	A-1
B.	FIELD OPERATION	A-1
C.	POST MISSION PROCESSING	A-2
D.	SYSTEM DESCRIPTION	A-3
	1. General	A-3
	2. Detailed Description	A-4
E.	GEONAV SELF CONTAINED QUALITY CONTROL	A-10
	1. Continuous Sensor Quality Control	A-10
	2. Quality Control on Satellite Position Fixes	
	3. Velocity/Heading Quality Control	A-17

GSI-709

LIST OF ILLUSTRATIONS

053

Figure	Title	Page
1.	GeoNav System Block Diagram	A-5
2.	Velocity Measurement Subsystem Block Diagram. .	A-7
3.	Azimuth Measurement Subsystem Block Diagram . .	A-8
4.	Satellite-Fix Distribution	A-15
5.	Satellite Fix Errors at Latitude 32°N, Due to Forced Dead Reckoning Errors	A-16
6.	Satellite Fix Errors at Latitude 32°N, Due to Forced Dead Reckoning Errors	A-16
7.	Standard Deviation Versus Satellite Elevation Angle	A-18
8.	Satellite-position Fix Standard-Deviation Estimate, Far East	A-19
9.	Differences Between Variance Estimate In Laboratory and Actual Position Error	A-20
10.	Calibration Principle	A-21

APPENDIX A*

GEONAV** POSITIONING SYSTEM

052

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.

---

* 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.

**A Geophysical Service Inc. service mark.

GSI-709

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.

055

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

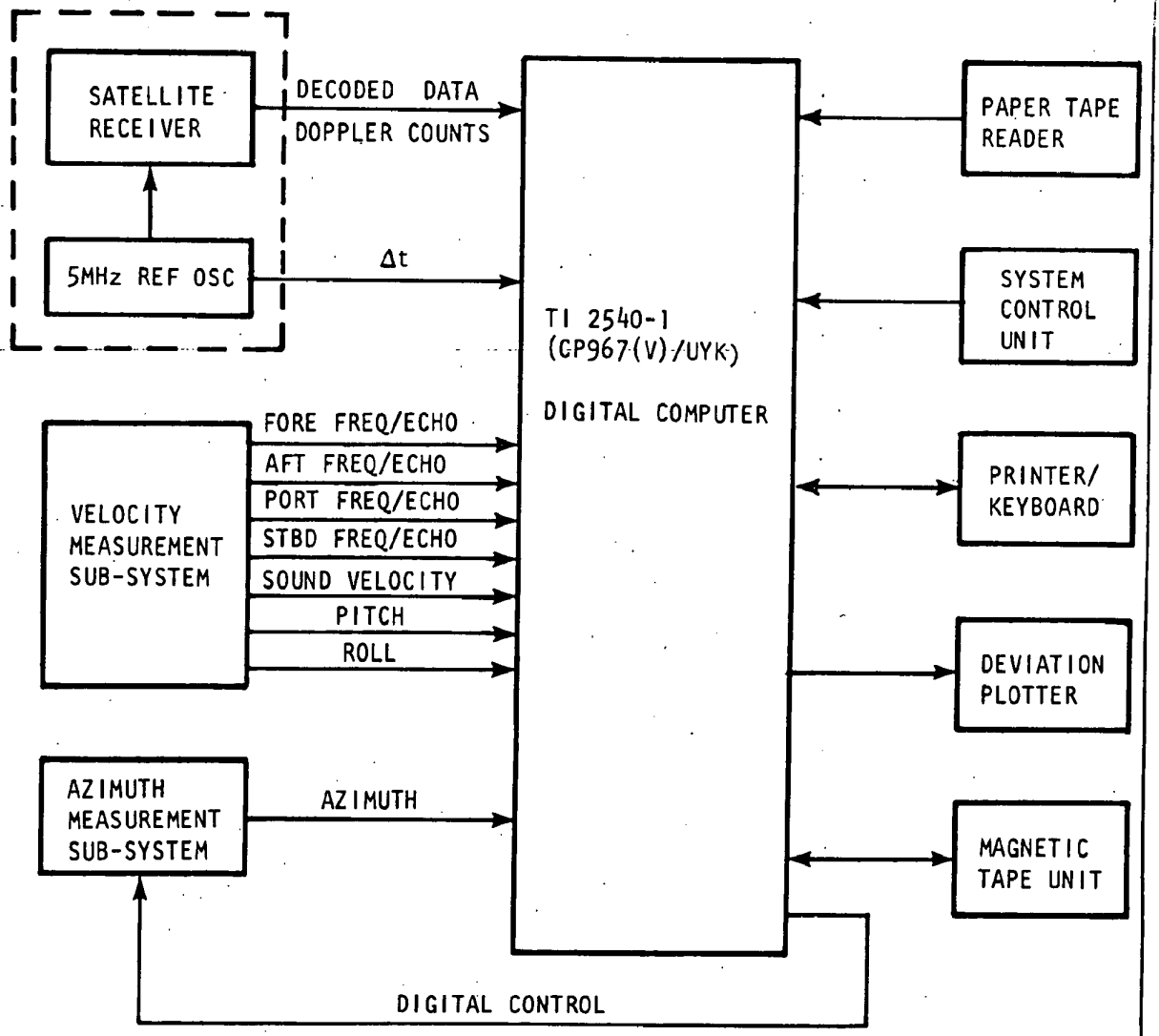


Fig. 1. GeoNav System Block Diagram.

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

058

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.

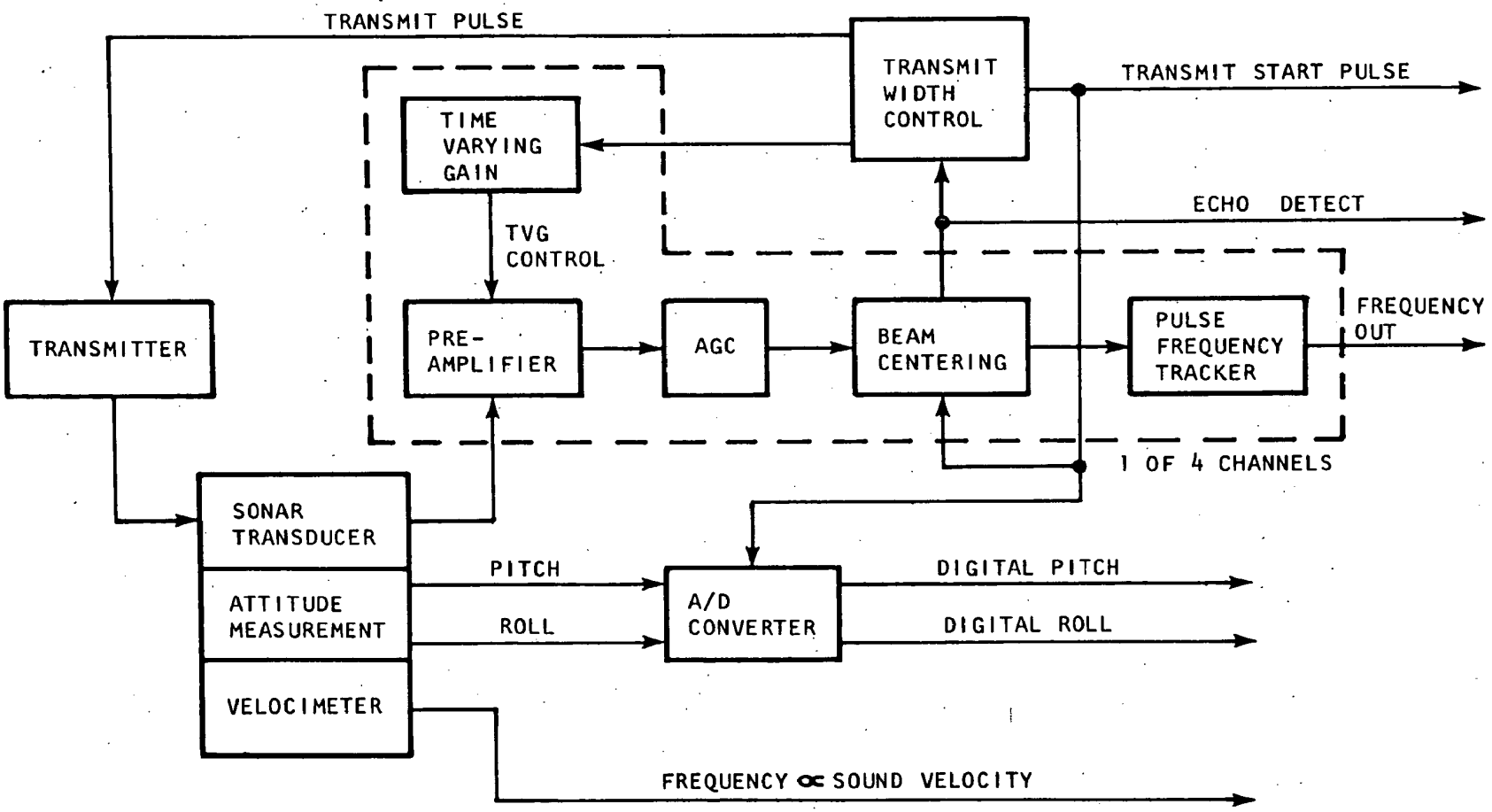


Fig. 2. Velocity Measurement Subsystem Block Diagram

GSI-709

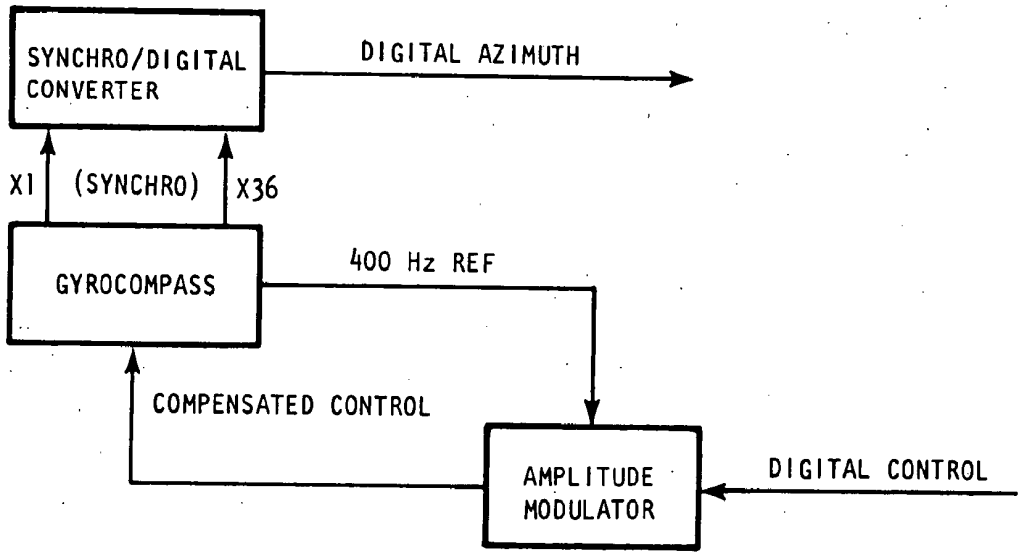


Fig. 3. Azimuth Measurement Subsystem Block Diagram.

Table I. Instrument Accuracy

Unit	Accuracy
Gyrocompass (with compensation)	0.2^{o}
Doppler Sonar	
<100 Ftm	0.2%
100-160 Ftm	0.5%
Inclinometer	0.1^{o}
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

GSI-709

- 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

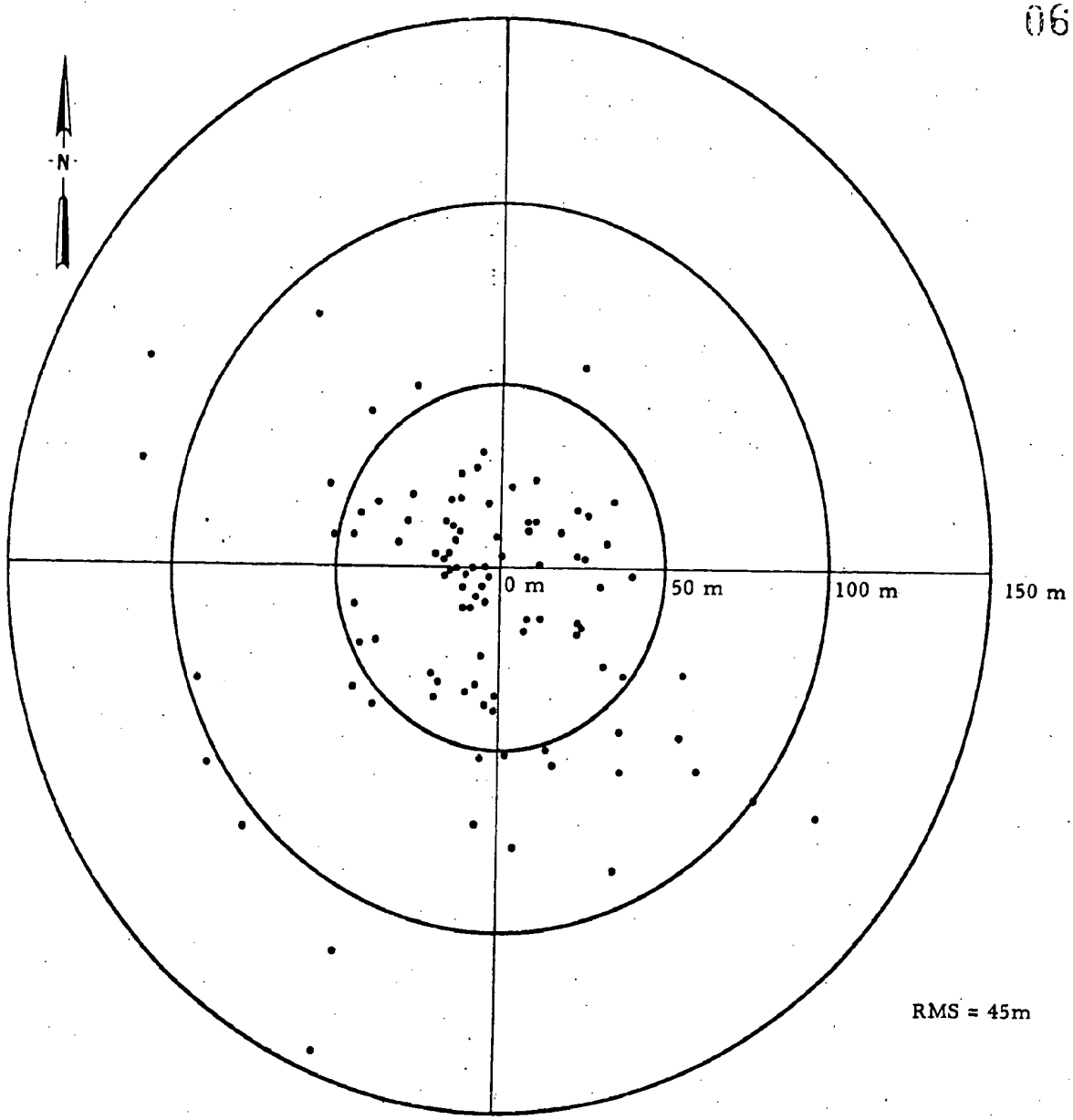


Fig. 4. Satellite-Fix Distribution.

GSI-709

068

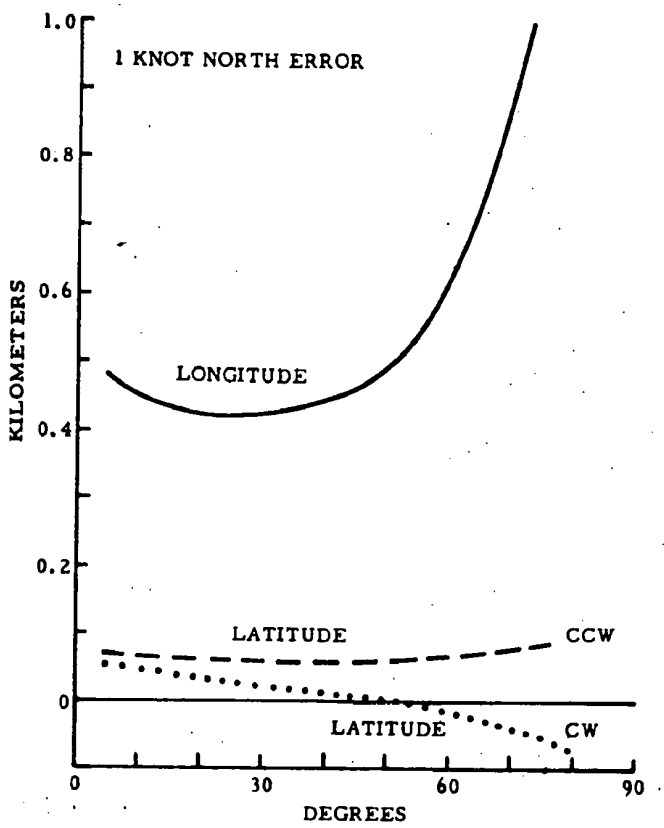


Fig. 5. Satellite Fix errors at Latitude 32°N, Due to Forced Dead Reckoning Errors.

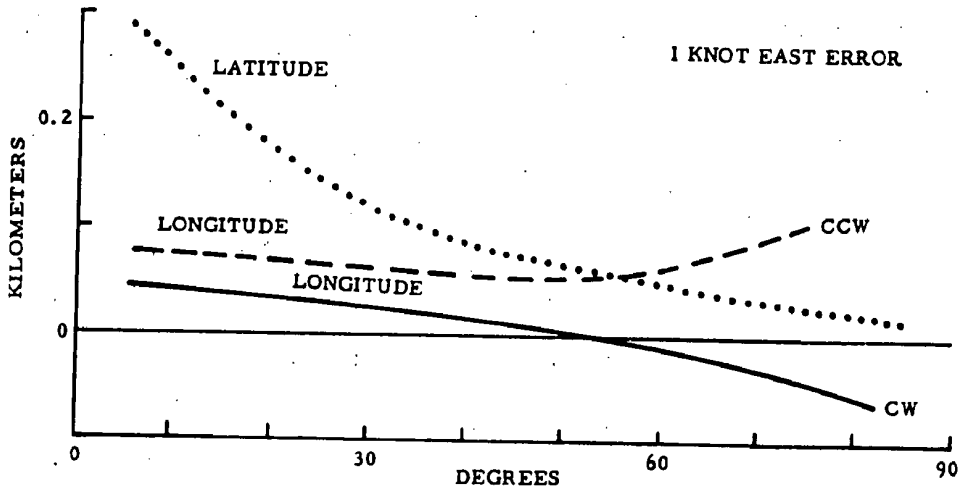


Fig. 6. Satellite Fix Errors at Latitude 32°N, Due to Forced Dead Reckoning Errors.

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°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° to 70°. 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.

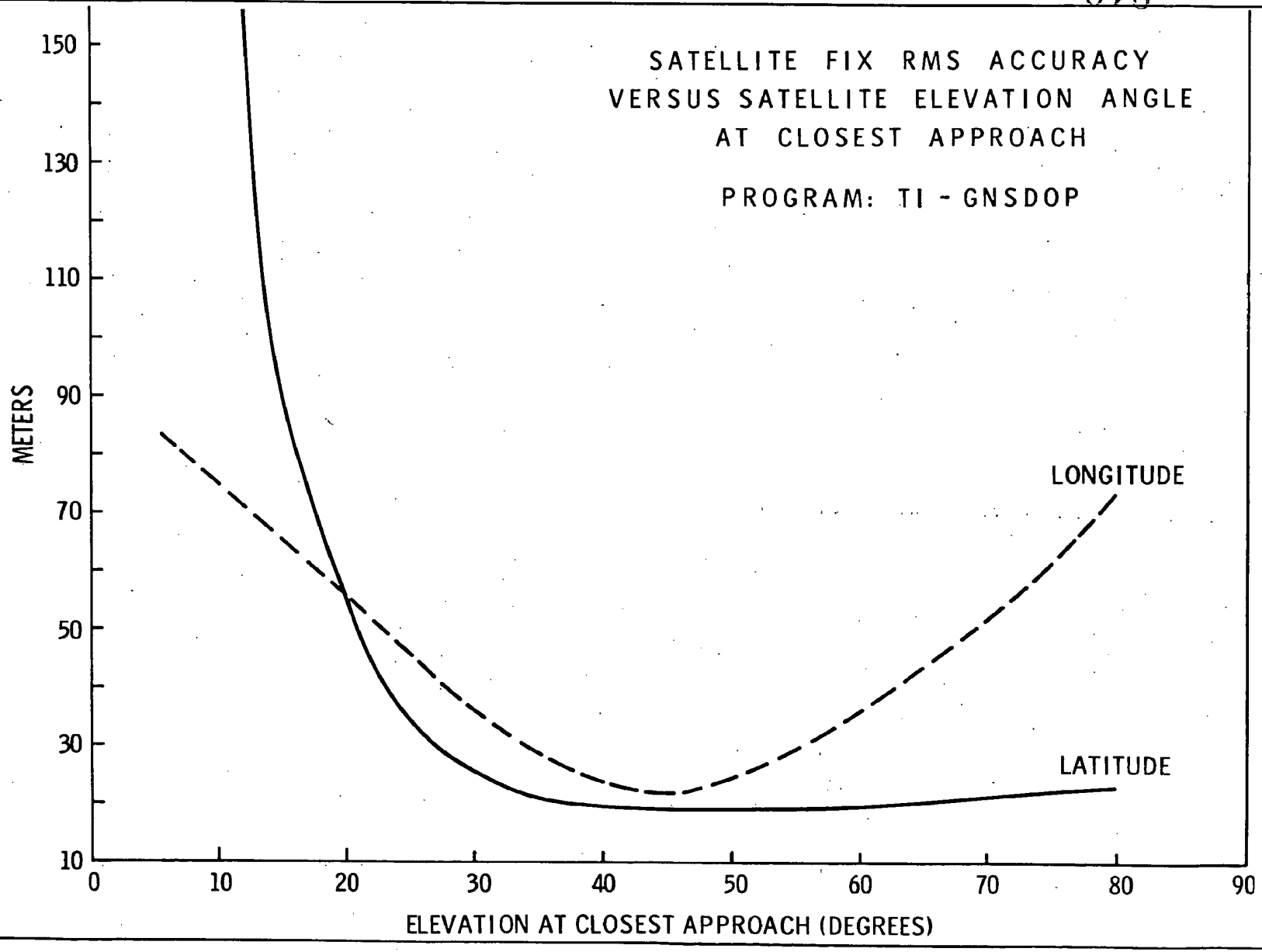
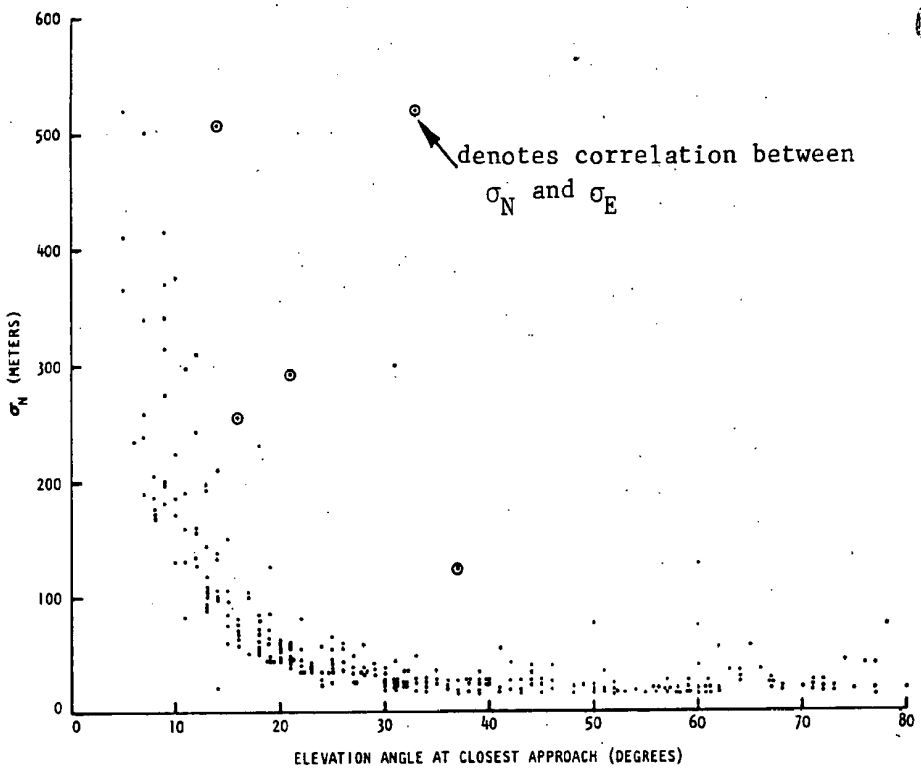


Fig. 7. Standard Deviation Versus Satellite Elevation Angle.

G91-709



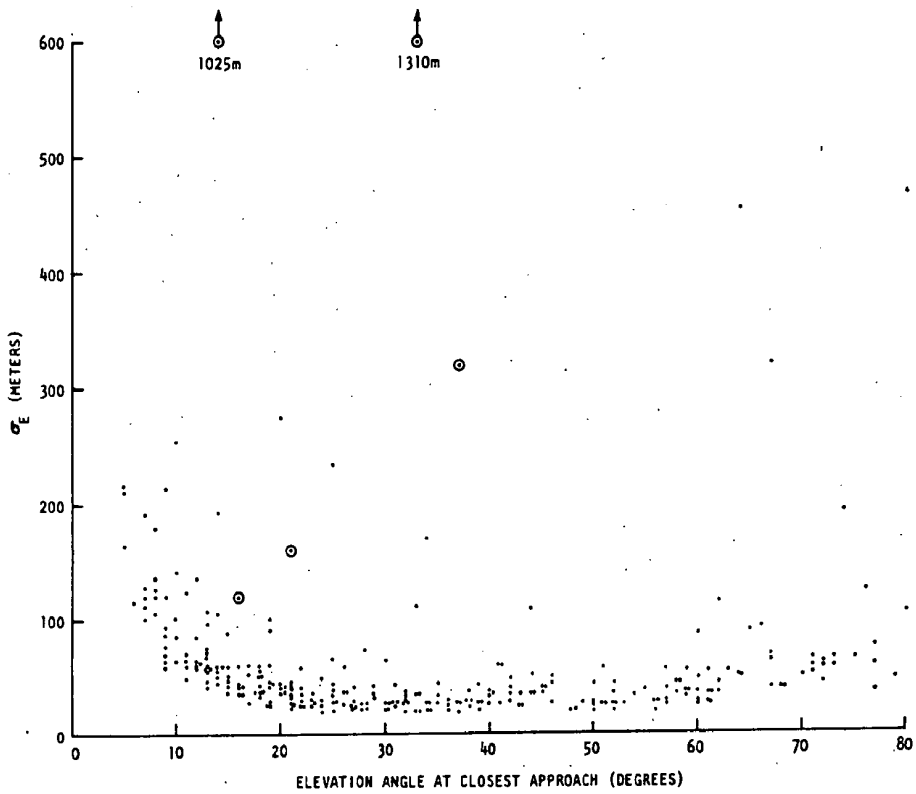


Fig. 8. Satellite-position Fix Standard-Deviation Estimate, Far East.

GSI-709

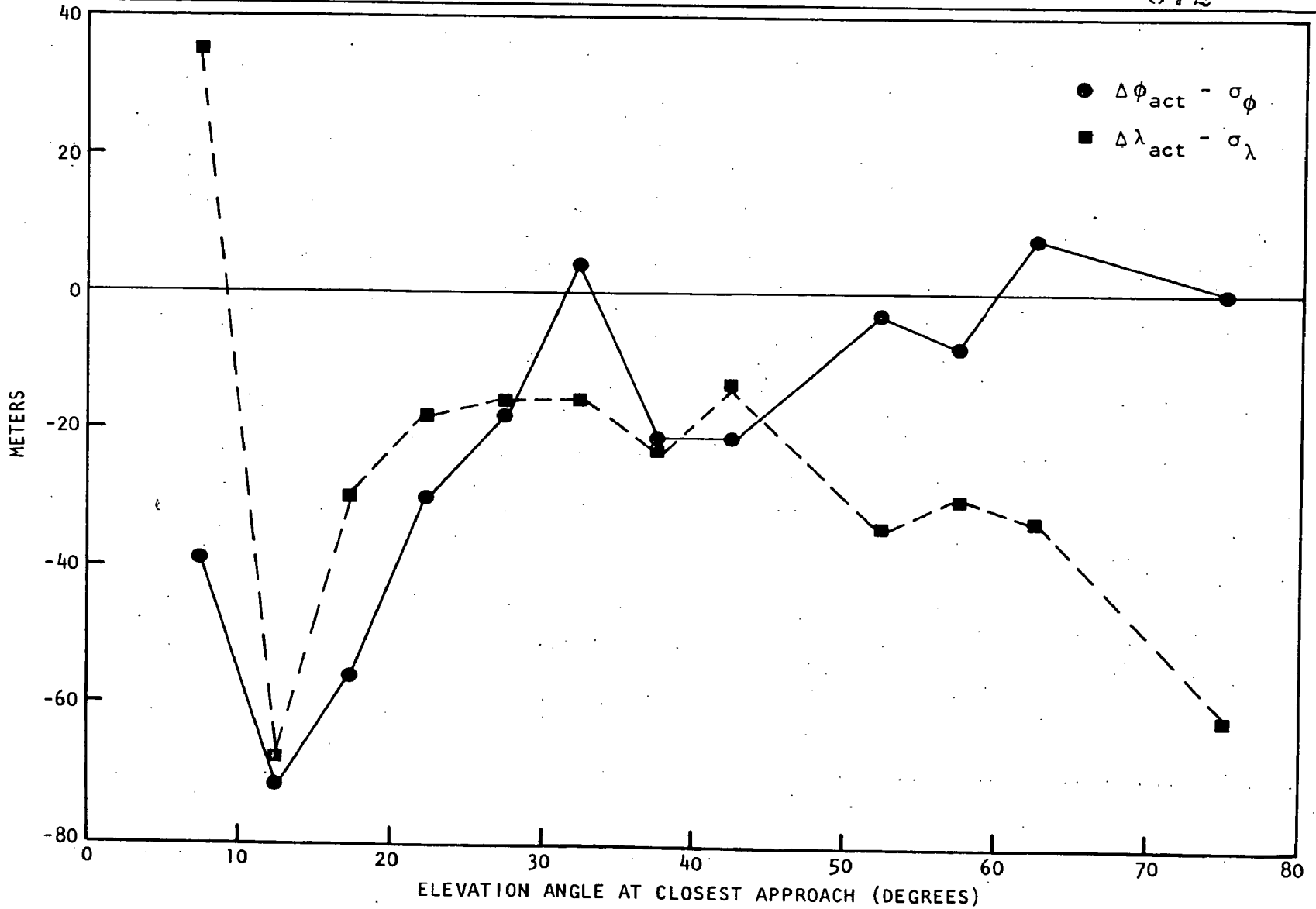


Fig. 9. Differences Between Variance Estimate In Laboratory and Actual Position Error.

GSI-709

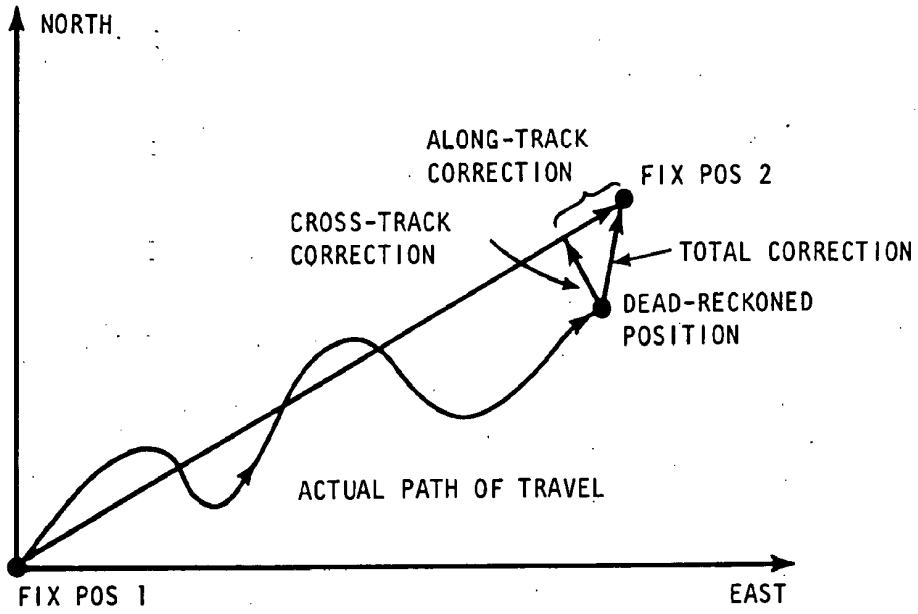


Fig. 10. Calibration Principle.

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

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

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

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

27/3/25
(27/1/5)

078

FINAL REPORT
SUPPLEMENT TO JULY 21, 1972 REPORT

SEISMIC INTERPRETATION OF THE DENMAN BASIN AREA OFFSHORE SOUTH AUSTRALIA

FOR
OUTBACK OIL COMPANY

BY
G. J. LONG & ASSOCIATES, INC.

RECEIVED
10 MAY 1973
DEPT. OF MINES
SECURITY
1952 III

HOUSTON, TEXAS

APRIL, 1973

TABLE OF CONTENTS

	Page
INTRODUCTION	1
DATA ACQUISITION AND PROCESSING	1
INTERPRETIVE METHODS	2
DISCUSSION OF RESULTS	2
CONCLUSIONS AND RECOMMENDATIONS	4

PLATES:

1. Outline of Area
2. Shallow Seismic Horizon(s)
3. Seismic Horizon in Mesozoic(?)
4. Isochron - Shallow Horizon(s) to Mesozoic(?)
5. Record Section, Line 107
6. Record Section, Line 108
7. Record section, Line 116
8. Record Section, Line 125
9. Record Section, Line 127
10. Record Section, Line 129
11. Record Section, Line 135

MAPS:

1. Water Depth
2. Shallow Seismic Horizon(s)
3. Seismic Horizon in Mesozoic(?)
4. Isochron - Shallow Horizon(s) to Mesozoic(?)

APPENDIX I:

Report of July, 1972

INTRODUCTION

This report supplements our report of the analysis of seismic data in the Denman Basin Area, dated July, 1972, which is included as Appendix I.

During November, 1972, 1146 miles of seismic coverage were obtained in the area. The location and orientation of the traverse lines were determined from the results of previous surveys in the area and were placed so as to provide maximum coverage over the areas of prime interest. Control for the delineation of drilling locations was to be provided by this survey.

Sufficient processed data to commence the interpretation became available during the first week of February, 1973. The process of integrating this data with the previous 1219 miles of coverage began at that time.

DATA ACQUISITION AND PROCESSING

Additional seismic control was obtained by Geophysical Service, Inc., Field Party #931 from November 1, 1972, through November 17, 1972, resulting in a completed survey totaling 1146 miles.

Field recordings were obtained using an air gun array totaling 1200 cubic inches, a digital sample rate of four milliseconds, spread length of 5966 feet (shortened from 8644 feet in previous seismic survey), pop interval of 109 feet (previous survey 164 feet), cable depth of 45 feet, twenty-four fold multiple subsurface coverage and a

group interval of 218 feet (previous group interval 328 feet). Data were processed in the GSI processing center in Houston, Texas. New line designations start with Line 101 and continue through Line 137.

The new Seismic data with the shorter spread length better delineates the shallow strata and by its character suggests an alternating sand-shale section above the Mesozoic(?) reflection.

INTERPRETIVE METHODS

The methods described in the previous report were used for the current work. Somewhat better continuity at shallow levels on the new coverage did permit more continuous mapping than had been possible earlier.

DISCUSSION OF RESULTS

GENERAL: The quality of the new (November, 1972) data is similar to that obtained earlier, except that the shorter cable has improved shallow reflections markedly.

The present interpretation differs from that of July, 1972, primarily in detail due to the additional control and some resulting modification of horizons in the east and west extremities of the area.

SHALLOW SEISMIC HORIZON(S): Changes in the portrayal of this horizon result largely from the greater continuity possible with additional data. Datum changes have been avoided wherever possible resulting in the mapping of several localities where the Shallow horizon onlaps the Mesozoic(?) reflector and is missing. The lack of datum changes

in and near the "Central Graben" area result in a more meaningful isochron over this area. This map should be regarded as being different from the previous Shallow Horizon in specifics rather than in generalities.

The character of the reflected data suggests a sand-shale section above the Mesozoic(?) Horizon. Available velocity data tend to confirm this appearance.

SEISMIC HORIZON IN MESOZOIC(?): The Mesozoic Horizon is based on a continuous reflection which is present over the southern two-thirds of the area. In some localities (such as Line 135, Station 250-600, Plate 10) this is followed by a second event approximately .100 seconds later. Velocity data suggest that the interval between these events is of relatively high velocity, such as a limestone.

The anomalies of primary interest lie along the structural trend H-I-J, which is essentially similar to the previous version. Additional control has localized the structures and furnished better measures of critical components of dip.

Anomaly H embraces an area of 30,000 acres, with east-west reversal in excess of .300 seconds (1200± feet) and a northwest closure of .100 seconds (400± feet). The unconformity observed at shallower levels in this locality suggests a stratigraphic trap covering a large area within the "Central Graben": see Plates 4, 5 and 6.

Anomaly I is a relatively small structure at the Mesozoic(?)

level covering approximately 3800 acres with a minimum of .050 seconds (225± feet) of closure. This feature lies within the area previously considered as a possible sand buildup or a reef-knoll (bioherm), which covers an area of 12,500 acres. This area is considered to be one of the most promising in the Tenement because of the multifold possibilities which may be tested by one well.

Anomaly J is an anticlinal feature covering 15,000 acres. Observed reversal is .150 seconds (950± feet). Additional control has localized this feature and emphasized north closure.

With the exception of anomaly E, the features previously discussed in the western "Platform Area" (A, B, C and D) are essentially as previously described. With the present control, these anomalies should be considered as leads only.

CONCLUSIONS AND RECOMMENDATIONS

The present degree of control adequately delineates Anomalies H, I and J for the purpose of drilling. The character of the sediments and their hydrocarbon potentialities are not and cannot be established by geophysical methods. The existence of sediments at depths below the Mesozoic(?) reflector likewise cannot be established by indirect methods.

In the vicinity of Anomaly I (Line 127, Station 228-348, Line 108, Station 996-1044), seismic phenomena are observed which are of a type that has been associated with hydrocarbon (gas) occurences elsewhere. These have been variously styled "bright spots", "hot

spots" and "DHI" (direct hydrocarbon indications) by other explorationists. These observations are regarded as support for favorable speculation regarding the hydrocarbon potential of the Denman Basin. While the enhancement of these "bright spots" might provide some comfort, we do not have a basis for the evaluation and comparison of such phenomena in the Denman Basin. We do not believe that the outcome of an enhancement program should directly influence future exploration plans.

The above conclusions indicate that the next exploratory effort in the Tenement should be drilling. The remoteness of the area and the relatively shallow depths expected suggest a multi-well program.

It is therefore recommended that:

1. A multi-well drilling program be established and that the features be given the following order of priority:
    a. Anomaly I
    b. Anomaly J
    c. Anomaly H
2. The drill depth required to test the strata identified by seismic reflectors will range from 2500 feet (Anomaly H) to 5000 feet (Anomaly J) over the areas of interest. A drilling program should contemplate the desirability of evaluating beds as deep as 7500 feet at Anomaly H to 10,000 feet at Anomaly J.

3. Tests be located on flanks of Mesozoic(?) structure to maximize stratigraphic potential. Tentative locations for these tests are indicated on the Mesozoic Structure Map.

Respectfully submitted,

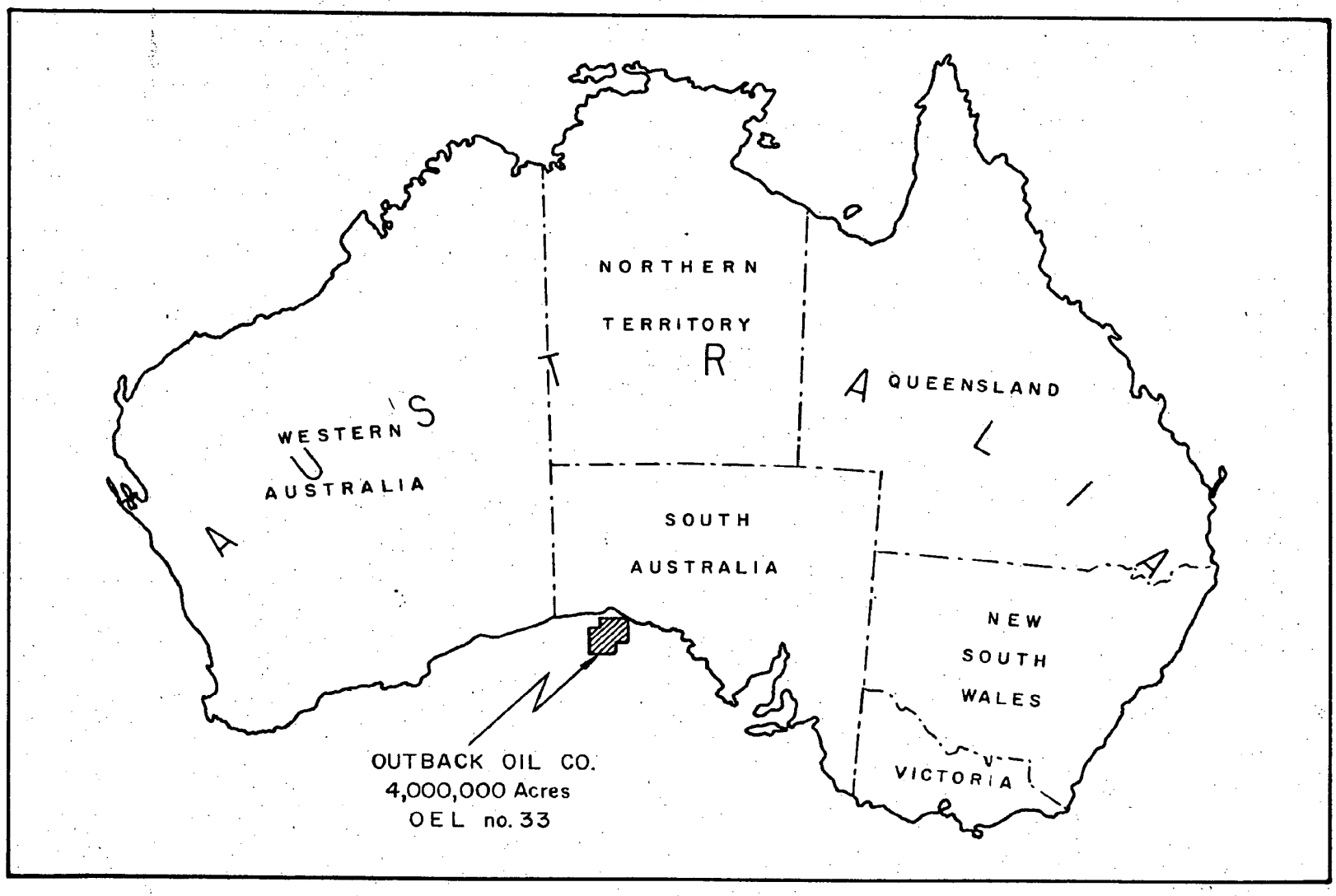
G. J. LONG & ASSOCIATES, INC.

By J. W. Perlman

J. W. Perlman

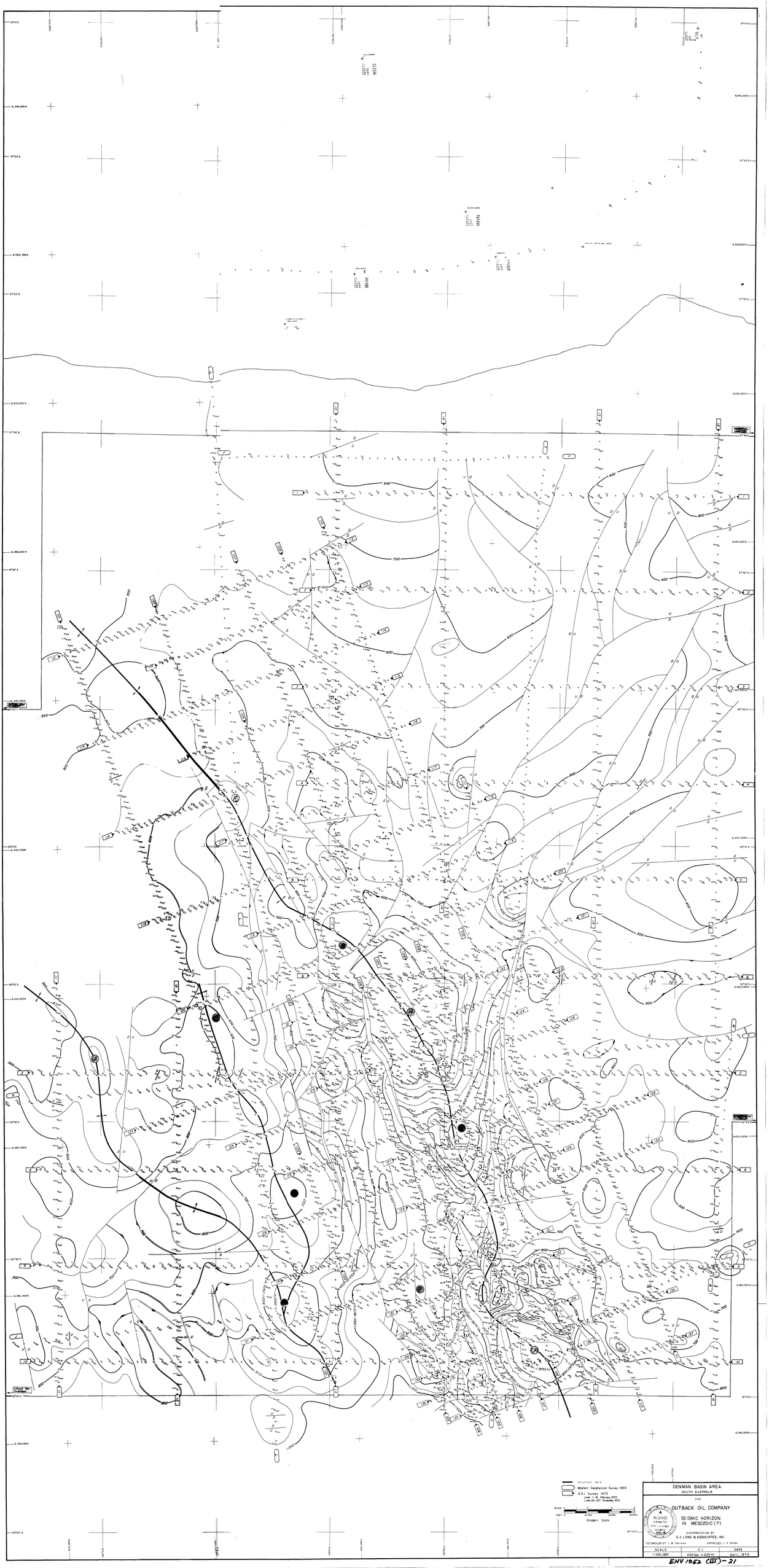
Approved:

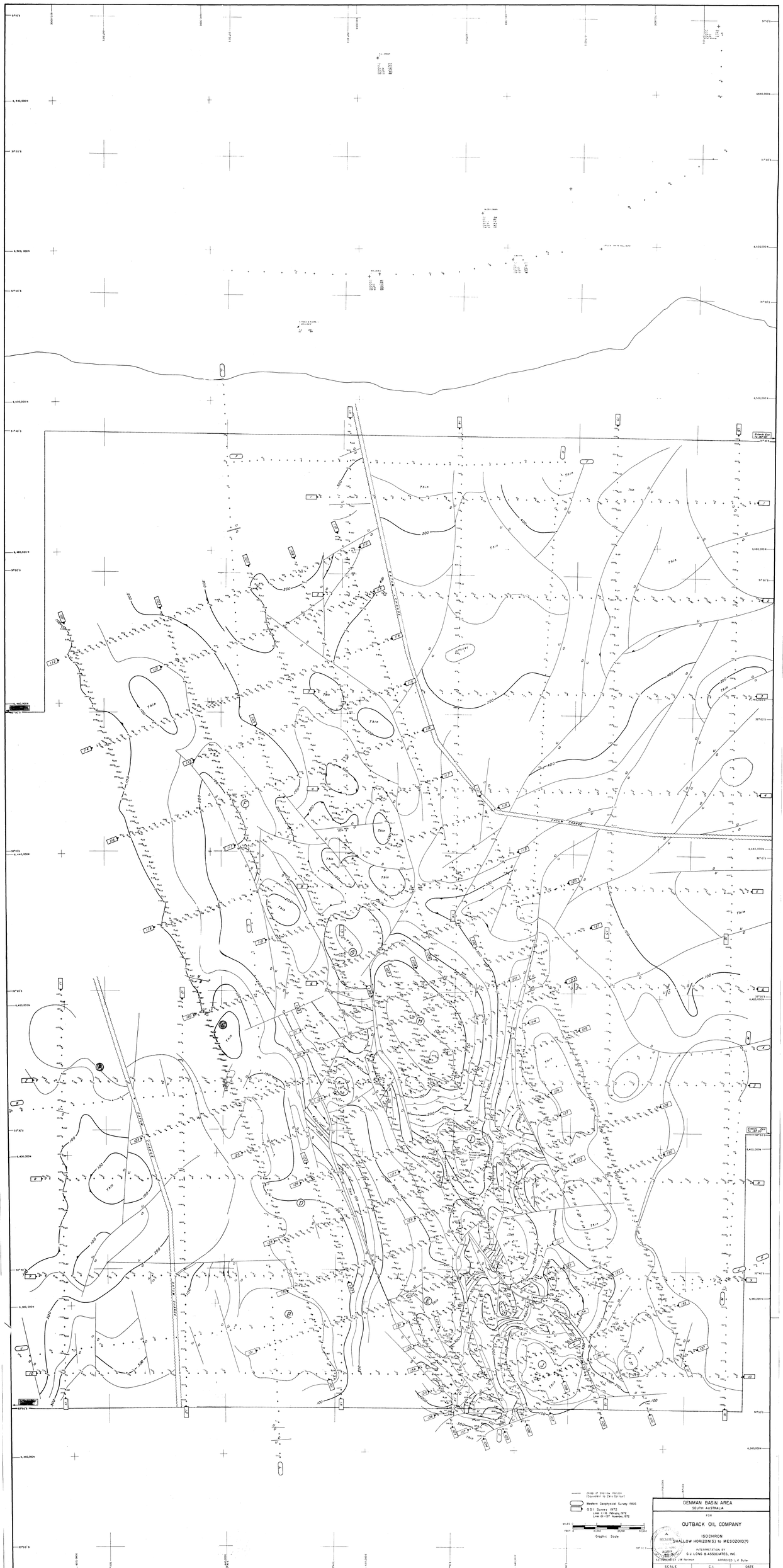
L. K. Buller



OUTLINE OF AREA

DATUM CHANGE
Western Geophysical Survey 1966
G.S.I. Survey 1972
Lines 01-06 November, 1972
Lines 01-07 November, 1972
Graphic Scale
DENMAN BASIN AREA
SOUTH AUSTRALIA
FOR
OUTBACK OIL COMPANY
SHALLOW SEISMIC HORIZON(S)
INTERPRETATION BY
G.J. LONG & ASSOCIATES, INC.
DRAWN BY: J.M. Perlman
APPROVED: L.K. Butler
SCALE
1:100,000
C.I.
NO SET
DATE
Apr. 1973
ENV 1982 (III)-13


Structural Axis
Western Geophysical Survey 1966
G.S.I. Survey 1972
Lines 1-16 February, 1972
Lines 17-137 November, 1972
MILES 0 1 2 3 4
FEET 0 10,000 20,000 30,000 40,000
Graphic Scale
DENMAN BASIN AREA
SOUTH AUSTRALIA
FOR
OUTBACK OIL COMPANY
SEISMIC HORIZON
IN MESOZOIC (?)
RECEIVED
INTERPRETATION BY
G.J. LONG & ASSOCIATES, INC.
SEISMOLOGIST J. W. Perlman
APPROVED L. K. Butler
SCALE
1:100,000
C.I.
250 feet (1:225%)
DATE
April, 1973
ENV 1962 (III) - 21


Drill of Shallow Horizon
(Equivalent to Zero Datum)
Western Geophysical Survey 1966
G.S.I. Survey 1972
Lines (1-18) February, 1972
Lines (19-137) November, 1972
Miles
Feet
Graphic Scale
DENMAN BASIN AREA
SOUTH AUSTRALIA
FOR
OUTBACK OIL COMPANY
ISOCHRON
SHALLOW HORIZON(S) to MESOZOIC(?)
INTERPRETATION BY
G. J. LONG & ASSOCIATES, INC.
TECHNOLOGIST J. W. Perman
APPROVED L. K. Butler
SCALE
1:100,000
C.I.
050 Sec (+225')
DATE
April, 1973
ENV 1052 (III) -22