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SEISMIC SURVEY REPORT

on the

TODD RIVER AREA

Northern Territory

AUSTRALIA

Submitted to

FLAMINGO PETROLEUM PTY., LTD.

by

NAMCO INTERNATIONAL, INC.

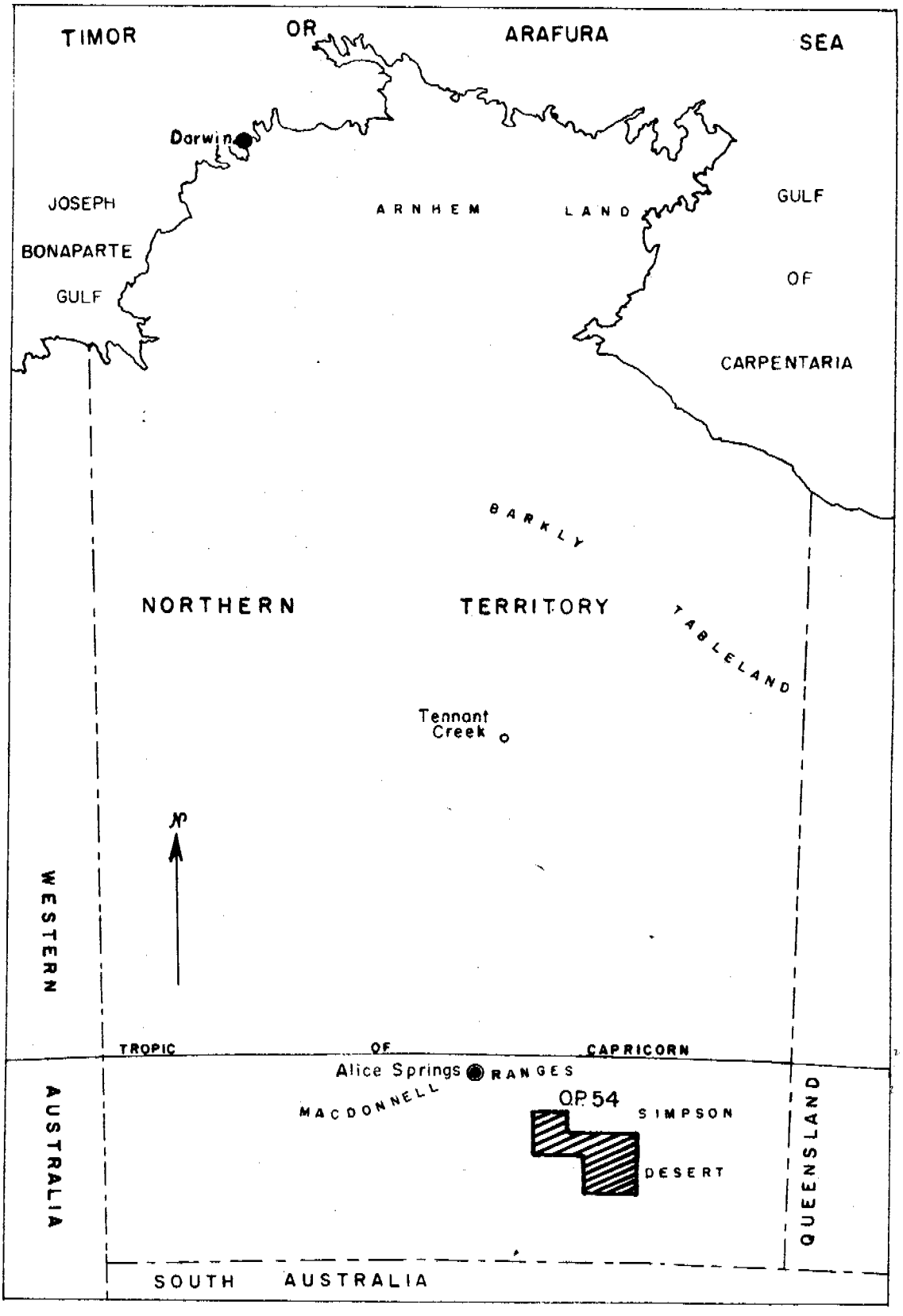
DALLAS

ABSTRACT

A reflection seismic survey was conducted during February, March, April, and May, 1963 for Flamingo Petroleum Proprietary, Limited, by Party No. 84 of Namco International, Incorporated, within O. P. 54 of the Northern Territory, Australia.

The purpose of the survey was to provide detailed subsurface control on the north flank of the Camel Flat syncline for evaluation of a gravity minimum in that area. In addition, program was assigned to develop regional subsurface control between Steele's Gap and Malcolm's Bore, to determine the thickness of sediments, and to detail any interesting geologic feature found by the initial reconnaissance.

The results of the survey indicate that the gravity anomaly is probably the result of a thickened Cambrian and Proterozoic section north of Camel Flat and that an east-plunging anticlinal feature in the area south of Steele's Gap may provide a fundamental divide between the Amadeus and Great Artesian Basins, with associated stratigraphic and structural possibilities.



LOCATION MAP

CONTENTS

1. INTRODUCTION

The Todd River Area seismic survey was conducted for Flamingo Petroleum Pty., Limited, with registered offices at Brisbane, Queensland, within O. P. 54 in the Northern Territory, Australia, Refer to the Location Map, frontispiece.

The geophysical contractor was Namco International, Incorporated, of Dallas, Texas, with Australian headquarters in Adelaide, South Australia. Details of equipment and personnel employed are presented in Appendix I and Appendix II. Commencement and completion dates and other statistics for the survey are presented in Appendix III.

The Todd River Area is located in the south-central section of the Northern Territory, 100 air miles southeast of Alice Springs. Access is via the Santa Teresa Mission and Allambi Homestead track and then by way of the road to the old Andado Homestead.

In the north part of the permit, surface topography is characterized by quartzite and sandstone ridges with rocky cliffs and steep slopes separated by flat or gently undulating sand plains. In the central section of the area the rocky outcrops give way to the spinfix sand plains and dune fields of Camel Flat. Further to the south the outcrops of the Steele's Gap Area provide the northern border of the sand plains and dune fields of the Simpson's desert.

The principal drainage in the area is to the south and east via the Todd River system. However, this drainage pattern becomes obscured in the reticulate system of sand dunes in the desert region.

The climate in this region is normally fine and clear. Rainfall is scarce and averages less than 5 inches annually. Temperatures during the summer months are uncomfortably hot but moderate during the winter.

2. GEOLOGY

The Todd River Area is located in the southeastern portion of the Northern Territory where the Simpson desert obscures the junction of the Great Artesian and Amadeus Basins. The limits (if any) of the basins have not been defined. However, it has been postulated, on the basis of the extension of the trend of the Musgrave-Mann Arunta complex, that the fundamental physical divide would pass through the southern portion of O. P. 54.

The rocks in the north and northwestern portions of the area are limited to those sediments associated with the Amadeus Basin. The deposits range in age from Proterozoic into Cambrian, Ordovician, and Upper Paleozoic, with scattered Cretaceous remnants. Bedrock is overlain by a thin veneer of Recent material.

South of Steele's Gap the paucity of outcrops prevents a thorough investigation of the subsurface by surface geology. Cretaceous outcrops and samples from bores in the vicinity signify the introduction of Great Artesian continental deposits in the permit. Little is known of the thick-

ness or stratigraphy of Great Artesian Basin deposits in the area, but there appears to be a similarity of sedimentary sequence to those areas within the Great Artesian Basin itself.

Structurally, the Pre-Mesozoic sediments in the Amadeus Basin were intensely folded and faulted. The east-west trend of the structures indicates that the major forces acted from the north, while other systems of folding and faulting aligned structures normal to this trend.

The strata of Permian to Recent age in this portion of the Great Artesian Basin have not been contoured in the manner mentioned above and are generally found as flat-lying formations with dips of less than 5 degrees. Regional dip is primarily to the south.

The most promising beds for oil and gas accumulations are those located in the Lower and Middle Paleozoic, where numerous beds offer both excellent sources and reservoir characteristics. Marine sediments of the Great Artesian Basin are also considered prospective, but there is some doubt whether they extend north into this region.

3. FIELD PROCEDURE

The results of the survey were obtained using the continuous reflection profile method of investigation. Shot points were spaced at 1320-foot intervals along the line of the traverses with 110-foot linear offset and seismometer group intervals. Refer to Figure 1, Typical Seismometer Spread.

Recording was accomplished using National Geophysical Company 26-AA amplifiers and a National 4F oscillograph. A Techno tape recorder and field playback unit was used in conjunction with the National instruments for magnetic tape recording. A monitor seismogram and a magnetic tape were recorded simultaneously for each shot, using a wide band filter setting with each seismometer group independently activating its respective galvonometer trace. The magnetic tapes were later played back through the field unit using a CH-CH filter setting, selected as optimum for the area, with 50% mixing of adjacent traces. This filter combination features a low cutoff of 24 cycles per second and a high cutoff of 58 cycles per second at 50% response, with a peak frequency of 37 cycles per second.

Usually, twelve seismometers were distributed uniformly along the line of the profile. An extra cable and a set of seismometers were employed to keep a spread laid ahead of the recorders.

Shot holes were obtained by two combination air-water drills. The drilling conditions varied but were generally good. Sandstone stringers and boulders proved the greatest hindrance to drill production. All of the shot points were drilled using a water injection method of controlling caving near-surface sand, and the method was extremely successful in gaining high drilling production.

All instrument spreads were chained, and horizontal and vertical control was obtained by alidade and plane table. The datum for the elevation and traverse control was a Geoseismic shot point in each area.

All traverses were checked by loop control or double sighting, and it is felt that the control has been established within the normal limits of accuracy.

The normal working day was ten hours, including driving time to and from the field. Twenty-two days, including holidays and move time, constituted a normal month.

4. QUALITY OF DATA

The record quality in the Todd River Area varied from poor to good. In the northwest part of the area, good records were obtained in the dune fields, but quality deteriorated as the control approached outcrops. Poor records were thought to be more the result of complex subsurface conditions rather than near-surface disturbances.

On the regional reconnaissance lines, in the southern portion of the permit, the quality of the recordings was generally fair but some of the records undoubtedly suffered from near-surface interference patterns created by the shot. At times the records showed the effects of diffraction patterns caused by irregularities in the subsurface, but these examples were definitely in the minority.

Initially, experimentation was performed to develop the shooting procedure producing the best results. It was found that 15 or 16 holes, 20 feet deep, spaced at intervals of 30 or 60 feet apart in the form of a square rotated 45° to the line gave the most improvement for time and labor expended. This procedure was used consistently throughout the

program. It is felt that the multiple holes were predominantly successful in cancelling noise patterns and in improving the results considerably.

5. OPERATION

In the beginning the severe weather common to this area during the summer made working conditions very unpleasant and many members of the crew suffered from heat exhaustion. The hot weather abated after several weeks, and as a result the efficiency of the crew increased.

The camp was located about 20 miles east of Allambi station while the lines in Map Area A were shot. Supply was effected with ease; good water was obtained from Desert Bore (near SP F-35) and most of the requirements of the crew could be acquired in Alice Springs.

The other camp site was located on the Steele's Gap-Andado Homestead track approximately 135 miles southeast of Alice Springs. The closest water was Desert Bore but supply was not difficult due to the generally good access road.

The surface conditions on most of the lines were such that movement was generally hindered. This was particularly true when the lines or access to the lines ran at right angles to the trend of the sand dunes. Loose sand and rough spinifex plains along the steep sand dunes contributed to long drive times and increased the time of seismometer pickup and movement along the line. While working a new line the crew

would find the easiest access to the line resulting in diminishing drive times, but move time was still considered abnormal.

The use of a bulldozer would be recommended for any further work in the area, particularly if the program consisted of a majority of east-west lines.

6. INTERPRETATION PROCEDURE

Observed reflection times were corrected to a plane established at 800 feet above sea level, using the standard uphole time procedure. Correctional velocities of 9000 feet per second and 7000 feet per second for Map Area A and B, respectively, were used in the computation. Any additional weathering below the shot reference position was determined by a rectilinear intercept method (Figure 2), the additional delay applied, and the shot reference position referred to the base of the weathering.

Subsequent shots in the hole were corrected to the reference shot using a factor equal to the difference in uphole times.

Standard cross sections were plotted and have been submitted. Since dips in the area rarely exceed 10^{o}, migrated sections were not considered necessary. A vertical scale of 1 cm. = .020 second reflected time and a horizontal scale of 1 cm. = 220 feet were used in preparing the cross sections.

Phantomed data have been shown for points shot by Geoseismic on Map A. The data were obtained from cross sections accompanying the other

geophysical and geological information furnished by the Client as background material, but since the actual recordings were not available, no character nor continuity study has been made in accumulating these data.

Four structural control maps have been constructed (Enclosure I - IV) for Map Area A and two structural control maps (Enclosure V and VI) for Map Area B. These are included with this report.

Enclosure I is a structural control map for an unidentified reflected event, Horizon "D". The map is thought to show the attitudes of Cambrian deposits.

Enclosure II is a structural control map for a reflection tentatively associated with Pre-Cambrian strata, Horizon "F". The event was not interpreted as a basement reflection but as a competent, continuous reflection related to beds near the base of the sedimentary section.

The Isochron (time-interval) map between Horizon "D" and Horizon "F" is submitted as Enclosure III.

Enclosure IV is a generalized topographic map of the surface contoured on a 20-foot contour interval. The data represent the surface elevation at each shot point.

Enclosure V is a structure map of Horizon "F" of Area B. The event used may be related to beds near the basement and has been interpreted in a manner similar to Horizon "F" of Area A. The relationship of the deepest events mapped in the two areas has not been determined, and

no assurance of stratigraphic correlation exists even though the events occupy similar positions in the section.

Enclosure VI is the Map Area B equivalent of the surface map of Map Area A.

7. DISCUSSION OF RESULTS

The three seismic maps presented for Map Area A are considered reliable and each provides an interesting study of geological conditions on the south flank of the Amadeus Basin.

The structural map of the "D" event shows the location of the trough of the Camel Flat syncline almost coincident with that postulated by surface geology. From the deepest point, located at Geoseismic F-61, the event shows moderate north dip to the south end of the line; northward from this point moderate then strong south dip is observed. In the north and northeastern portions of the detailed area, poor records hinder the interpretation and are believed to be due to faulting which may penetrate the entire sedimentary section. Isolated indications of north dip make this idea credulous and support a complex interpretation.

The structure map of the "F" (Pre-Cambrian ?) event indicates moderately strong north dip (0. 2 second) from the south end of the Geoseismic line to the beginning of the "A" line, at which point the axis of the snycline is reached. From this point the direction of the dip reverses to south until the poor record area is reached. On the "B" line several

correlations indicate a departure from the south dip and probably sug-test faulting. Once again the quality of the data has deteriorated to the point where no firm conviction can be reached, but north dip between the "E" line and the "B" line is certainly a contradiction of regional tendencies in this area.

With reference to the Isochron map of the "D" and "F" events, Enclosure III, the data infer a high Pre-Cambrian ? area at "D" event time in the vicinity of Geoseismic SP 52, with the divergence south from this point indicating rather gentle south dip. The moderate then strong divergence to the north of this point indicates that the deepest part of the syncline is located at least as far north as the most reliable data shown on the map. The extremely thick value at SP B-11, although questionable, extends the plunge.

The divergence to the north probably defines an angular unconformity between Pre-Cambrian ? and Cambrian sediments and can be interpreted as showing that the Amadeus Basin, in this region at least, was in a period of subsidence during Cambrian time.

In most respects, the interval map supports the results of the regional gravity survey in this area, indicating a northerly offset of the trough of the Camel Flat syncline at depth. The gravity minimum is coincicent with the position of the thick area on the interval map. It would appear that the gravity depression is an expression of a thickened Cambrian section.

Enclosures IV and VI show the generalized attitude of the surface in the area. The agreement of the position of surface features with subsurface relief may mean that there is positive conformity of the surface with the shallow members of the geologic section but that the relationship is lost where a subsurface unconformity is involved.

Enclosure V presents the results of the survey on the regional reconnaissance lines. As mentioned above, the event probably is associated with beds occupying the same position in the section as Horizon "F". The map has been constructed to show the deeper attitudes in the section; unfortunately no event was found to persist sufficiently to describe the relief in the upper parts of the geologic column. The amount of control obtained precludes a complete description of the separation, or divide, between the Amadeus and Great Artesian Basin, but judging from the results of this survey and the outcrop information to the southwest, it would appear that a fundamental divide has been traced through most of O. P. 54. The area on the extreme east side of the permit could still serve as a link between the two structural units since the regional dip usually includes an eastern component. Anticipated west dip has not been defined, which might serve as evidence of a positive basement feature in that region.

A comparison of the results of this seismic reconnaissance survey with a prior gravity interpretation of the area indicates that the Bouguer Gravity Data are compatible with increases in thickness of the shallow sediments, but that the deeper formations are not as well-defined by gravity.

The cross sections of the regional lines display a prominent divergence between the shallow and deep reflections. The divergence to the north results from persistent south dip on the shallow beds and gentle north dip on the deeper horizons from the culmination of the deep-seated anticlinal feature. The amount of divergence south of the high trend is reduced due to conformance of dips between upper and lower levels.

Various stratigraphic pinchouts can be recognized on the north side of the positive feature, as might be expected in an area of unconformity. One zone of pinchouts occurs in the deepest part of the section mapped, where a reflection from below the "F" event displays irregular dips with resultant changes of time interval between the two of as much as .030 second. This condition might be explained by the assumption that the deeper reflection is associated with basement. The other zone of pinchouts occurs immediately above the "F" event. The convergence of reflecting interfaces at this level is a progressive feature evidenced by loss of successive cycles of energy. This latter condition has similarity with that observed on the line across Camel Flat. The locations of the more obvious pinchouts are outlined on the cross sections.

A differential time analysis for velocity determination was made with data obtained south of Steele's Gap, and the results are considered useful in assessing the nature of the section. Graphs of average and interval velocities vs. reflection time are displayed on the central portion of the cross section for Line "H". The analysis indicates relatively low average velocities to the deepest reflection (7900 to 8900 feet per sec-

ond), which are characteristic of Great Artesian Basin deposits. The observed velocities for the Cambrian and Proterozoic beds of the Amadeus Basin are considerably higher.

8. CONCLUSIONS

The results of both the detailed survey in Map Area A and the reconnaissance survey in Map Area B suggest that several major undulations exist in the section but that the most prospective anomalies may be associated with stratigraphic pinchouts in both regions.

The selection of a drill site in either area can not be adequately founded on the basis of present geological and geophysical information. Stratigraphic tests are needed to determine the most prospective reservoir formation, which then could be delineated for its most favorable position with additional seismic control.

APPENDIX I

EQUIPMENT

RECORDING:

1 International Model 160 4-wheel-drive recording truck, complete with cable reels and recording cab

1 International Model 160 4-wheel-drive cable truck, complete with seismometer racks and cable reels

1 Complete set of 24-channel National Geophysical Type 26-AA seismic instruments capable of recording both reflections and refractions

1 Complete Model 401-A Techno magnetic recording system with Model TI-480B moveout corrector

3 Cables designed to accomodate one-third mile reflection spreads

480 Electro-Tech type EVS 20-cycle geophones in groups of six per string with 15-foot spacing between phones

SHOOTING:

1 International Model 190 6-wheel-drive explosive truck complete with 1200-gallon flat-type water tank

1 Complete set of shooting equipment, including both conventional and multi-hole blasters and firing harnesses

SURVEYING:

1 J-6 Jeep 4-wheel-drive truck

1 Complete set of surveying equipment and instruments, including both theodolite and alidade

DRILLING:

2 Heavy-duty Mayhew 1000 combination air-water rigs, mounted on International 190 6-wheel-drive trucks. These rigs are equipped with 667 CFM air compressors, 5 x 6 Gardner-Denver mud pumps, and 300 feet of heavy-duty Mayhew drill stem per unit

2 International Model 190 6-wheel-drive heavy-duty water trucks with 1200-gallon flat-type tanks and stake bodies

1 1 Land Rover 4-wheel-drive truck for drill supervisor

SUPPLY:

1 International Model A-160 4-wheel-drive supply truck with stake body

OFFICE:

1 Elder trailer office completely equipped with office machines, drafting equipment, radio and air conditioner

1 Land Rover 4-wheel-drive truck for camp use

SHOP:

1 Elder trailer machine shop complete with drill press, benches, vises, air compressor, and all necessary hand tools and equipment for all repairs

1 Welding trailer, complete with both arc and acetylene welding equipment and supplies

CAMP:

1 Elder trailer all-electric kitchen, air-conditioned, complete with all appliances and utensils

1 Elder trailer diner, with necessary furniture, fixtures, tableware, and air-conditioner

1 Elder trailer shower and utility unit

1 Elder Power Trailer, complete with two 25-KW diesel generators for camp power

1 1200-gallon camp water trailer, complete with pressure system

All trucks and trailers equipped with sand tires. All trucks equipped with front end winches. All International trucks equipped with power steering.

APPENDIX II

PERSONNEL

Party Chief	H. E. Bowman
Seismologist	J. F. Homola
Observer	R. R. Kocian
Surveyor	G. W. Cozby
Drill Supervisor	G. W. Pfau
Drillers	T. J. Adam R. Belsham

The basic field crew comprised a total of 20 men. One additional man was provided for field duty.

Technical and administrative supervision was provided by Mr. W. J. Harkey.

APPENDIX III

STATISTICAL DATA

Starting date, first shot	February 25, 1963
Completion date, last shot	April 21, 1963
Total number of holes shot	407
Total number of shots	671
Total miles of subsurface coverage	100.6
Total number of moving days	7.18
Days lost due to equipment failure	0

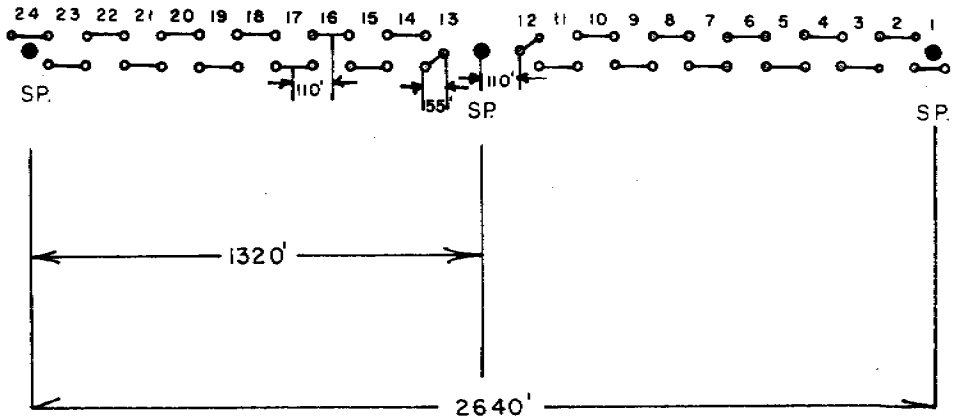
Days lost due to holidays	2
Days lost due to weather	0
Total number of field days, recording	43.83
Total number of field hours, recording	352.5
Total number of driving hours, recording	85.8
Total pounds of dynamite used	13142.5
Total number of detonators used	5183
Total number of drill shifts in field	81.82
Total number of drill shifts, stand by	4.00
Total number of field hours, drilling	649.3
Total number of driving hours, drilling	168.9
Rock bits used	17
Insert bits used	65
Total footage drilled	137254
Total number of holes or patterns drilled	422
Average number of holes or patterns drilled per field shift	5.16
Average footage per hole including patterns	325
Average number of holes shot per day	9.3
Average depth of shot, excluding patterns	60
Depth of pattern holes (usually 15 holes)	20
Mud, chemicals, and casing used	0

NAMCO INTERNATIONAL, INC.

H. E. Bowman
Party Chief Party No. 84

W. J. Harkey
Supervisor

April 1963



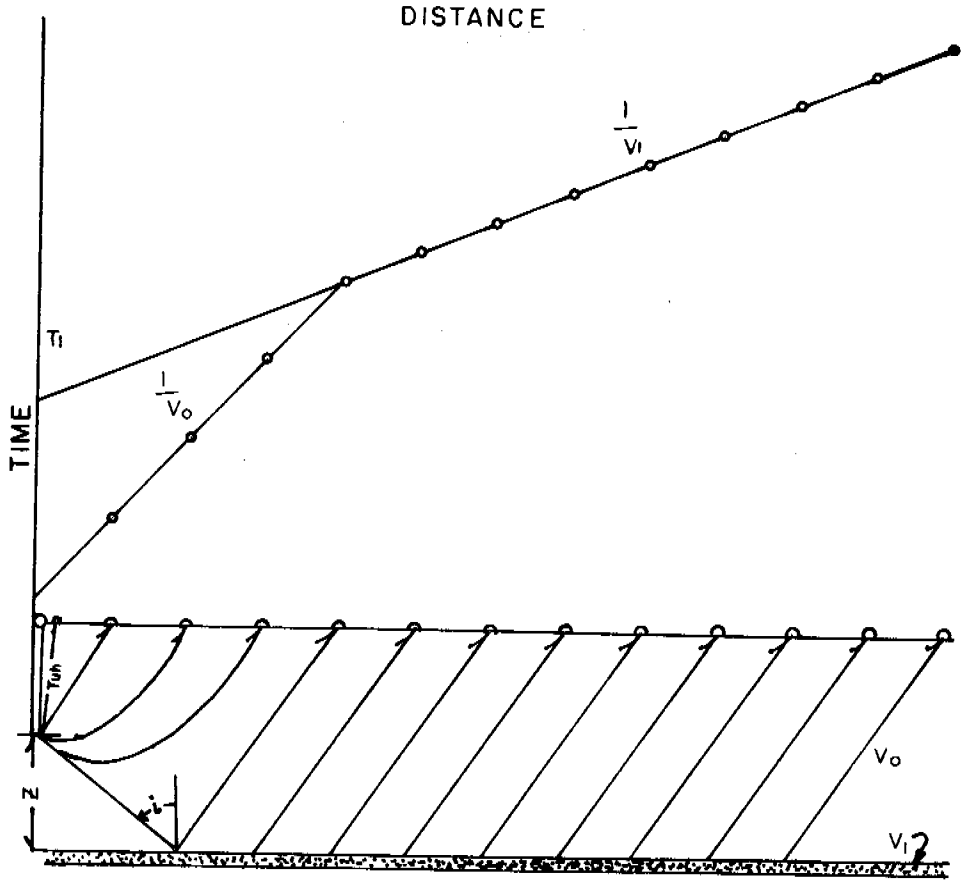
TYPICAL SPREAD

24 TRACES

12 SEIS. PER. TRACE

10' SEIS. SPACING

FIGURE 1



CALCULATION - WEATHERING THICKNESS

$$Z = \frac{(T_1 - T_{uh})\, V_0}{2 \cos i}$$

WHERE

Z = DEPTH OF BASE OF WEATHERING BELOW SHOT

T_1 = INTERCEPT TIME OF SLOPE $\frac{1}{V_1}$

V_0 = WEATHERING VELOCITY

V_1 = SUBWEATHERING VELOCITY

$\sin i = \frac{V_0}{V_1} \therefore \cos i = \frac{\sqrt{V_1^2 - V_0^2}}{V_1}$

T_{uh} = UPHOLE TIME OF SHOT

FIGURE 2.