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PHILIPPINES MARINE SEISMIC SURVEY PROJECT

CRUISE REPORT

by

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CRUISE REPORT

Division of Marine Geosciences & Petroleum Geology
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The Philippines Marine Seismic Survey Project is being conducted by the Bureau of Mineral Resources, Geology and Geophysics (BMR) for the Philippines Office of Energy Affaris (OEA) under funding from the Australian International Development Assistance Bureau (AIDAB).

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SUMMARY

During March to May 1992, the Australian Bureau of Mineral Resources (BMR) and the Philippine Office of Energy Affairs (OEA) conducted a joint marine seismic and sniffer survey in four Philippine offshore sedimentary basins. The project was funded by the Australian International Development Assistance Bureau (AIDAB), and the survey was conducted using the Australian government's geoscience research vessel *Rig Seismic*. A total of 2750 km of 192-channel seismic data, plus geochemical sniffer, gravity, magnetic and bathymetric data was obtained jointly. This comprised 580 km in the NE Palawan Shelf, 730 km over the Cuyo Platform, 490 km in Tayabas Bay, and 950 km in Ragay Gulf. Because of the extensive fishing activities at night time, particularly in Ragay Gulf, acquisition of seismic data after dark was abandoned in the latter part of the survey. During these hours the geochemical sniffer program was continued over identified anomalies, and an additional 900 km of sniffer, gravity and bathymetry data were recorded.

Although not a lot can be deduced before the seismic data are processed, the ship-board seismic monitors show plenty of structuring, and deep depocentres with up to 4 seconds of stratified section. Because the weather during the survey period was very calm and therefore conducive to the collecting of low-noise data, the quality of the processed sections is expected to be excellent.

Geochemical anomalies were recognised in the NE Palawan Shelf and in Ragay Gulf. These were particularly significant in Ragay Gulf and were related to: (1) previously identified prospects (ie R-1 and R-2 in the OEA-World Bank Report, and the Alibijaban prospect identified by Far East Resources); (2) faults; and (3) deep diapir structures. They fall into two distinct anomaly types: type 1 is characterised by high methane, ethane and propane with traces of butane and pentane, indicating dry to wet thermogenic gas; type two has high methane and traces of C_2+, indicating very dry gas.

In order to better understand the flux rate of hydrocarbon release and the component fractionation and magnitude of the source of the seep, Ragay Gulf was revisited after the seismic shooting was completed. Here, eight geochemical vertical profiles were recorded and 28 gas samples collected for isotope analysis. In one example, hydrocarbons were concentrated under the thermocline at about 140 m water depth.

The newly acquired data will be processed in BMR, integrated with existing seismic and well data from previous industry sources, interpreted and analysed for petroleum potential. The final analysis, together with basic data, will then be presented to the exploration industry, initially in the Philippines and Australia, and later internationally, in order to promote further exploration.

1. INTRODUCTION

This document describes the preliminary results of the marine data acquisition phase of a cooperative project to assist the Government of the Republic of the Philippines in undertaking technical and geoscientific programs to promote exploration for petroleum in offshore Philippine basins. The project is being jointly run by the Australian Bureau of Mineral Resources (BMR) and the Philippine Office of Energy Affairs (OEA), is funded by the Australian International Development Assistance Bureau (AIDAB), and has the following overall objectives :

- to upgrade the knowledge of petroleum prospectivity of selected areas in the Philippines and thus promote potential opportunities for future Philippines-Australia joint venture exploration; and

- to assist the Philippine Government in acquiring the skills to plan, obtain and interpret seismic data and other petroleum resource related information and use these to focus future petroleum exploration in Philippine waters.

The marine acquisition phase involved the collection of about 2750 km of modern multichannel seismic reflection data, plus hydrocarbon-detection data and other underway geophysical data, over two selected offshore areas in Philippine waters. Survey Area 1 consisted of the northeast Palawan Shelf and the Cuyo Platform, and survey Area 2 consisted of Tayabas Bay and Ragay Gulf. These data will be processed in Australia, integrated with existing exploration data from previous industry sources, interpreted and analysed for petroleum potential. The final analysis, together with the basic data, will then be presented to the exploration industry, initially in the Philippines and Australia, and later internationally, in order to promote further exploration. In this regard, a number of exploration companies, both in Australia and the Philippines, have registered an interest in this project. They will be entitled to first access to the data, and are termed 'Consultative Oil Companies'. The anticipated medium- to long-term result of the project is expected to be increased awareness by the international petroleum industry of the petroleum potential of the Philippines. In particular, it is hoped that Australian and Filipino exploration companies will enter one or more joint ventures to further explore the areas surveyed.

The project will provide the government of the Republic of the Philippines with independent assessments of petroleum resource potential and information necessary for the designing, awarding and management of exploration permits. The project will also provide OEA with an Australian designed computer-based mapping system to assist OEA's ongoing seismic mapping and database capability for the Philippine sedimentary basins.

The project has involved staff of OEA, some representatives from petroleum exploration companies in the Philippines, and BMR. The data collection was carried out using BMR's geoscientific research vessel *Rig Seismic*. Data processing will be carried out in BMR laboratories and computer centres in Canberra.

We draw extensively on the OEA-World Bank Report (1986) in the following discussion.

2. REGIONAL GEOLOGY AND TECTONICS

The Philippine Archipelago lies in an area of complex regional geology and tectonics (Fig. 1). It is located near the junction of three major tectonic plates: the Southeast Asia plate to the west, the Philippine Sea plate to the east and the Indo-Australia plate to the south. The Philippine Sea plate consists of Eocene oceanic crust, while the 2 other plates consist of units of oceanic crust, continental blocks, and magmatic arcs with associated basins and collisional melange.

The active archipelago zone is undergoing overall oblique compressive deformation between the Philippine Sea and Southeast Asia plates. In the central Philippines, the major shear component is taken up by the sinistral Philippine Fault system which dominates regional structures.

The convergence that has taken place between the Philippine Sea and Southeast Asia plates since early Cenozoic is substantial. This convergence resulted in the collision of several terranes - each with a unique stratigraphy and geologic history - which have been amalgamated into the main north-south archipelago. These terranes include a rifted continental block, metamorphic blocks, magmatic arcs, accretionary wedges and oceanic crusts.

Regional tectonics and the resultant structure have controlled the evolution of the Philippine sedimentary basins. Two distinct sedimentary domains have been identified: the Philippine Island Arc System, which hosts 11 major sedimentary basins, and the continental Kalayaan-Calamian Microplate, which hosts 2 sedimentary basins. Sedimentation in the Philippine Island Arc system began in the Cenozoic and is characterised by an abundance of sediments deposited in mostly forearc and backarc settings. In the Kalayaan-Calamian Microplate, a continental margin style of sedimentation commenced in the Mesozoic.

3. RANKING OF INDIVIDUAL BASINS

The 13 major Tertiary sedimentary basins have varying oil and/or gas potential, expected hydrocarbon types and exploration maturity. These can be categorized into 6 classes based on relative prospectivity (OEA-World Bank Report, 1986 and Fig. 2).

Class I basins are considered to have very good hydrocarbon potential. The Northwest Palawan Shelf alone qualifies under this category. It is regarded as a marginally explored basin which offers very good possibilities for future hydrocarbon finds.

Class II basins are rated as having fair to good potential for predominantly oil plays. The Southeast Luzon Basin, the Visayan Basin and the Sandakan Sub-

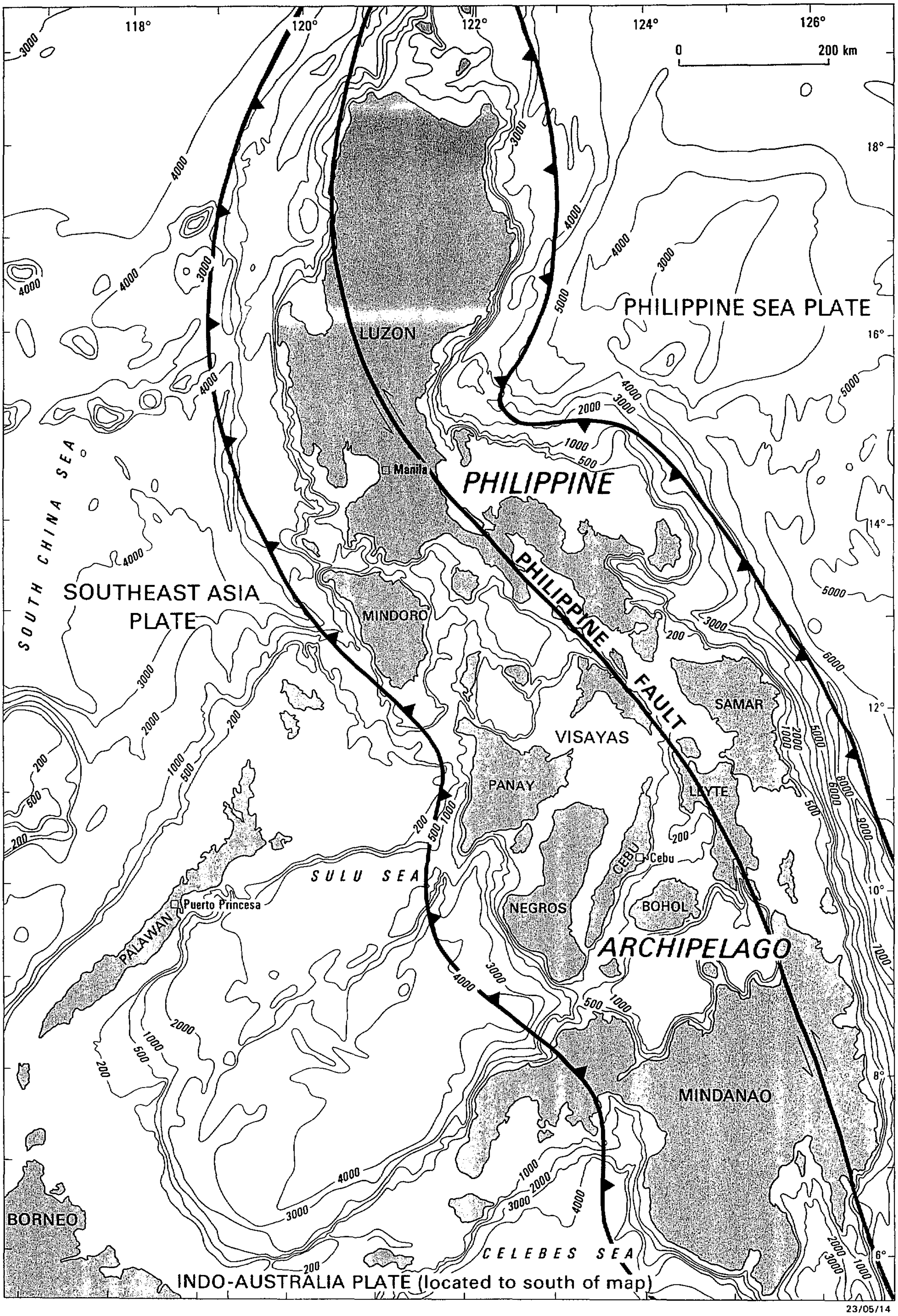

FIG. 1. Philippine Archipelago regional tectonic setting

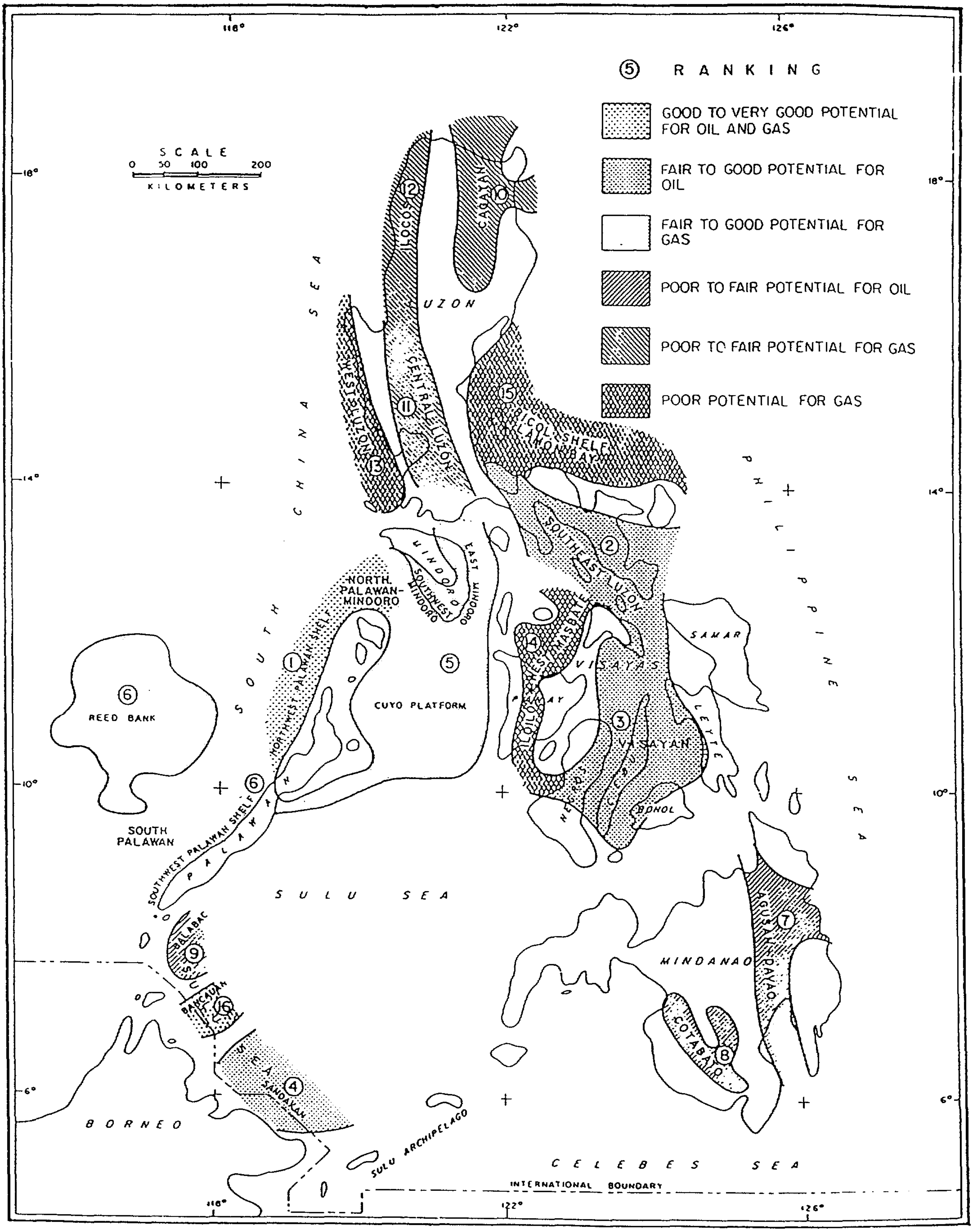

FIG. 2. Philippine sedimentary basins appraisal map

basin belong to this class. Southeast Luzon Basin and the Visayan Basin are given higher rankings due to their potential gas accumulations as well as oil. Southeast Luzon Basin, moreover, is a frontier basin with virtually no wells to test numerous play concepts.

Class III basins are rated as having fair to good potential for predominantly gas plays. The Mindoro-Cuyo region of North Palawan-Mindoro Basin and the South Palawan Basin fall under this group. The Mindoro-Cuyo region consisting of the East Mindoro Depression and Cuyo Platform is frontier, while the South Palawan Basin has been only marginally explored by drilling.

Class IV basins include those assessed with poor to fair oil potential. These consist of three frontier basins, namely: Agusan-Davao and Cotabato Basins, and Balabac Sub-basin. The Agusan-Davao Basin has gas potential while the Cotabato Basin has oil potential.

Class V basins are rated as having poor to fair potential for predominantly gas plays. Cagayan Basin, Central Luzon Basin and Ilocos Trough comprise this group. Cagayan Basin has minor oil potential in addition to its known gas finds. Central Luzon Basin has better parameters for petroleum accumulation, particularly gas.

Class VI basins are regarded as having poor potential for gas play. These include West Luzon Platform, Iloilo Basin/West Masbate Shelf, Bicol Shelf/Lamon Bay and Bancauan Sub-basin. The West Luzon Platform is more promising because of one deep sub-basin whose sedimentary provenance may have been the continental terrane of the Kalayaan-Calamian Microplate. Iloilo Basin/West Masbate Shelf have at least two deep depocentres which offer a number of drilling targets. The potential of Bicol Shelf/Lamon Bay area seems to hinge on the Paleogene plays only. The Bancauan Sub-basin is the least prospective because of its thin sedimentary fill (low thermal maturity).

4. HISTORY OF PETROLEUM EXPLORATION AND PRODUCTION

4.1 *EXPLORATION*

Petroleum exploration in the Philippines dates back to 1896 when the first well was drilled in Cebu, central Philippines. From the 1950s to 1970s, there was widespread exploration activity with 301 onshore wells and 4 offshore wells being drilled. Of these, 68% were drilled on the basis of surface mapping and/or oil seeps and the remainder based on some surface gravity and magnetic surveys or seismic surveys. 74% of the wells drilled were less than 1000 m deep and most in fact were virtually shallow stratigraphic test holes. The results, however, produced only sub-commercial quantities of hydrocarbons in two basins; gas in the Cagayan Basin, and oil and gas in Cebu and the Visayan Basin.

From 1949 to 1972 the legislation regulating petroleum exploration and development was the Republic Act No 387, known as the "Petroleum Act of 1949". This act granted petroleum concessions to qualified parties. In return the Philippine government was due to receive a royalty payment of 12.5% of the proceeds should there be commercial oil production.

The service contract system took effect in 1973 with the enactment of Presidential Decree No 87. This resulted in a big increase in offshore drilling. The majority of the wells drilled were located using seismic data, and drilling depths increased.

The shift of exploration interest to the offshore areas in the 1970s paved the way to several oil discoveries in offshore northwest Palawan. The first oil discovery, the Nido-1 well, was drilled in 1976 by a consortium led by Philippine Cities Service, Inc (PCSI) on a Lower Miocene reefal build-up. This turned out later to be non-commercial although it proved to be the impetus for renewed drilling activities in the country.

Subsequent drilling by PCSI along the same Lower Miocene reefal trend led to the discovery of the South and West Nido oilfields which were later jointly developed as the Nido Oil Complex. Amoco Philippines Inc also made a commercial discovery in northwest Palawan when it drilled the Cadlao-1 well in 1977. It tested oil from a similar Lower Miocene carbonate build-up and started production in 1979.

From 1978 to 1980, PCSI drilled additional wells in the Matinloc Complex in offshore northwest Palawan. The Complex proved to be commercially viable and started production in 1981. It consists of the Matinloc, Pandan and Libro fields.

In the Reed Bank area, Sampaguita-1 well, drilled by a Swedish consortium, yielded gas from Paleocene-Eocene sands. Significant oil and gas discoveries have also been found in deep water areas off Palawan. The Galoc-1 well, drilled by PCSI in 1981, flowed 35° API oil from Lower Miocene turbidite sands. The San Martin A-1X well, drilled by Phillips Petroleum, yielded substantial gas from a Lower Miocene reefal carbonate.

From 1983 to 1986, a major catalyst was the World Bank-financed Petroleum Exploration Promotion Project which produced a comprehensive 12-volume report on the petroleum potential of the country's 13 sedimentary basins. Included in the package are updated atlas-sized plates, figures, tables, a synopsis, and numerous enclosures. Figures and tables within the text show a variety of petroleum geological features including petrophysical characteristics, engineering data, lists and appraisals of all the wells drilled, diagrammatic cross-sections and detailed stratigraphic columns. Basins were individually assessed and ranked according to petroleum prospectivity.

Up to 1990, a total of 155 wells was drilled under the service contract system and more than 201,000 line-kms. of seismic data were also acquired.

4.2 *PRODUCTION*

In 1986, the Philippines had three oil fields producing from Lower Miocene reefal limestone reservoirs. There are now six declared fields. All are off NW Palawan.

The Nido Complex started production in 1979 from five wells in two fields. As of the end of 1986, cumulative production reached a total of 15.4 million barrels of 27° API crude. The Cadlao field was put on stream in 1981. The two producing wells had flowed 8.5 million barrels of 46° API oil at the end of 1986. Production in the Matinloc Complex started in 1982 from five wells in three separate reefal build-ups. At the end of 1986, total cumulative production amounted to 7.89 million barrels of 44° API oil. Cumulative production from the above three offshore complexes at the end of 1986 had reached 31.8 million barrels.

To date, only 6 fields are producing. A total of 39.6 million barrels of oil have been produced from 1979 to 1990 from these fields.

5. GEOLOGICAL SETTING OF THE SURVEY AREAS

5.1 *SURVEY AREA 1 - NE Palawan Shelf and Cuyo Platform*

Tectonics - The NE Palawan Shelf and Cuyo Platform are located in the offshore area northeast of the island of Palawan (Fig. 3). They are part of the Kalayaan-Calamian Microplate which rifted from the South China continental margin during Late Oligocene through Middle Miocene times (Hamilton, 1979). The area is considered to be a continental rift basin. The Late Mesozoic and Tertiary marine clastic/carbonate section has a thickness of over 10 km, of which the Tertiary fill probably accounts for as much as 4 to 5 km. Substantial amounts of quartz are present in the clastic intervals. Deformation is characterised by extensional block faulting and tilting except in the eastern and southern margins where compressional features dominate.

Stratigraphy - Sediments range in age from Late Paleozoic to Holocene with significant gaps in the Late Cretaceous, Paleocene, Oligocene and Middle Miocene (Fig 4).

Outcrops of Permian formations (Bacuit Fm. and Miniloc Ls.) occur in northern Palawan. These consist of cherts, limestones, conglomerates, sandstones and shales. Outcrops of Permian shallow marine limestones and clastics are also found on Carabao Island, south of Tablas Island (Fontaine, 1983). In the Cuyo Platform proper, the oldest outcrops are cherts occurring in the northernmost islands of the Cuyo Group (Alcala, 1987). These are very similar to cherts found in northern Palawan, which were dated by Hashimoto and Sato (1973) as Middle Triassic, based on conodont

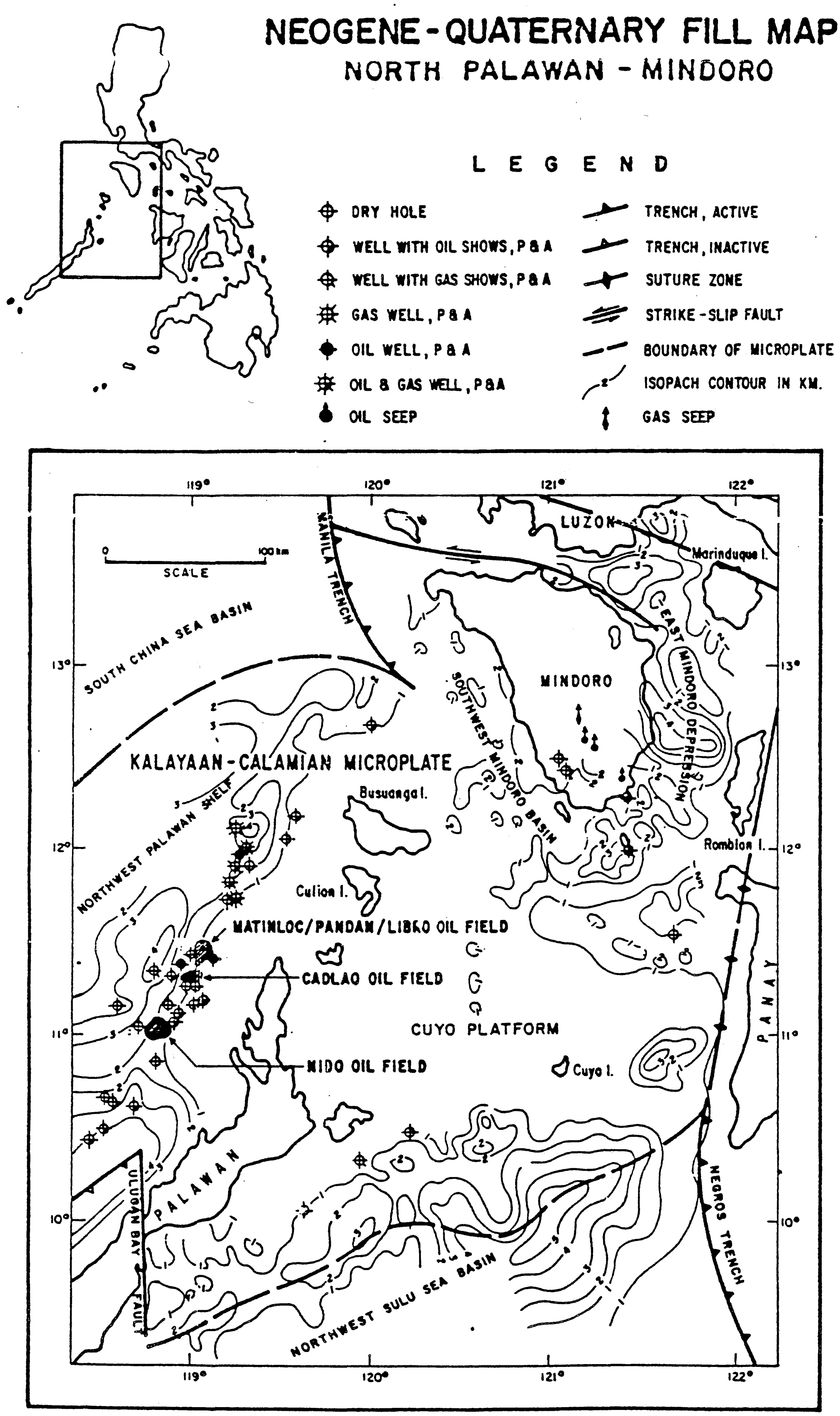

FIG. 3. Location map : NE Palawan shelf and Cuyo platform

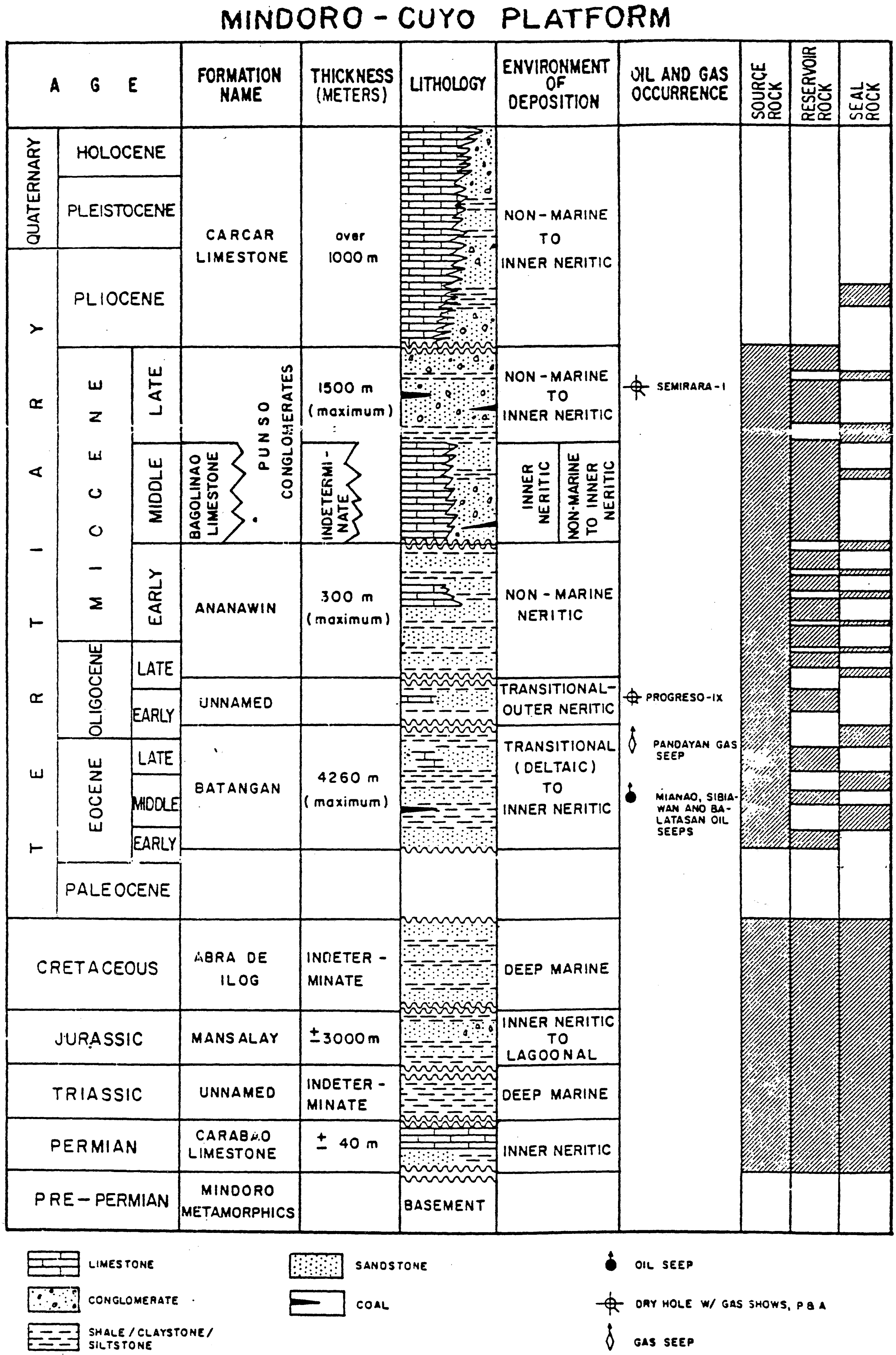

FIG. 4. Stratigraphy of NE Palawan shelf and Cuyo platform

fossils. Wolfart et al. (1984) confirmed the Middle Triassic age based on radiolarian fossils in chert collected from Busuanga Island.

The Jurassic outcrops on Mindoro consist of nonmarine to shallow marine quartzose sandstone, shale and conglomerate (Maasalay Fm.). The Cretaceous sediments, as exposed in North Palawan and Mindoro, are turbidite, chert, limestone with minor shale, quartzose sandstone, tuff and conglomerate deposited in nonmarine to bathyal environments.

The Palaeogene section consists of sandstone, shale, and limestone, with minor coal and quartzite. These were deposited in transitional to neritic environments.

Lower Miocene to Pliocene sediments consist of reefal limestone, and nonmarine to neritic conglomerate, quartzose and argillaceous sandstone with interbeds of siltstone, shale and microcrystalline limestone.

The Quaternary sediments encountered in wells are composed predominantly of coralline to biomicritic limestone with minor sandstone, siltstone and claystone.

Numerous small islands in the central part of the Cuyo Platform are covered with volcanic rocks such as basalt, andesite and pyroclastics which are believed to be Quaternary in age (Alcala, 1987).

Geophysics - The first seismic survey of the Cuyo Platform was conducted by Brascan in 1974. Subsequently, data were acquired by Multi-Natural, POGEI, and Seafront between 1976 to 1982. The most recent survey comprising several grids was conducted by Petro-Canada International Assistance Corporation in 1986.

A reconnaissance aeromagnetic survey (metastable helium magnetometer type) was flown across part of the Cuyo Platform/Palawan area in 1969. The results show high amplitude, steep-gradient anomalies elongated to the northeast, and the presence of two sets of lineaments trending northeast and northwest (Bosum et al., 1971).

Drilling - The only wells in the area are three drilled in the NE Palawan shelf by Cities Service from 1979 to 1981. The depths of these wells, namely: Roxas-1, Paly-1 and Dumaran-1, range from 2031 to 2187 m. Only Dumaran-1 bottomed in pre-Cretaceous ultramafic basement rocks.

The Roxas-1 well was intended to test a reefal buildup but found clastics underlying a major erosional unconformity (Fig. 5). No structural closure is apparent at this location; however, porous Middle Miocene sands were encountered from 823 to 1220 m.

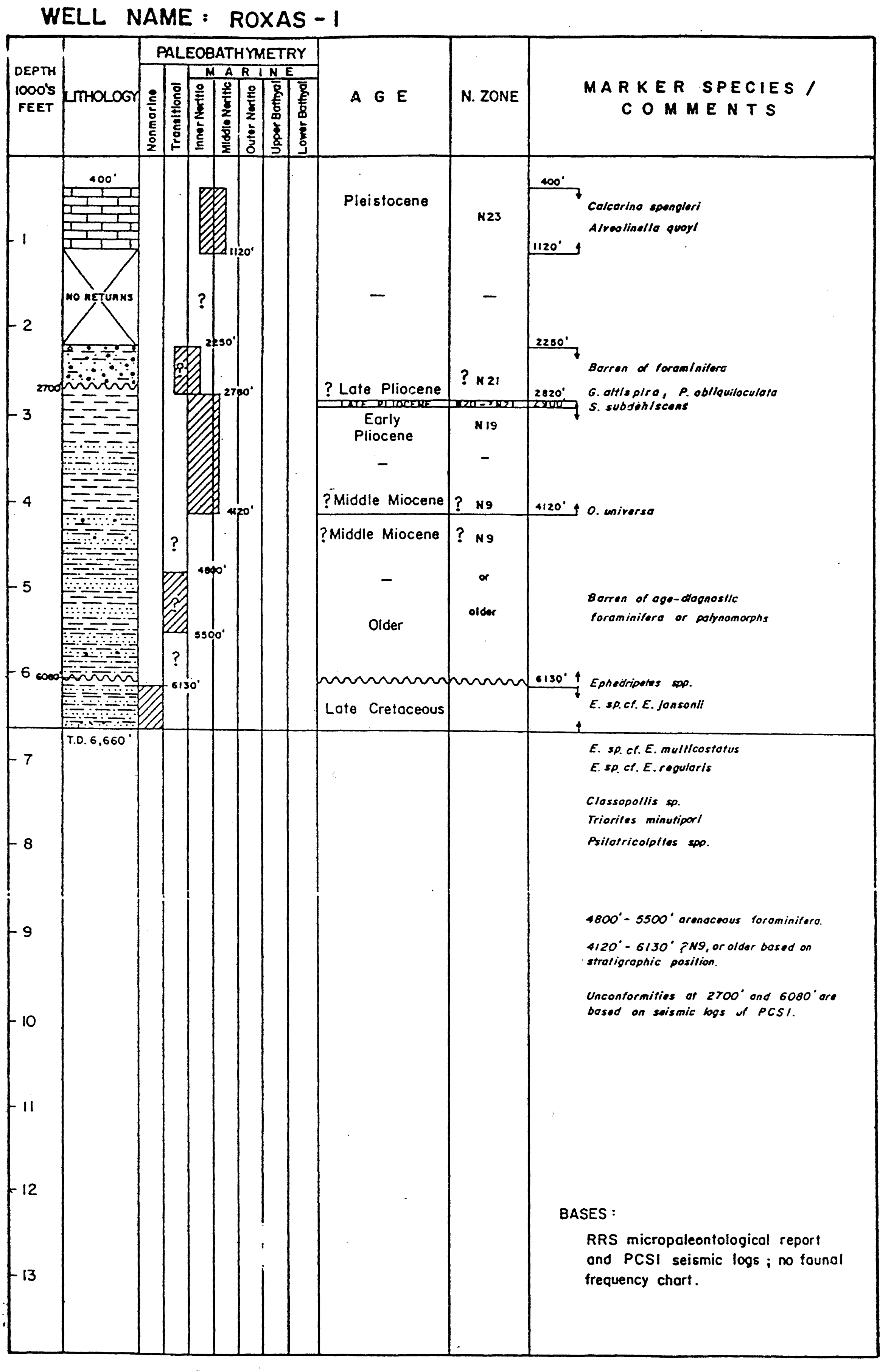

FIG. 5. Lithology of Roxas-1 well

The Dumaran-1 well targeted another possible carbonate buildup, but the seismic anomaly turned out to be a sandy conglomerate, from 1524 to 1829 m, having traces of dead oil (Fig. 6).

The Paly-1 well tested an unconformity trap formed by truncated southeast-dipping, presumed Upper Cretaceous sediments, but encountered poor reservoir rocks of undifferentiated Oligocene-Early Miocene age at T.D. (Fig. 7).

5.2 *SURVEY AREA 2 - Ragay Gulf and Tayabas Bay*

Tectonics - The Ragay Gulf and Tayabas Bay area contains narrow, northwest-trending horst and graben features. The basin fill is composed of Oligocene to Holocene clastics and carbonates of shallow to deep marine paleoenvironments. The deepest grabens contain up to 9 km of Tertiary sediments. Basin deformation is the combined result of extensional block faulting, differential uplift, and shearing along individual faults of the Philippine Fault System. Folds are small and mostly wrench-induced. These basins are considered to be backarc basins.

Stratigraphy - The Paleocene-Oligocene period is characterised by stable tectonic conditions wherein sedimentation occurred on a broad, shallow, basement floor. Transitional to shallow marine deposits typify this episode and are represented by coal measures, basal conglomerates and carbonates with occasional basalt flows and associated volcaniclastics (Fig. 8).

Tensional forces at the onset of the Oligocene initiated horst and graben features in the central part of the basin. From Late Oligocene to Early Miocene time, shallow marine conditions prevailed with the deposition of lagoonal to shelfal carbonates and their clastic equivalents. Towards the Middle Miocene, significant subsidence of the basin occurred. Turbidites were deposited within the graben while shelfal sandstones and shales accumulated along basin margins and over the submerged horst blocks. The Upper Oligocene-Middle Miocene sequence represents a major transgressive phase.

Wrench tectonism at the end of the Middle Miocene caused a short period of local uplift and erosion. From the late Miocene to Holocene, the ensuing sedimentation took place generally under transitional to shallow marine conditions. The sedimentary section is represented by a regressive sequence of conglomerates, sandstones, claystones and shelfal carbonates with reef development. Minor turbidite deposition in Late Miocene time occurred in the deep central portions of the basin.

Geophysics - Prior to the 1986 Petro-Canada International Assistance Corporation seismic survey, survey area 2 was covered by about 4000 km of seismic data recorded by several exploration companies since 1973. These data include a number of regional lines by Philips in 1979, SEDCO in 1980, and BED in 1983. The Petro-Canada survey recorded 975 km in Ragay

WELL NAME : DUMARAN - I

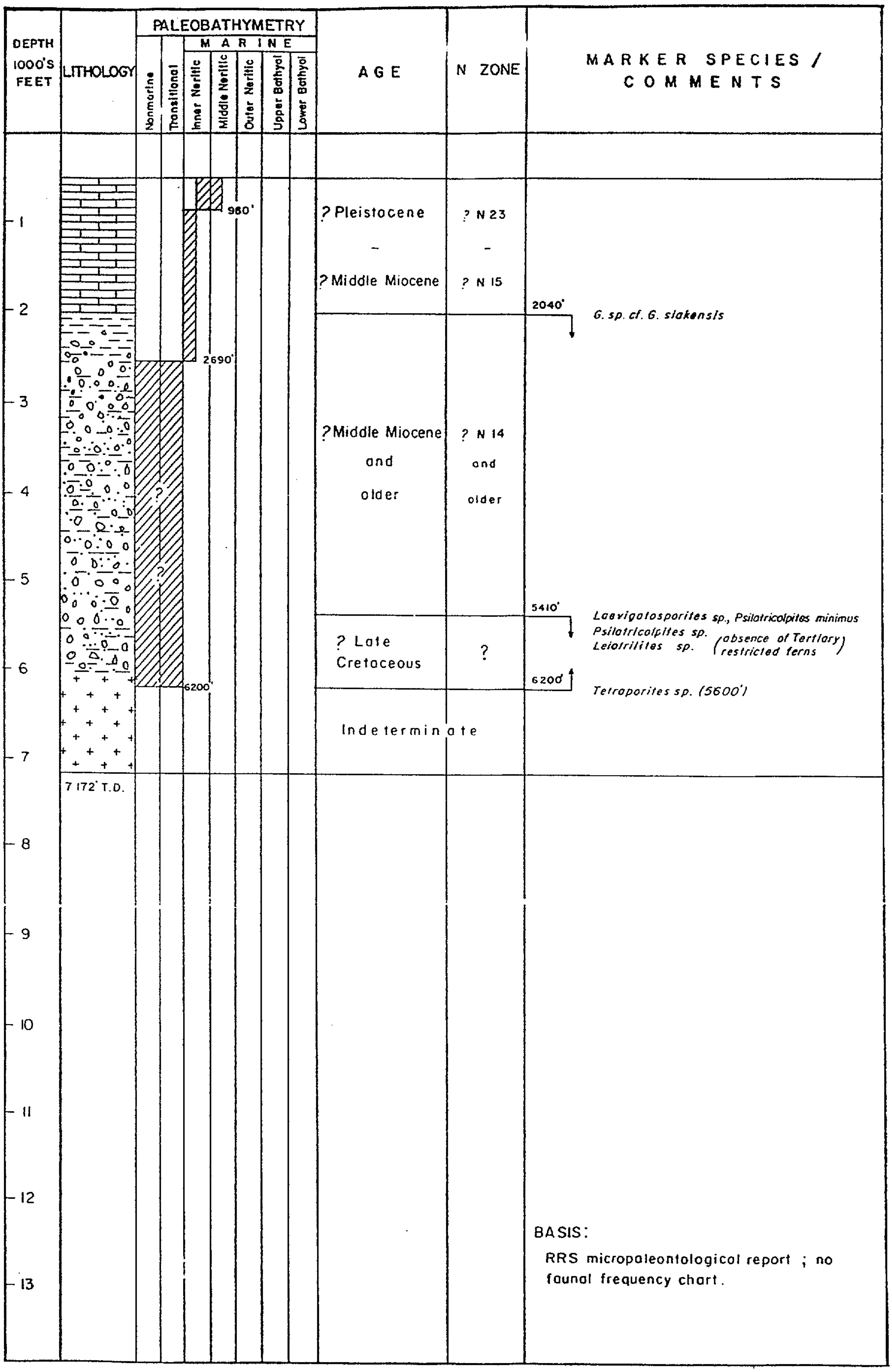

FIG. 6. Lithology of Dumaran-1 well

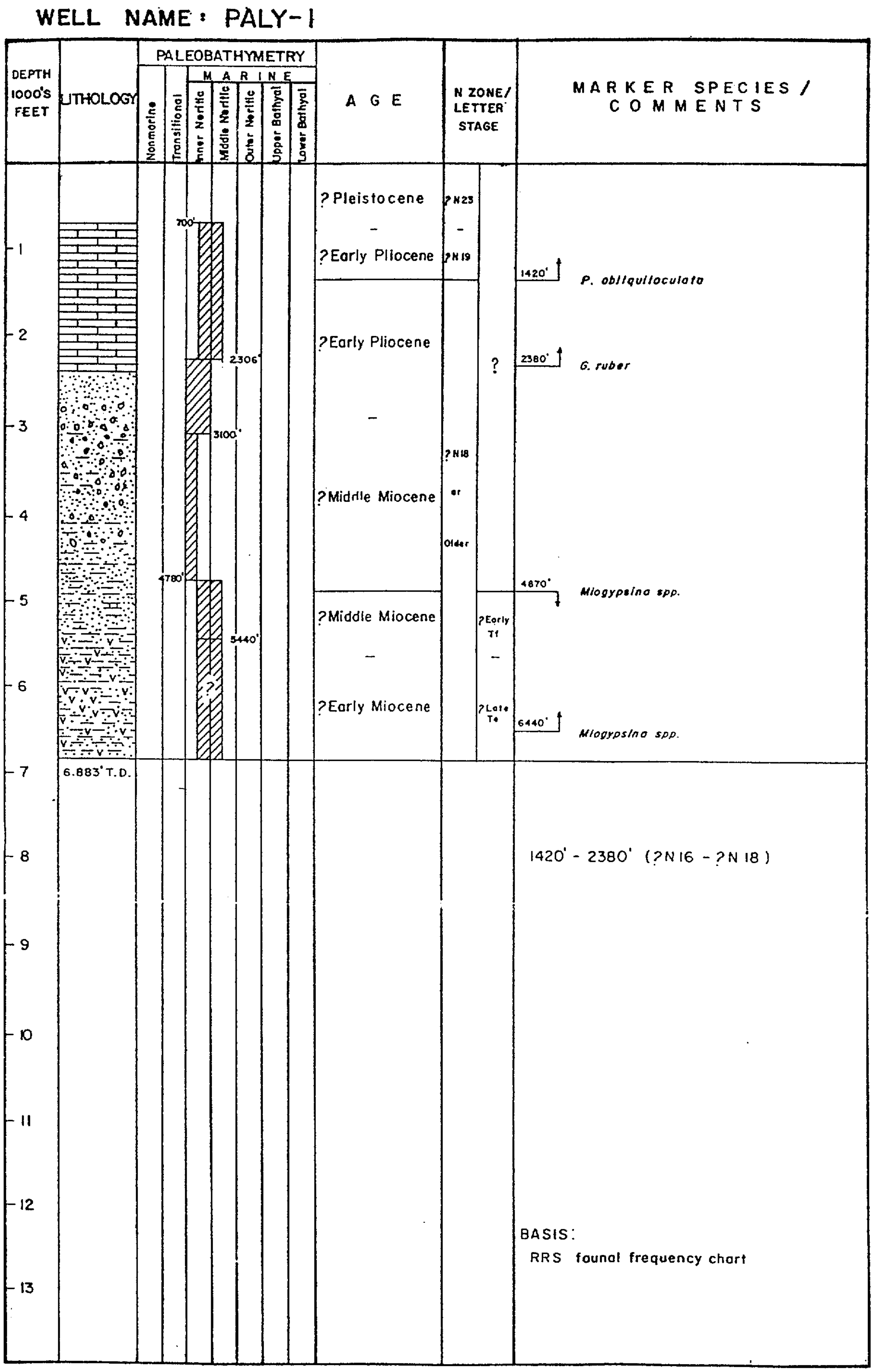

FIG. 7. Lithology of Paly-1 well

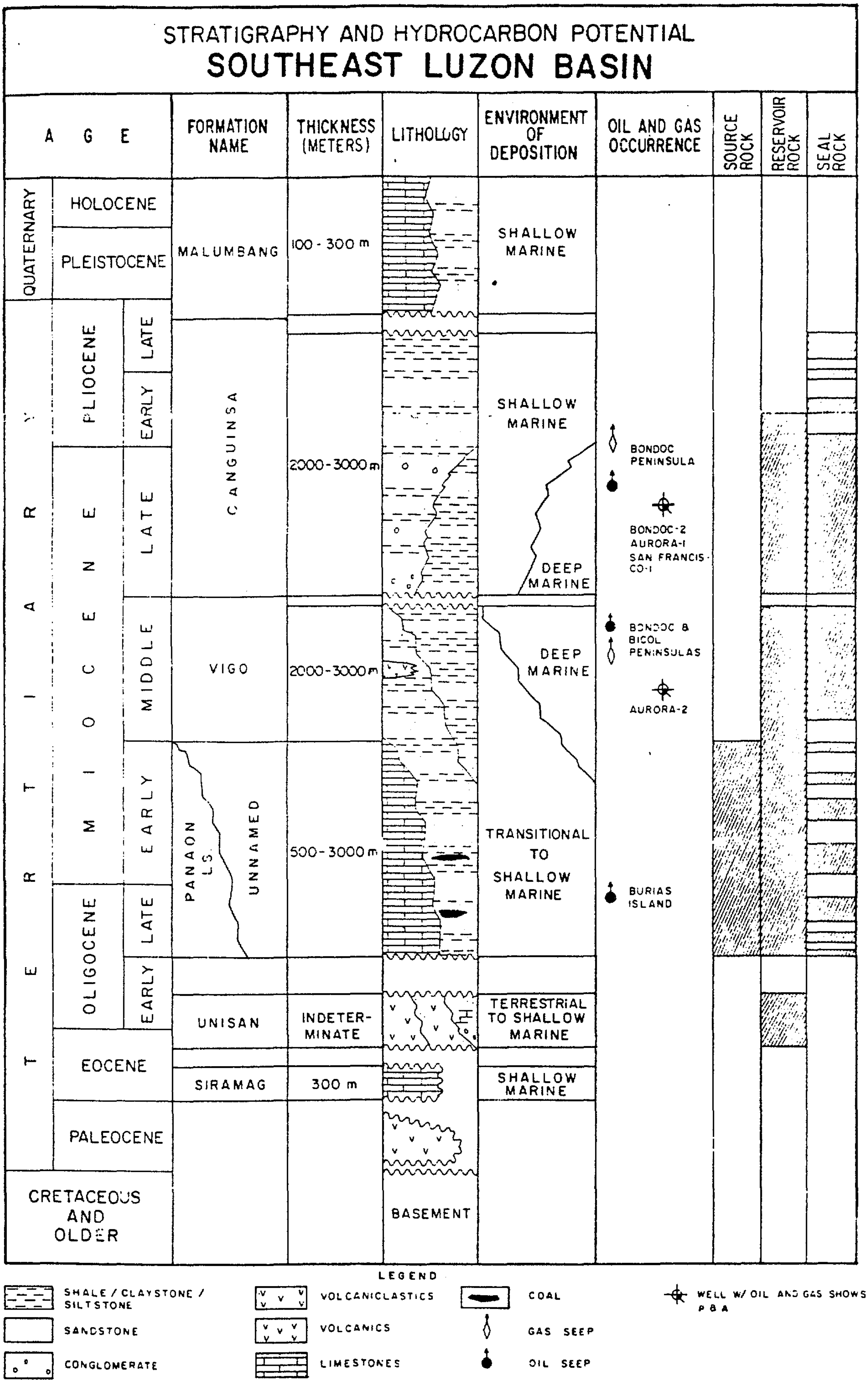

FIG. 8. Stratigraphy of Tayabas Bay and Ragay Gulf

Gulf. Overall, data quality is good, except in some structurally disturbed areas where reflections are obliterated.

Onshore seismic data are confined to the Bondoc Peninsula, but these are few, widely spaced, and were acquired before 1980.

Also as part of the OEA-World Bank petroleum exploration promotion project, a total of 10,500 km (2 km x 15 km detailed grid) of aeromagnetic data covering the Southeast Luzon Basin was acquired in 1983-1984. These data served to complement the seismic data in defining the regional structures and thickness of sediments throughout the basin.

Drilling - No wells have been drilled offshore. Onshore drilling in the Bondoc and Bicol Peninsulas started in 1906. Forty-seven wells have been drilled to depths ranging from 32 to 2100 m with 80% of the wells penetrating less than 1000 m. These shallow wells were drilled in the vicinity of oil seeps, based solely on surface geology or following up shows, and some had significant oil and gas shows.

Generation of hydrocarbons is indicated by small oil and gas flows and tar traces in 22 wells and numerous surface oil/gas seepages on the Bondoc and Bicol Peninsulas and one seep on Burias Island.

Prospects - 5 play types (A-1, R-1, R-2, B-1 and B-2) have been identified and include Oligocene/Miocene carbonate talus and reefal features, turbidity mounds, delta fans and shelfal sand (Figs 9-13). Stratigraphic, structural and combination trap types are all present. The untested offshore areas offer the most promising plays.

6. SURVEY OBJECTIVES

The main objective of the cruise was to acquire a minimum of 2500 km of high-quality multichannel seismic data concurrently with geochemical direct hydrocarbon detection (DHD) data, in two pre-selected areas in Philippine waters.

A secondary objective was to train four Filipino geoscientists in the techniques of data acquisition onboard a modern, multi-purpose research vessel.

Area 1 (NE Palawan and Cuyo Platform) is considered to be a frontier area, with a number of small, scattered data sets, but does have three wells. The objective of this part of the cruise was therefore to record essentially regional lines, forming a wide grid in their own right, but also linking the older data sets and the wells.

Area 2 (Tayabas Bay and Ragay Gulf) has been more thoroughly explored in the past, particularly Ragay Gulf. Our objective here was twofold: 1) to

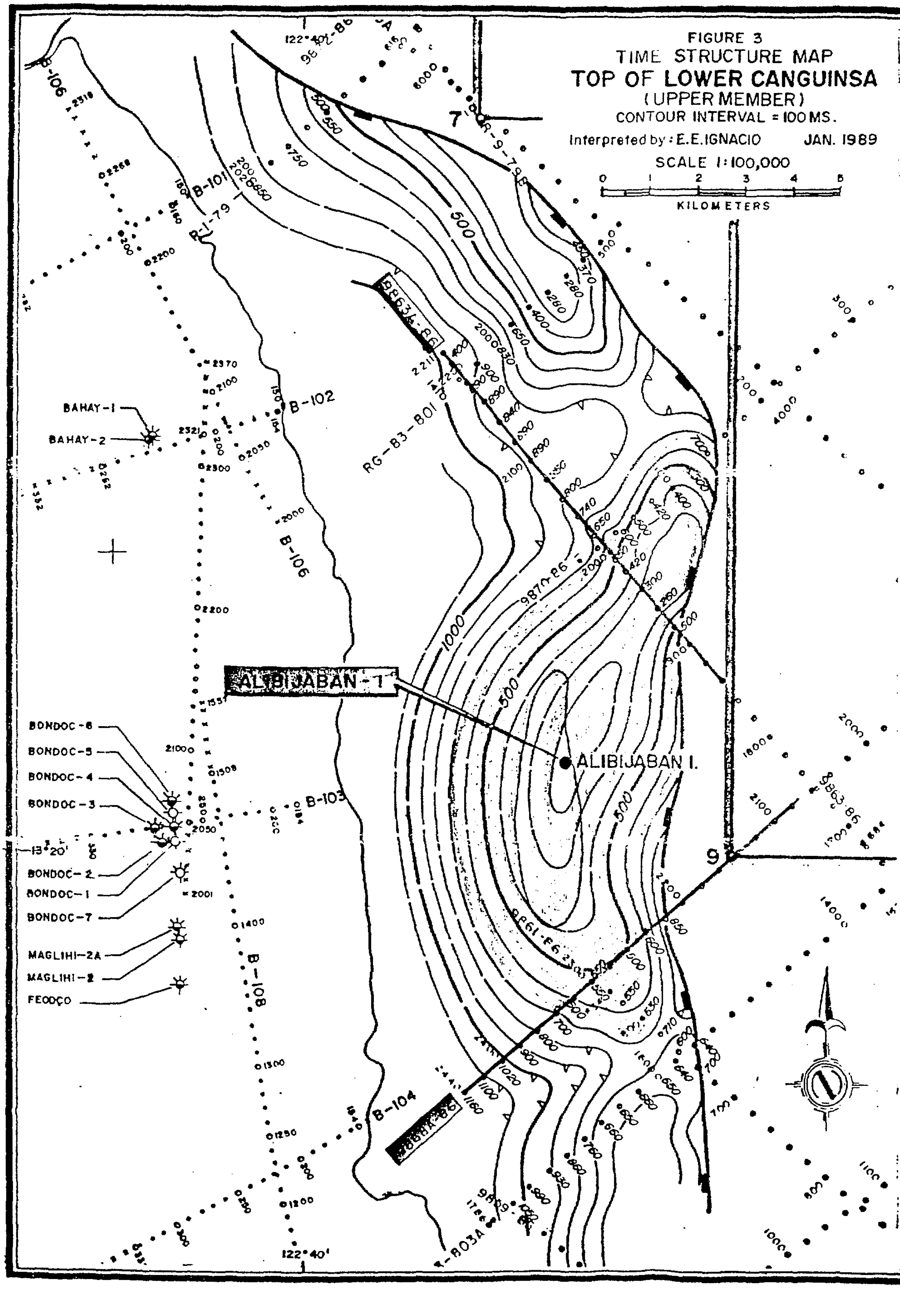

FIG. 9. Structure map of Alibijaban prospect (A-1)

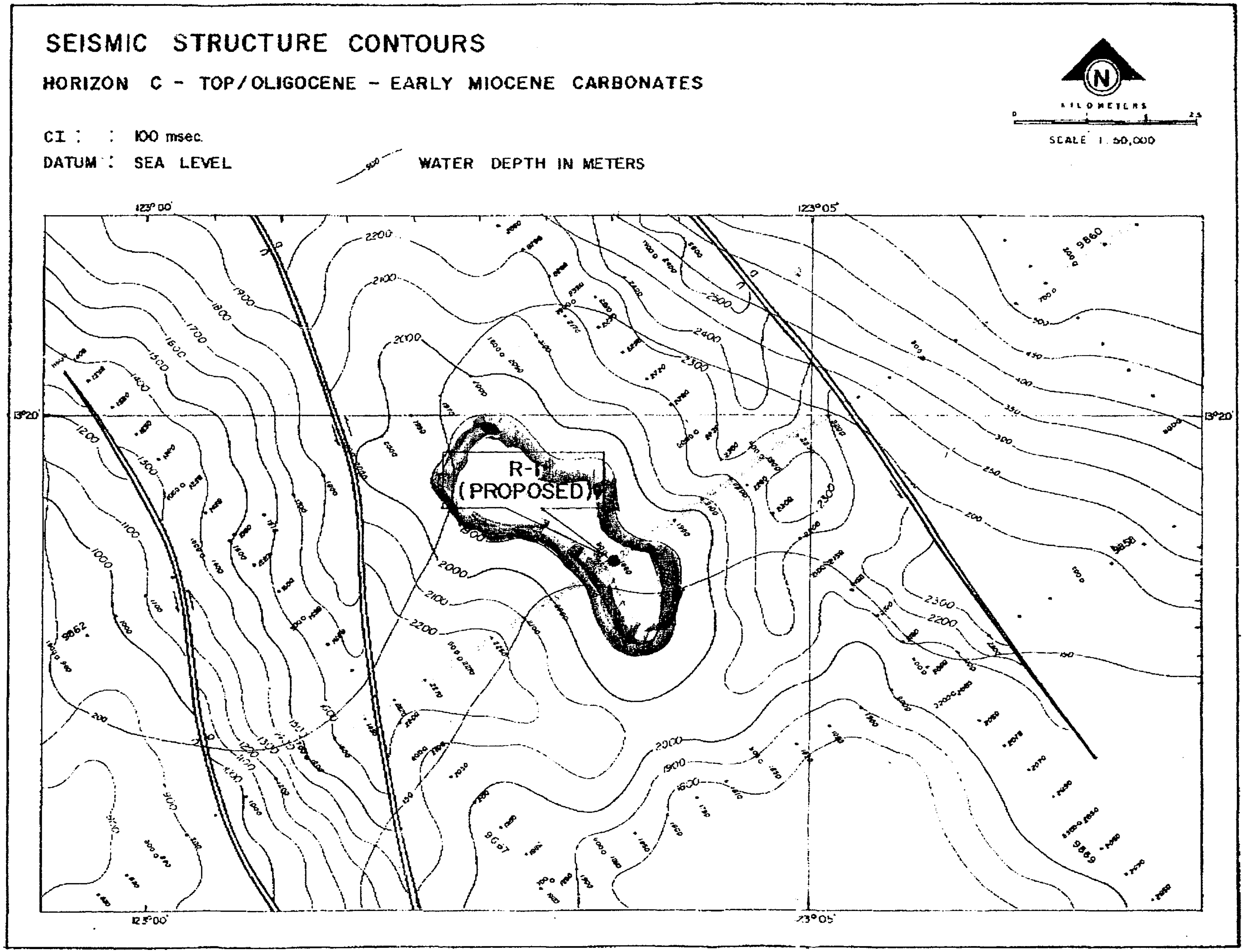

FIG. 10. Structure map of prospect R-1

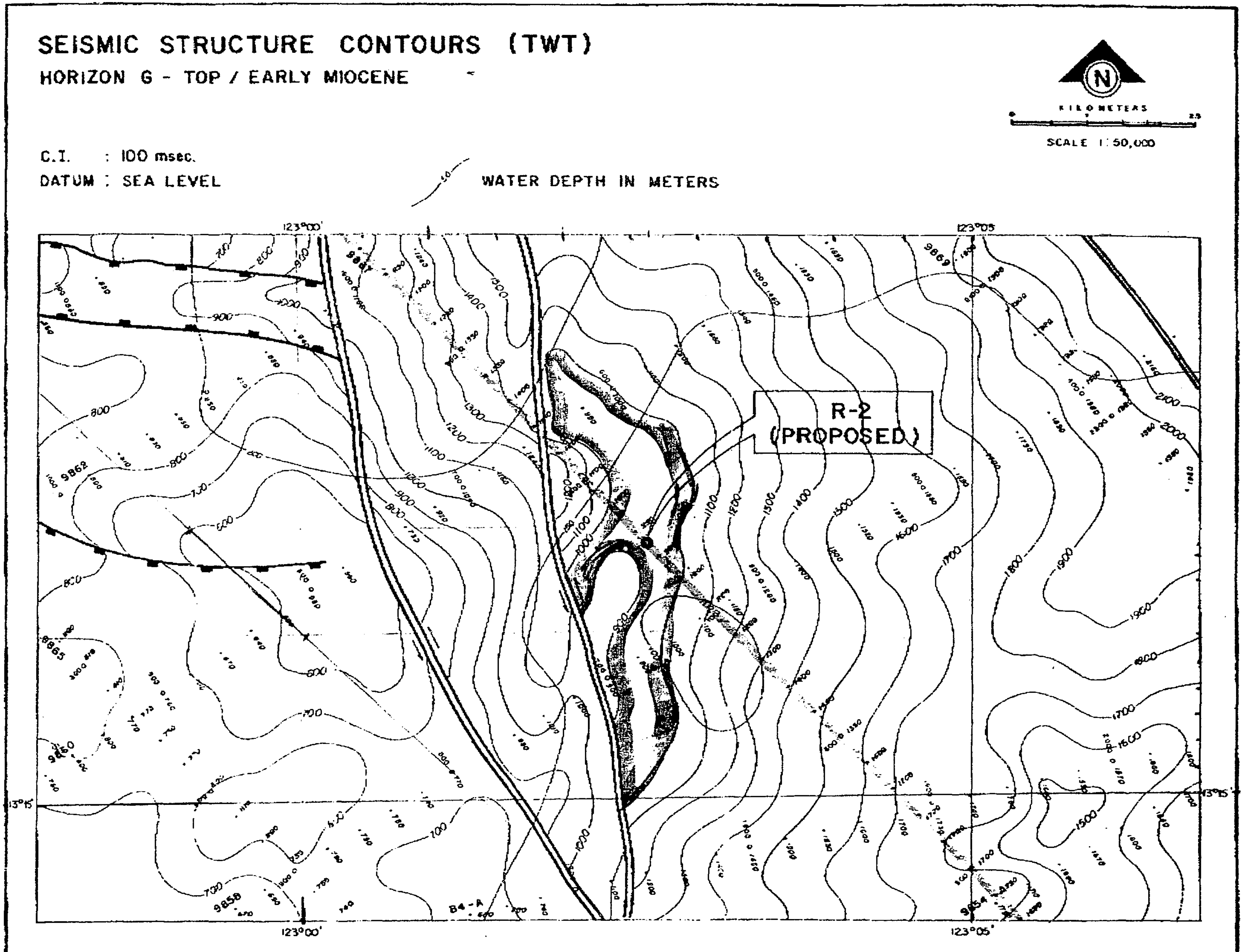

FIG. 11. Structure map of prospect R-2

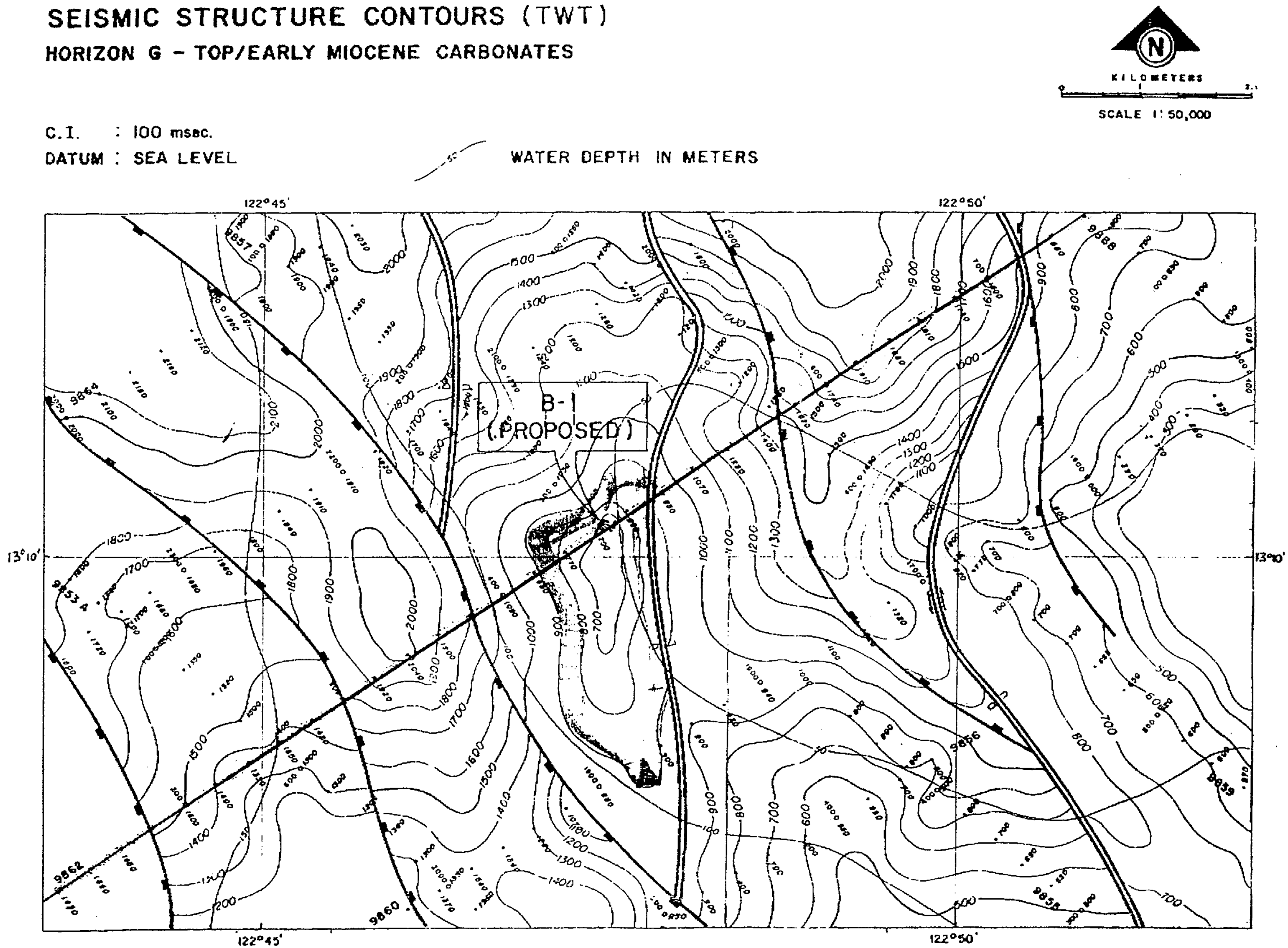

FIG. 12. Structure map of prospect B-1

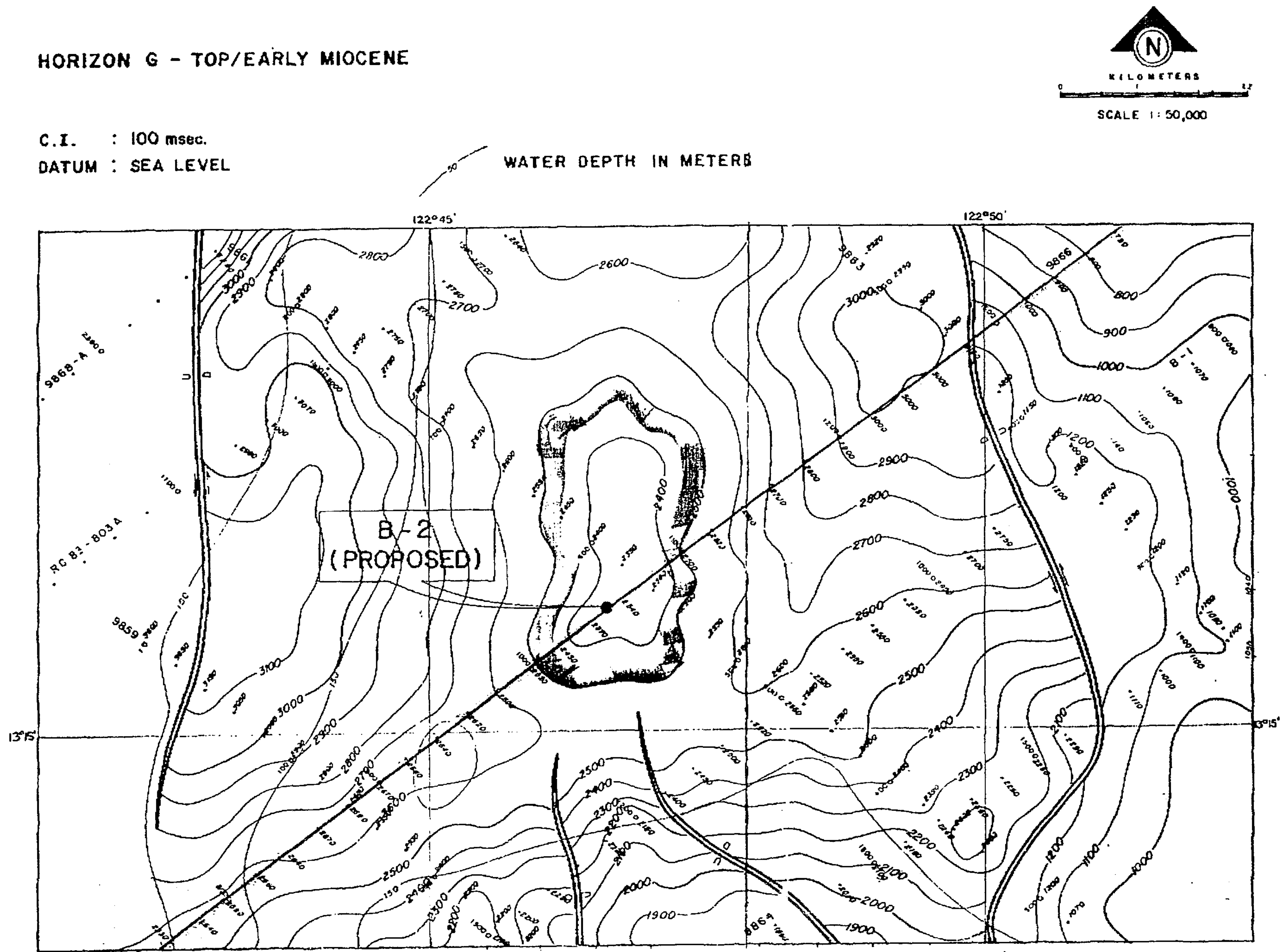

FIG. 13. Structure map of prospect B-2

complement the existing data set by recording additional lines, parallel to and between known lines; and 2) having interpreted the existing data, to record a new set of lines, at an angle of about 45° to the prevailing alignment. It was hoped that this data set might better define a particular suite of faults which is not aligned with the major fault set. Shortly before commencing the survey, we received advice from a number of the Australian consultative oil companies (see Appendix 1), recommending a change in emphasis towards more of the 'fill-in' lines, at the expense of the 'new orientation' lines. As a result, the ship track plan for Ragay Gulf was modified during the cruise to accommodate this request, but the overall objective remained the same.

7. ASSESSMENT OF CRUISE DATA

A total of 2750 km of 192-channel seismic, geochemical sniffer, gravity, magnetic and bathymetric data was obtained jointly. This consisted of 580 km in NE Palawan Shelf and 730 km over the Cuyo Platform; 490 km in Tayabas Bay and 950 km in Ragay Gulf. An additional 900 km of sniffer, gravity and bathymetry data were recorded during the hours of darkness, when it was considered too dangerous to attempt recording seismic data in 'virgin' country. Finally, eight DHD vertical profiles were carried out in the Ragay Gulf after completion of the seismic survey.

A realistic appraisal of the seismic data will necessarily have to await full processing, expected to be complete by March 1993, but the following general observations may be made. In parts of all four of the surveyed areas, the shipboard seismic monitors show many faults and folds, and deep depocentres with up to 4 seconds of stratified section. Because of the favourable weather conditions prevailing during the period of the survey, the processed sections are expected to be of excellent quality. In some cases, the on board monitors showed almost as much detail as copies of (admittedly old) stack sections from previous surveys. We believe this data set will aid significantly the understanding of the areas targetted.

The Ragay Gulf was the most interesting area from the geochemical viewpoint, because of the large number of anomalies detected, suggesting the possible presence of mature thermogenic hydrocarbons.

NE PALAWAN / CUYO PLATFORM

20 seismic and sniffer lines, consisting of 6 strike lines and 14 dip lines, were collected in this areas (Fig. 14). Line 1 ties with the location of Dumaran-1 well, and Line 2 with both Paly-1 and Roxas-1 wells. Line 12 also crosses the location of Roxas-1 well.

Preliminary seismic results from this area are encouraging. Dipping reflectors are evident in several places along the seismic lines across shelf

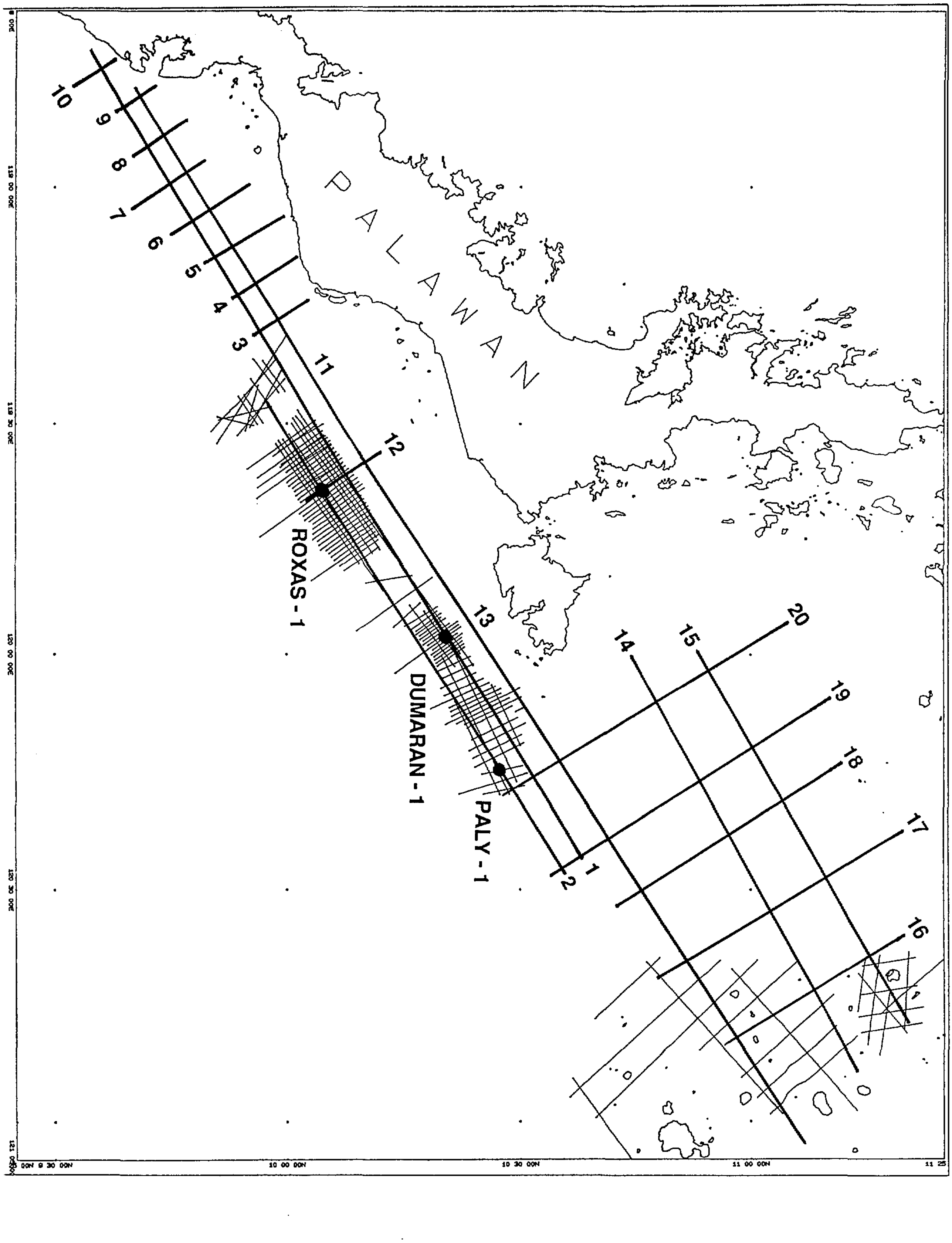

FIG. 14. Track map for Palawan/Cuyo area

platforms. Several platforms (eg Constancia Shoal, West Pasig Shoal, Panglimo Reef and Honda Bay) appear to be fault-related structures. A possible sedimentary depocentre with a northwesterly trend can be observed in the middle of the Cuyo Island Group. This widespread sedimentary basin appears to be associated with low amplitude magnetic anomalies (~ 50-100 nT).

A well defined area of high amplitude, steep-gradient magnetic anomalies is indicated between Dumaran and Cuyo islands. This is consistent with the results from an aeromagnetic survey by Bosum et al. (1971). The significance of this anomalous region is not immediately obvious, nor does it appear to correlate with any major changes visible on the shipboard seismic monitors. Several other localised magnetic anomalies, particularly in the Cuyo Island area, suggest the existence of shallow volcanic rocks at these locations.

Two small DHD sniffer anomalies were detected: one is located in the vicinity of Dumaran-1 well, and the other at the edge of Pasig Shoal. These anomalies are weak in THC/C_1/C_2 content (THC = total hydrocarbons). Careful examination will be needed.

TAYABAS BAY

16 lines were recorded in Tayabas Bay, roughly half north and south of Mompog Island, which lies between Marinduque Island and the mainland of Bondoc Peninsula (Fig. 15). There are no offshore wells in this area. We recorded no DHD anomalies.

Examination of the seismic monitors reveals a depocentre just SE of Mompog Island, with reflectors visible to 2 to 3 seconds. In contrast, the area north of Mompog (and north of Marinduque Island) is characterised by seismic records displaying only multiples, typical of a hard-bottomed carbonate platform. However, the magnetics in the same area show medium level anomalies, with one particularly high anomaly (approximately 650 nT peak-to-peak) just off the NW tip of Marinduque; this probably rules out a purely carbonate regime.

The southern area of Tayabas Bay, towards the tip of Bondoc Peninsula, appears to be a basement high, with no reflectors at all visible. This area correlates with an area of magnetic highs as described by Bischke et al. (1990).

RAGAY GULF

In this area, probably the most interesting immediately, we recorded 26 lines. Again there are no offshore wells here, but our lines tied with previously identified prospects: Alibijaban-1 (Far East Resources, 1989); B-1, B-2, R-1, R-2 (OEA-World Bank Report, 1986).

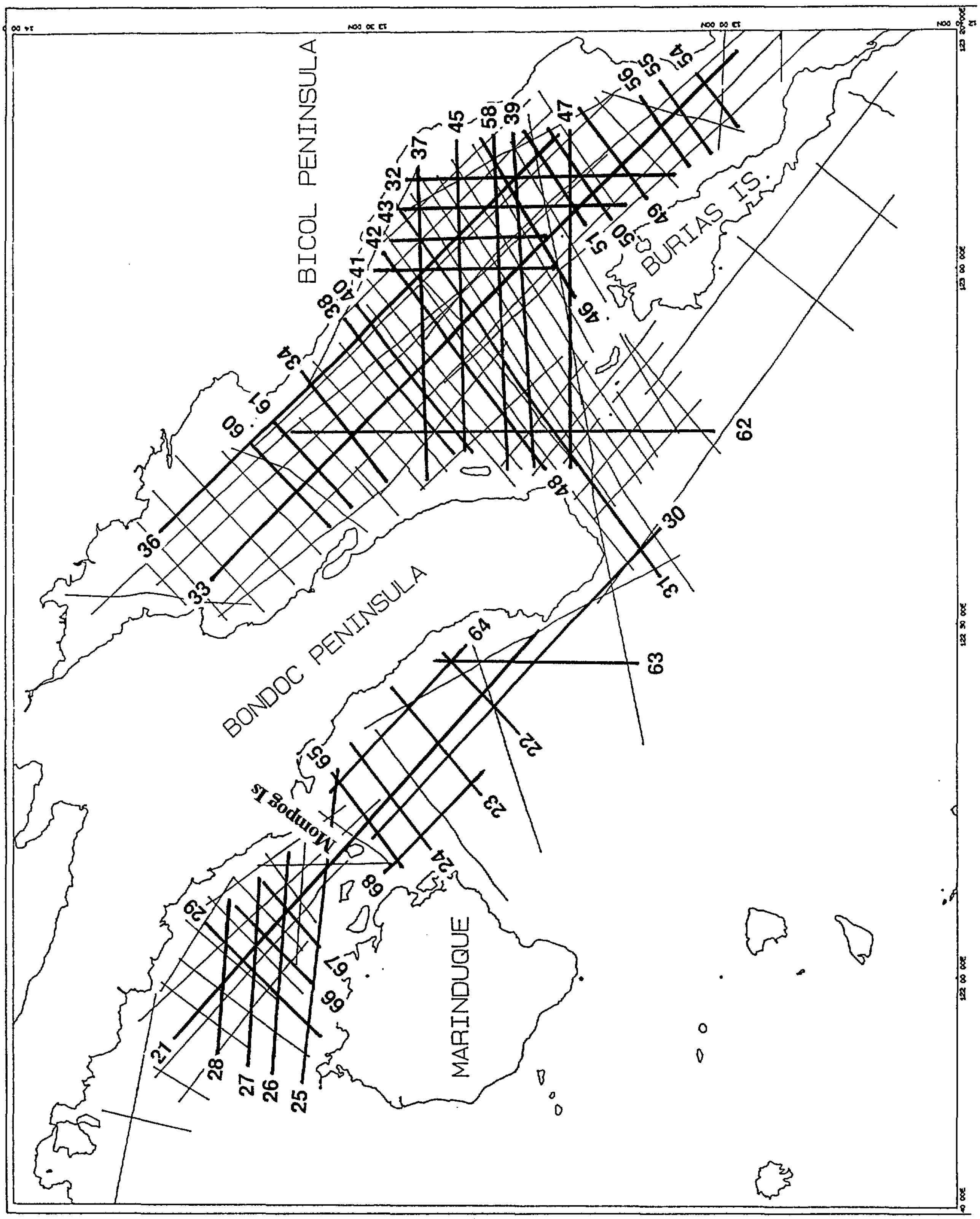

FIG. 15. Track map for Tayabas Bay/Ragay Gulf area

Numerous geochemical anomalies were recorded in this area, particularly around prospects R-1 and R-2. Other anomalies were associated with either faults or diapir structures, visible on our ship-board seismic monitors. All the anomalies recorded in Ragay Gulf fall into two distinct types: type 1 is a dry gas, very rich in methane, with only minor traces of ethane, and with wetness values less than 0.5%; type 2 is a wet gas, with methane, ethane and propane, plus traces of C_4 and C_5, and with wetness values of 1.0 to 1.5%. These two types are shown in Figure 16, which plots % wetness versus methane concentration for each anomalous value. A typical anomaly pattern giving values of THC and methane along a line in Ragay Gulf is shown in Figure 17.

A number of DHD vertical profiles were also recorded, to determine the vertical distribution of hydrocarbons emanating from an identified seep. Figure 18 is an example and shows in this case temperature and methane concentration versus depth. The highest values of methane are seen to lie just below a major change in water temperature, a thermocline at about 140 m water depth. Further analysis of these data should enable us to better understand the flux rate of hydrocarbon release, the fractionation of the components, and the magnitude of the seep source.

Magnetic anomalies are visible off the northern tip of Burias Island, extending to the northwest, and most likely correlate with the main Philippines fault system shown in Figure 1. Particularly clear anomalies are shown on Line 31. A very high magnetic gradient was observed along the most northerly of the short dip lines, with high values at the NE and low values at the SW end.

A distinct gravity anomaly was observed over the deep-water section of the gulf. We need to examine this to ascertain whether this difference can be attributed to the water depth alone and whether diapir structures, known to exist in the deep-water graben (OEA-World Bank Report, 1986), have any expression in the gravity profile.

8. CRUISE NARRATIVE

Wednesday , 25 March, 1992
Fly Manila to Puerto Princesa, arriving at 0700 local time. Jeepney ride to *Rig Seismic* which is tied up alongside the wharf. A day for planning and organizing the work to be done before we set sail. Start on extensive pre-survey testing and aligning of the seismic acquisition system. All but 5 guns have to be dismantled to install volume reduction kits. Five Filipino scientists are given a run-down on the safety requirements and features of *Rig Seismic.*

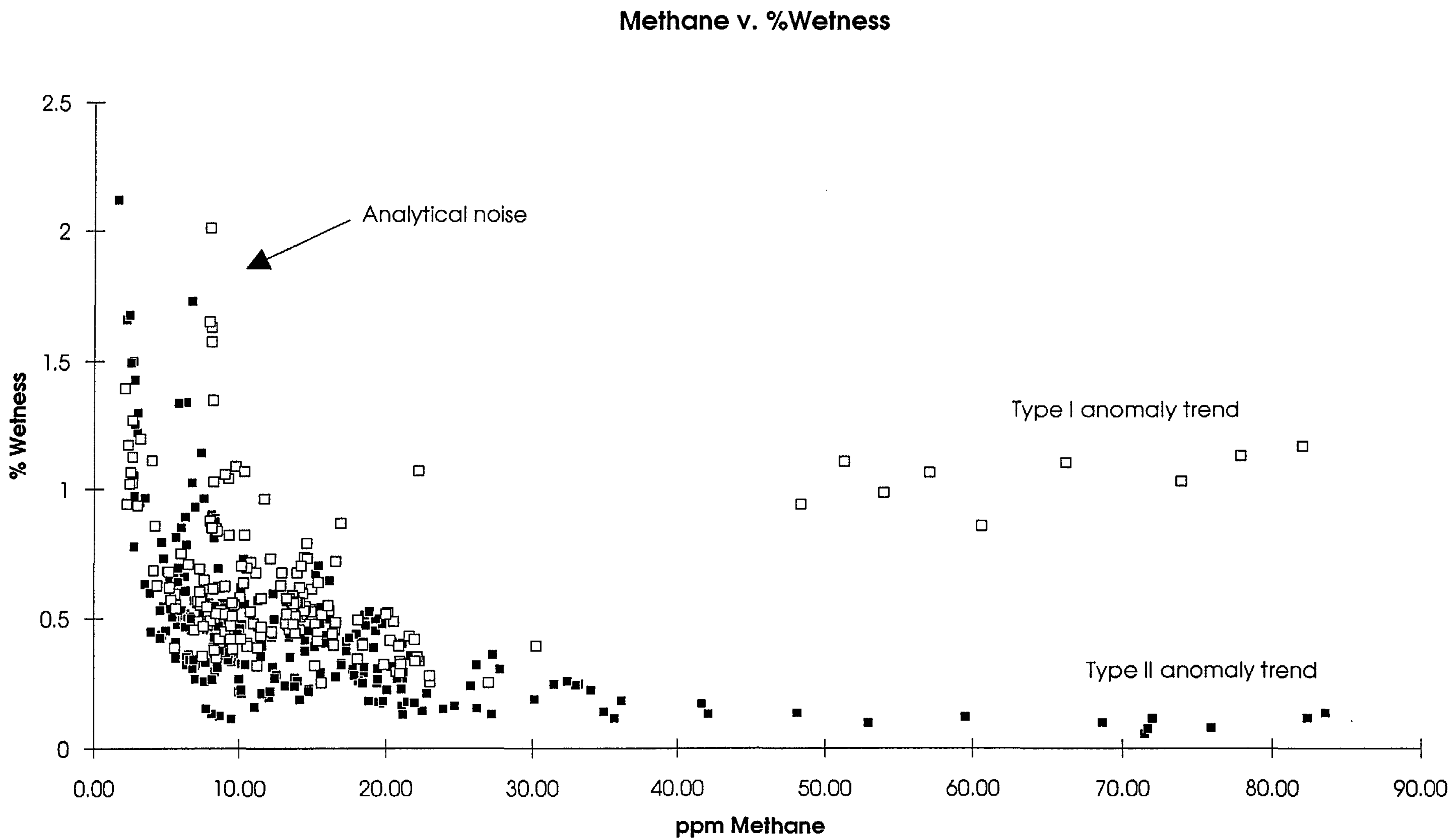

FIG. 16. Methane concentration versus % wetness

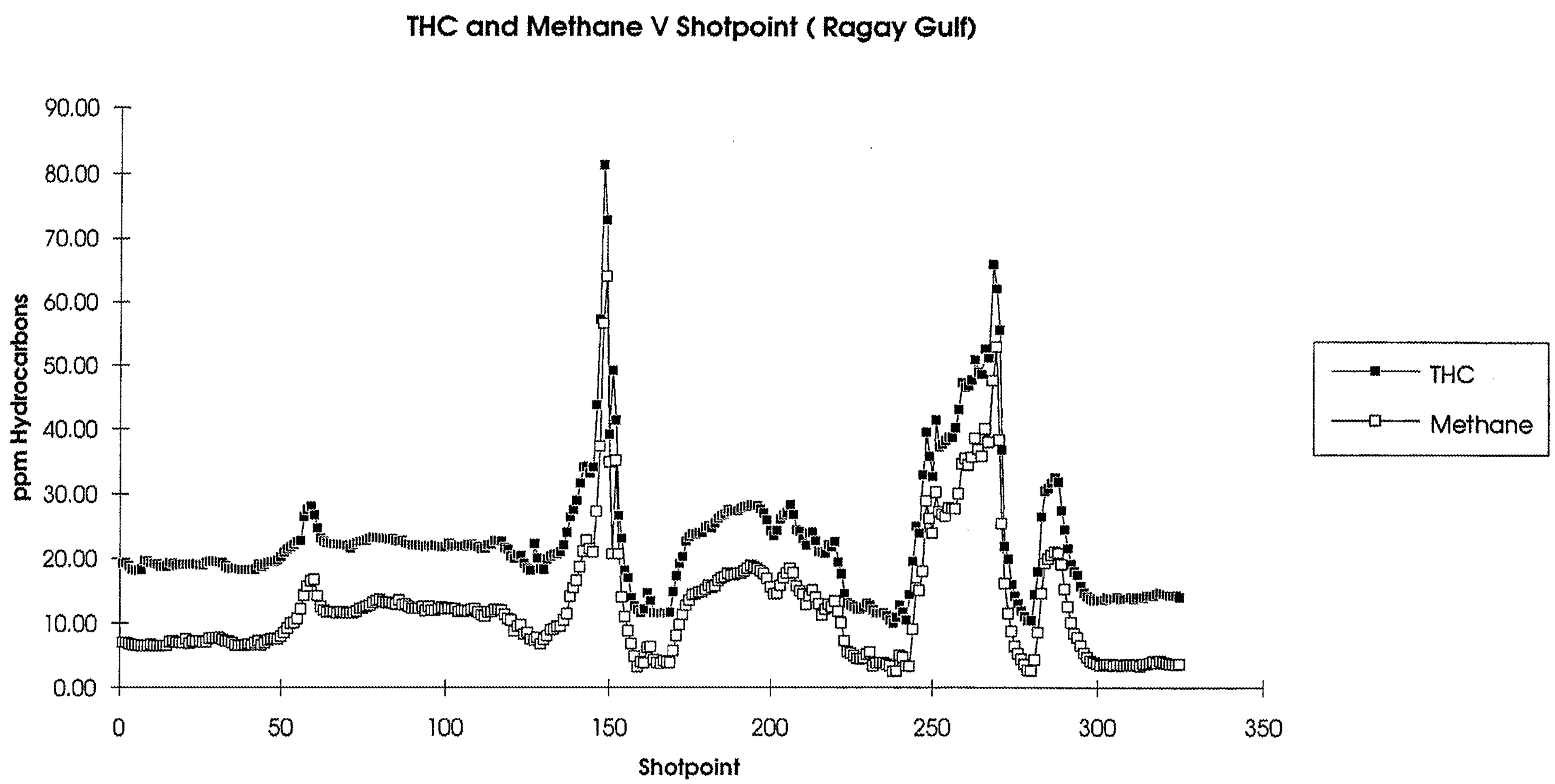

FIG. 17. THC and methane concentrations versus shotpoint

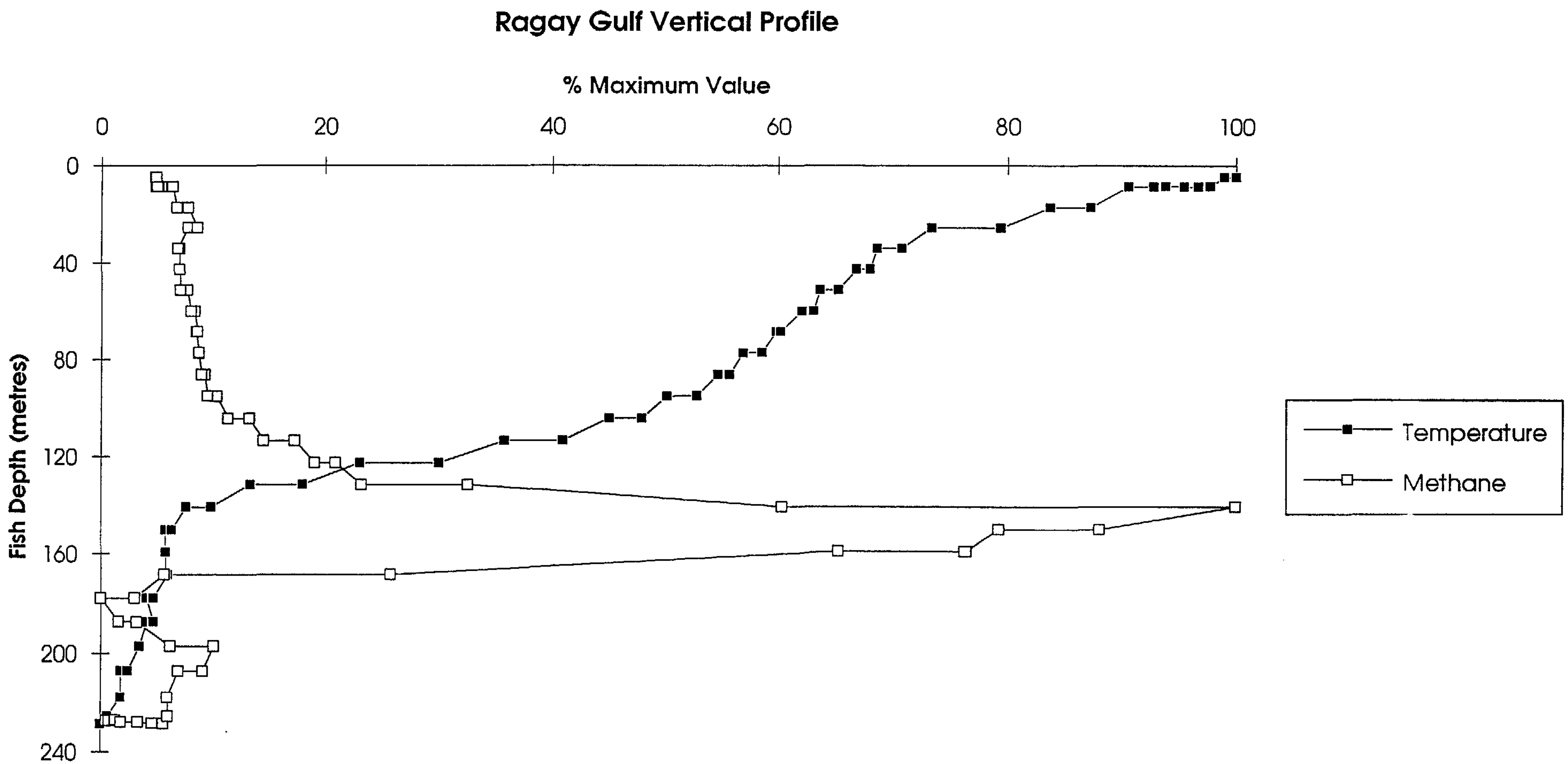

FIG. 18. Methane concentration and temperature versus depth

Thursday, 26 March
Continue working on guns, seismic system and geochemistry fish. Magnavox MX-100 GPS receivers are fitted to bridge of *Rig Seismic*, and to *African Queen*, our chase boat. Do gravity tie between ship and an old station located at Puerto Princesa airport. Ambassador's party starts about 1100. The Ambassador, Mr. Mack Williams, and the Philippine Presidential Advisor on Energy, Attorney de la Paz, address the party. More than 30 Filipino guests and Australian Embassy staff attend and tour the ship. Last guests leave about 1430, and depart wharf at 1500. Hold safety meeting shortly after sailing, then anchor offshore to continue working.

Friday, 27 March
Conduct tests with *African Queen* to formalize communication procedures, and to check that both boats can navigate along the same line. Commence deploying the seismic streamer cable at 1300 to check buoyancy and noise characteristics. During this procedure, the tailbuoy contacts a fish lure, apparently anchored in about 2000 m water depth. Have to partially reel in cable again and send rubber boat back with divers to disentangle tailbuoy from the lure. There seems not to be any damage, so continue deploying the cable.

Saturday, 28 March
Tests show that the cable is heavy, despite being positively buoyant on East Arafura cruise where the water was the same temperature (probably the water is less salty and hence less dense in the Philippines). Decide to remove 6 cable levelers (birds) to return the cable to the same specs as used on Arafura. In doing this, find that original bird #12, at 2200 m from the front of the cable, has a bent wing, presumably as a result of the collision with the fish lure. Also conduct noise tests, to correlate noisy channels with known wrinkles in the cable skin. Cable still appears to be heavy, but seems to depend on direction of vessel, and possibly also affected by shape of sea-bed. Decide to try ultimate test of buoyancy: slow ship down to almost a halt, and cable slowly sinks! Begin to change out identified noisy sections. Work still progressing on gun rebuilding, and seismic system calibration.

Sunday, 29 March
Continue changing out noisy sections with replacements which have been refurbished at our cable workshop in Canberra. Stream cable to check on noise and buoyancy conditions: looks better.

Monday, 30 March
Change out last 2 noisy sections identified for replacement, and stream cable again to do noise and buoyancy tests. Buoyancy looks good; all but last three birds (now have 13 birds fitted to cable; one every 200 m) indicate that the cable is positively buoyant. Also have completed work on guns, and fire some test shots to check on polarity of channels etc; this also looks good. Pull in cable for final time, to add 10 L of cable oil to each of last 5 active sections plus tail stretch section, to improve the buoyancy at the end of the cable. Final tests look OK.

Tuesday, 31 March
Commence recording on line 1 at 0200. After about 2 hours, a seal on the starboard Christmas tree fails, drastically reducing air pressure, so we have to do our first loop. Restart line at 0730 and continue without incident. Magnetometer and gravity meter working well; geochemistry has one gas chromatograph down, but system still functional. This line ties Dumaran-1 well.

Wednesday, 1 April
First real signs of fishing activity: pass more than 40 boats fishing off Dumaran Island during the night. End long line 1 at 0600. Both gun arrays and compressors need plenty of maintenance, so cannot start line 2 till 1400. Then continue without problems. Line 2 ties Paly-1 and Roxas-1 wells.

Thursday, 2 April
End line 2 at 0500 on northern edge of Constancia Shoal, then loop around reef to start short, 8 nautical mile, line 3 at 0930. Finish line 3 at 1130, and transit to start line 4 at 1530. So far, the weather has been perfect for seismic recording; very flat seas and little wind.

Friday, 3 April
Continue recording short dip lines. No problems with any of the systems.

Saturday, 4 April
Finish last of short dip lines (line 10) at 0730. Short transit to start of another long strike line, L11, at 0815. Because of the intense fishing activity encountered on line 1, decide not to pass Dumaran Island at night-time, so stop L11 and start a cross-line, L12, at 2300. Line 12 also ties with Roxas-1 well.

Sunday, 5 April
Recommence long strike line, now called L13, at 0430, and continue to the NE.

Monday, 6 April
End L13 at 0130, then manoeuvre around some fishing boats and islands to start 60 nm L14 at 0500. Fax in from Chief of Division regarding desires of some project related commercial companies to alter the orientation of some of the survey lines in Tayabas Bay and Ragay Gulf. C-S Lee phones OEA in Manila to alert them to this possible change in plans. End L14 at 1700.

Tuesday, 7 April
End L15 at 0730 - last of the strike lines on the Cuyo Platform. Bird #13 has a flat battery, so change bird using rubber boat. Start line 16, first of 5 dip lines, at 1300. Seismic channel 87 has become low amplitude, but no cause is apparent; probably just a resistive connection somewhere along the line.

Wednesday, 8 April
Sea a bit choppy in the morning, but flattens out in the afternoon. End L17 at 0530 and start L18 at 0930. End L18 at 1630. Slight scare in the morning when a leak develops in the ship's main engine cooling water pipe. If this gets worse, will have to stop the ship which means retrieving the cable. Luckily, the engineers manage to patch up the problem. Still trying to repair some of the seismic amplifier cards, as we have no useable spares. Start L19 at 2200.

Thursday, 9 April
Have to do another loop when one bank of amplifiers drops out and cannot be resuscitated in time. Finally end line 19 at 0815. *African Queen* leaves us to go to Mabini to re-fuel and re-provision. During transit to start of line 20, the ship's auto-pilot gives up the ghost, so the ship has to be steered manually. Decide that *Rig Seismic* also will go to Mabini for 24 hours in order to (a) consult with OEA personnel on proposed changes to line orientation, and (b) disembark Dan Carlos, a visiting Filipino scientist from Basic Petroleum, and embark Ian Hawkshaw, AIDAB representative who will be with us for about two weeks to assess our quality control on seismic data. Start L20 at 1130. The geochemistry fish, Wanda, has a major collision with a small reef judging by the assorted coral debris inside the body when brought on deck for repairs.

Friday, 10 April
Another loop when the last bank of amplifiers fails again. End L20, last line in the Palawan/Cuyo area, at 0015. Retrieve cable by 0430, and start transit to Mabini. Have now completed 1310 km of seismic data in 10 days of shooting time. Repairs to Wanda, and to the seismic amplifiers.

Saturday, 11 April
Dock at Mabini at 0800. Ian Hawkshaw arrives with three scientists from OEA, to discuss final siting of lines in Tayabas Bay and Ragay Gulf. Dan Carlos gets off to return home. Ian is shown safety aspects of *Rig Seismic* by our Safety Officer.

Sunday, 12 April
Depart Mabini at 0800 and transit to northern end of Tayabas Bay. Start deploying cable at 1400, and commence L21 at 1900. Several fish lures evident in this area.

Monday, 13 April
Slight shower of rain early in morning - the first (and only) rain we see. End L21 at 0430 without incident, although many fish lures apparent at this southern end of line. Start L22, first of a series of short dip lines, at 0800; finish this line at 1030. Decide to send *African Queen* ahead to scout lines 24 and 25, which we will be recording after dark. Meanwhile, we proceed with L23 alone, after changing batteries on one tailbuoy light, and adding another independent light to the tailbuoy, using the rubber boat. Start L24 at 1900, and finish without incident at 2115. Could not start proposed line 25

because of presence of fishing boats around start of line, so have to start another line, running north of Marinduque Island (L25), at midnight.

Tuesday, 14 April
End L25 at 0600 and discover fault in noise test at end of line. Take some time to deduce that fault is in one amplifier card only, and was not faulty during recording of line. Start L26 at 1000, and end L28 at 0015. Finally decide to curtail night shooting after some close encounters with fishing boats off the north coast of Marinduque Island the previous night.

Wednesday, 15 April
After end of L28, transit back out to deep water along safe line 27, to arrive at start of next line at day-break. Start L29 at 0600, just after first light. End L29 at 0850, and in turning around to go to next line, **ship hits an uncharted (and unseen) reef** at 0855. Miraculously, all gear retrieved safely by 1045. Because of ingress of water into the ASDIC room, and the fear that it might spread to the Instrument Room, all power here is switched off. Main device affected by this is the gravity meter, which will lose continuity. With the aid of *African Queen*, *Rig Seismic* is manoeuvred off the reef to anchor in deep(er) water by 1300. More inspections by divers confirm that damage is relatively slight: most of through-the-hull transducers have been removed or at least damaged, plus some damage to propeller and rudder. Then arrange to travel back to Mabini to have ship inspected by a DNV surveyor, to see if we can continue the survey.

Thursday, 16 April
Dock at Mabini at 1000. Talk more with BMR in Canberra. All clear is given, and we depart Mabini at 1800. Transit back towards survey area.

Friday, 17 April
Start deploying cable at first light, about 0500. After accident, now intend to record lines in Ragay Gulf, since they are probably of most interest, and then if time permits, come back and complete lines in Tayabas Bay. Conduct noise tests with cable to see if any effect from damaged propeller. No overall change in character of ship noise, but more noisy channels especially at front of cable, caused by extra wrinkles in the skin which were evident when the cable was retrieved under low tension following the grounding. Cable still within specifications, so start L30 at 1030. L30 is a tie line, to tie the Tayabas Bay lines to the forthcoming Ragay Gulf lines. No extra fish lures observed south of the ones plotted while recording L21. Finish line without incident at 1745. Turn back up parallel course for safety during darkness.

Saturday, 18 April
Start L31 at 0430, just before daylight. Come across a flurry of small boats at about 0600 (as they cease fishing and go home for the day), then all clear. Finish L31 at 1220. Complete L32 in daylight, then run down to the south after dark.

Sunday, 19 April
Partially retrieve cable to investigate malfunctioning #3 bird. It appears to be OK, but find that #1 stretch section has a pin-hole puncture, so it is changed out. Eventually start L33 at 0430, about 6.5 nm beyond the intended start of line. Stop recording on L33 at 1300 to repair guns and to replace tailbuoy light (again). Start cross-line (L34) at 1630 and complete it at 1900. Then go sniffing during the night.

Monday, 20 April
Start L35 (continuation of long L33) at 0430, and finish at 0800. Start at northern end of line 36 at 0945. Have to deviate off line because of veritable forest of fish traps and lures in mouth of Caima Bay. End L36 at 1900, about 3 miles short, because of the large number of fishing boats present around the proposed end of line. At night, collect sniffer data on a half mile grid around prospects R-1 and R-2; find a number of good anomalies.

Tuesday, 21 April
Start L37 at 0600. Gun mechanic Brian Dickinson injures a thumb while removing a broken crankshaft from a compressor. After having the wound stabilized by the ship's medical officer, Brian is sent ashore on the *African Queen* to have it treated properly by a doctor in Pasacao, the nearest settlement. End L37 at 1115. On transit to next line, yet again put two more lights on the tailbuoy. Start L38 at 1400, and end at 1700. On this line, pass through a reasonable sized fleet of trawlers, which (luckily) are anchored for the day. Brian back on board at end of line. Try some sniffing in the north end of Ragay Gulf during the night, but too many fishing boats, so return again to R-1/R-2 area to do another tight grid.

Wednesday, 22 April
Start L39 at 0700, after dodging many fishermen. Have to do a loop because of a tape change problem, and finish line at 1500. Decide that Brian should be repatriated to Australia for safety reasons; main risk is the possibility of infection in the damaged thumb. Start L40 at 1600, and complete without incident at 1930.

Thursday, 23 April
Start L41 at 0600. *African Queen* alongside at 0630, and Ian Hawkshaw and Brian Dickinson off to disembark at Pasacao and then travel on to Manila. *African Queen* will also re-fuel. End L43 at 1730, close to the north east coast of Burias Island. Just after end of line, a huge flotilla of fishermen 'surround' Rig Seismic, and happily proceed to deploy nets, lines etc. Miraculously, the cable and tailbuoy avoid hitting anything or anybody. The night-time occupation of sniffing is resumed as usual.

Friday, 24 April
Start L44 at 0530 - too early, as lots of fishing boats with nets still about, so miss first 3 miles. End L44 at 1030 and start L45 at 1245. Because GPS satellite #11 is unserviceable, navigation is substandard for about two hours. Then discover that because of a fault which occurred late on Thursday, we

have not been recording navigational data to tape. Whole of L44 and beginning of L45 will have to be re-recorded. End L45 at 1730. There appear to be more fishing boats out at night as the moon wanes.

Saturday, 25 April
Start L46 at 0600. Have to abandon line 2 miles before end point, again because of fishing activity. End L46 at 0845, and start L47 at 1200. Another patch of poor navigation for the same reasons as yesterday, but keep going, and end L47 at 1730. End of line 46 and beginning of line 47 will be re-recorded if time permits. Start L48 at 1800 and complete at 2230.

Sunday, 26 April
Start L49 at 0700 and end L51 at 1415 without incident. Record a patch on NE end of L46 (called L52), and another patch on E end of L39 (called L53), ending at 2015.

Monday, 27 April
Start L54 at 0700; this is the farthest south cross-line and is only 5 miles long. End L56 at 1220. Then transit north to patch in some bits of lines where navigation was substandard. Patch eastern end of L47 and this is called L57.

Tuesday, 28 April
The clutch pressure plate on one of the diesels has died and we do not have a replacement on board; hence we now have no spare compressor. Start L58 at 0700; this is a repeat of L44. Again, lots of small boats at or near the start of line, but manage to get through. End L58 at 1230, and start L59 at 1430; this is a repeat of L45, of which we need to re-record approximately half the line. End L59 at 1730. More sniffing at night, as usual.

Wednesday, 29 April
Ship's main engine has a suspected damaged injector, so will have to stop the ship to investigate; this means retrieving the cable. In doing so, find a large gash in active section #13 (at channel 104), so change out this section. At the same time, decide to try streamlining some of the worst wrinkles, to see if that will decrease the noise produced. The streamlining is achieved with rags and/or foam, wrapped up with tape, and turns out to be very effective. While ship stopped, record a trial DHD vertical profile. Cable back out again by 1200. Consequently, only start L60 at 1330, and finish at 1530. Start L61 at 1600, and end at 1800. Decide to live dangerously and start L62, a long tie-line down the western side of Ragay Gulf, at 1830.

Thursday, 30 April
End L62, the last seismic line in Ragay Gulf at 0130, without any problems. Transit during night out past tip of Bondoc Peninsula; beautiful silhouette of Mayon volcano at sun-rise. Start L63 at 0600, and end at 0930. Start L64 at 1100, and end at 1430. Start L65 at 1600, and end at 1800. Find a safe place to steam for the night.

Friday, 1 May
At 0330 we know we have run over a fishing net, and birds #1 and 2 are indicating full climb, so once again have to partially retrieve the cable. Possible signs of contact on #1, but both check out OK. Wanda the geochem fish has more concrete evidence - several metres of fishing net are removed. Re-deploy and start L66 at 0630. End L67 at 1045. Long transit around islands to start L68 at 1415. End L68 at 1715. This is the end of seismic recording, and the total is some 2750 km. Record some final noise tests for later analysis, then finally retrieve the cable, having it on board at 2100. Head back to Ragay Gulf for some final sniffing.

Saturday, 2 May
Arrive at first sniffer site at 0200, unencumbered by the seismic cable. Short sniffer line to determine exact location for first DHD vertical profile.

Sunday, 3 May
In all, eight vertical profile sites are recorded in different types of anomaly situations. Finish at 2200, so pack up and set course for Puerto Princesa.

Monday, 4 May
Transit all day. Working on reports, clearing up etc.

Tuesday, 5 May
Final safety meeting at 1030, just before arriving off Puerto Princesa at 1100, but no room at the wharf. Eventually tie up alongside another ship at about 1300. Gravity tie completed that afternoon, and that concludes the survey.

9. SHIPBOARD SYSTEMS PERFORMANCE

9.1 *SEISMIC SYSTEM*

The seismic acquisition system ran smoothly during all periods of data collection.

Sampling and conversion of the data is controlled by a Phoenix 6000 series high level analogue data acquisition system containing the BMR-ESU designed IFP (instantaneous floating point) card. Testing and calibration of the amplifier and Phoenix system were carried out prior to the survey

The seismic cable consisted of a 192-channel 2400-metre Fjord Instruments programmable streamer cable, three fore and one aft 50-metre stretch sections, thirteen Syntron DCL-3 cable levellers 200m apart, 200 metres of tow rope and an aluminium tailbuoy. It was towed at a depth of 8 metres.

The seismic source consisted of twenty 150 c.i. sleeve guns reduced to 110 c.i. by inserts, and fired at 2000 psi. The guns were towed as two 16-gun arrays, one array deployed from each side of the stern, 30 metres behind the ship at a depth of six metres.

During all periods of data acquisition the shot interval was controlled by speed data from the navigation computer. Shotpoint data were recorded by the navigation computer to provide tying of the seismic data to shot points during navigation processing.

Seismic shooting was conducted consistently within the specified standard. Channel 104 was dead from start of Line 34 to start of Line 60, and channel 87 was intermittently of low amplitude.

9.2 *NON-SEISMIC SYSTEMS*

The non-seismic data acquisition system (DAS) ran for the duration of the cruise with only four breaks in data collection. Two were intentional reboots of the system by the system personnel during transit; one occurred when all the equipment was powered down after the ship ran aground on an uncharted reef. Lastly, sixteen hours of data were lost because of an unobserved termination of tape recording; seismic data collected during this period were reshot.

NAVIGATION

Positioning of the ship is derived from three systems: Navstar Global Positioning System with and without differential correction data (dGPS and GPS), and dead reckoning with updates from the U.S. Navy Navigation Satellite System (Transit satnavs). The 2 GPS systems use the same satellites but all onboard equipment is completely independent.

All ship positions are calculated in the WGS84 coordinate system.

Navstar Global Positioning System

The dGPS system consists of a Trimble 4000 series GPS receiver, a Racal satellite data demodulator and Racal supplied software running on a Compaq 386 PC. The Trimble receiver provides basic GPS data. Pseudo-range corrections are transmitted from a reference station operated by Racal via a geostationary satellite. The supplied software incorporates the data and corrections to provide dGPS positioning and provides the operator with a monitoring and control interface. The positioning data are in turn read by the DAS navigation computer. During this survey, two identical systems (RACAL 1 and RACAL 2) were run using separate Trimble receivers and PCs. RACAL 1 and RACAL 2 were set to receive differential corrections from Manila, Philippines and Miri, Malaysia, respectively. During instances when Manila station was down, RACAL 1 was set to Singapore. In addition, software was available to download Almanacs from the receivers and predict GPS satellite availability and quality in advance.

GPS positions without corrections are also obtained from the onboard Magnavox T-Set receiver.

Both systems use the GPS coarse/acquisition code. This provides the T-Set system with positioning within 35 metres rms under optimum conditions.

Racal estimate the error in dGPS to be 7.5 m at a distance of 900 km from the reference station with a horizontal dilution of precision of 1.5. Operating distances from the Manila reference station ranged up to 300 km; in general dGPS positioning data were within 5 metres. A section of one line was reshot due to a faulty satellite causing unacceptable navigation.

Dead Reckoning Systems

Dead Reckoning is provided by incorporating a gyro compass, dual axis sonar-doppler and Transit satnav receiver for periods when the other navigation systems prove inadequate.

The primary dead reckoning system of Sperry gyro-compass, Magnavox MX610D sonar-doppler and MX1107RS dual channel satnav receiver provides one of the best available positioning systems of this type. A lower grade system of Sperry gyro, Raytheon DSN450 sonar-doppler and MX1142 single channel satnav receiver is used as a backup. A SG-Brown gyro-compass is also available.

The dead reckoning system, was, however, available for only a few weeks before the ship ran aground on an uncharted reef. Transducers for the doppler sonars were either lost or damaged beyond repair in the accident. Fortunately dGPS provided 24-hour navigation coverage except for a few days when data were unavailable or unacceptable for up to 90 minutes each day.

BATHYMETRY

Bathymetric data were obtained from a Raytheon echo-sounder operating at 12 kHz with a maximum output of 2 kW. The recorded data require a shift of 6 metres to relate to sea surface.

GRAVITY

Gravity data were obtained throughout the survey using a Bodenseewerk KSS-31 Marine Gravity meter with no problem. Gravity ties were carried out in Puerto Princesa, Palawan, at the start and the end of the survey. The meter was, however, turned off following the grounding of the ship.

MAGNETICS

Magnetic data were collected whenever possible during seismic acquisition using a Geometrics G801/3 marine proton precession magnetometer. With the exception of some brief periods, noise levels were typically of the order of 2-3 nT, and some distinct anomalies were noted.

9.3 *DHD SYSTEMS*

The cable was reterminated twice, once at the start of the survey, prior to line 109/001, and once at the end of the NE Palawan/Cuyo Platform section of the survey, after the fish hit the bottom near the start of line 109/020, and the electrical systems failed towards the end of that line.

The fish hit the bottom numerous other times, including when the ship ran aground on an uncharted reef in Tayabas Bay. Collisions were generally caused by either a) a rapid decrease in water depth with little or no warning, i.e. reefs and similar structures, or b) soft muddy bottoms that were not detected by the echo sounder. Most of these collisions resulted in little damage, with the exception of the collision on line 109/020, other than denting the fish's nose and failure of two of the Druck depth transducers. On one occasion the fish had to be retrieved in order to clean it of soft mud.

Three of the Druck depth transducers failed during the survey. One suffered a gradual failure, becoming noisier during lines 109/004 to 109/006 before failing completely prior to line 109/007, following which no depth data were recorded for lines 109/008 to 109/010. In addition, no conductivity data were obtained for lines 109/009 and 109/010, due to removal of the depth transducer and electronics pod for replacement. The other two depth transducers failed when the fish collided with reefs.

The Mesotech altimeters generally worked well, although two failed and were replaced and repaired as required. In parts of Ragay Gulf the soft muddy bottom often could not be detected by the altimeter, and as a result, the fish hit the bottom on several occasions. No damage occurred as a result of any of these collisions, but on one occasion the fish had to be retrieved in order to wash out the mud that had become trapped inside it.

On a good note, after redeployment following the second Mabini port call, the fish was in the water for about 12 days continuously, and the system was fully operational for most of this time. The continuity was only broken when a piece of fishing net became wrapped around the cable and we had to retrieve the fish in order to cut it free.

No significant problems were experienced with the gas extractor system during the survey. The gas chromatographs operated throughout the survey with generally few problems, although LHC2 suffered a stuck valve or valve actuator early on line 109/001 and was not operational for most of this line, resulting in light hydrocarbon data being acquired every 4 minutes instead of every 2. The problem seemed to fix itself, and LHC2 operated throughout the rest of the survey, although it continued to suffer from occasional, intermittent problems.

9.4 *ELECTRICAL ENGINEERING SYSTEMS*

NAVIGATION

Two Magnavox MX100 GPS navigators were purchased for this survey. One was fitted in the bridge during the pre-survey trials, and the other to the *African Queen* in Puerto Princesa. These both operated satisfactorily. Primary navigation was by the Racal/Trimble dGPSs which also had no electrical problems. An Argos satellite beacon was fitted to the tailbuoy for positioning and worked until the Mabini portcall. The Argos cable-attached device was also used throughout the survey. On retrieval it was found that its batteries were flat and the automatic disassembly procedure inoperative.

Subsequent examination of the internals revealed some moisture (a few drops), sufficient to cause corrosion to the PCB and battery terminals. However, the tailbuoy transmitter in particular is a good idea and our experience with this unit should allow us to use it to better effect in the future.

SEISMIC CABLE

The seismic cable had no channels out at the start of the survey, but because of the requirement to remove wrinkled sections for noise considerations, valuable time was lost when replacements proved to have U/S channels. Several pins were repaired in three or four sections.

AMPLIFIERS

There were several seismic amplifier cards that did not meet specification in the system at the start of the survey. Five cards were repaired and others gradually weeded out as the survey progressed, as there were no spares for immediate replacement. At the end of the survey all channels were within specification.

PHOENIX A/D CONVERTER

The work put in on the trials by Marine and D&D staff proved successful. The pre-cruise tests showed satisfactory alignment, although the S&H card was fine-tuned to minimise offset. No problems were encountered on survey.

GUN ARRAYS

All DTs and some Hydrophones were replaced prior to or during the survey along with a substantial number of pigtails. Despite the flat seas many reterminations were required on the arrays.

CABLE ALARMS

Both the Fjord Instruments tension meter and the BMR one were used on the large seismic reel. The conversion of the resistance alarm to DC proved satisfactory, and as an added measure the rotating light which had been disconnected was rewired through a relay to activate off both BMR alarm circuits.

TAILBUOY

Tailbuoy lights again proved to be a problem. The black unit was repaired so that it can again be positioned upright as it was designed. It failed again however (with a different fault) and the new lamp package was used while the old one was repaired. The white flashing light which was giving intermittent service was lost when its mounting bracket broke off at sea. It appears the 'g' forces on the tailbuoy are such that things invariably work their way loose. For most of the survey we had two lights on the buoy for reliability, but still had to change lights three times with the rubber boat.

GEOCHEMISTRY

In the course of the survey, the fish hit the bottom many times. On one occasion just before the Mabini portcall, the strike was hard enough to damage the cable and a complete retermination was required. Two DTs were destroyed and another could be suspect. Generally the geochemical operation ran superbly from an engineering viewpoint, with no measureable downtime, and the terminations were left in good condition for the next sniffer survey.

GRAVITY METER

The gravity meter gave no trouble. During the grounding emergency the power was turned off to the instrument room so that the meter required rebooting. Other than this, operation was incident free.

MAGNETOMETER

The magnetometer also ran exceptionally well. The thorough overhaul of the head which took place recently had the desired result. Noise levels were acceptable with a good clean sinusoid on the CRO. Little water has ingressed into the head. Because of the shallowness of the water, the magnetometer was often towed close to the ship, but still gave results which appear useful.

9.5 *MECHANICAL SYSTEMS*

COMPRESSORS/DIESELS

All units worked well during the cruise, receiving minor maintenance such as valve replacement, oil changes, etc. High and low stage oil coolers were fitted to all compressors during the course of the cruise, generally with improved results. Specific problems encountered included:

- two diesels needed replacement cylinder heads; one due to a bent valve, the other due to a burnt valve
- one compressor suffered a broken low-stage crankshaft, thought to be one of the original, suspected faulty units; this was replaced
- the clutch on one unit was replaced when worn out, but a second unit failed late in the survey, leaving that compressor unuseable, and consequently no spare.

AIRGUN ARRAYS

The arrays were towed outboard from the magnetometer booms, in the hope of minimizing the chances of entangling the guns in the seismic cable, if drastic manoeuvring of the ship were required. This eventuality never occurred in fact, but the deployment method proved to be very successful, with no major problems encountered.

The sleeve guns themselves performed reasonably well, the main problem being premature failure of the wear ring in some units. Another problematic area was the condition of the bolts securing the volume-reducing inserts to the gun bodies.

10. ACKNOWLEDGEMENTS

The enthusiasm, skill, and cooperation of the master, Captain Andy Codrington, and crew of the Australian Maritime Safety Authority ship *Rig Seismic* in these conditions, foreign to most of us, are gratefully acknowledged. They have undoubtedly made a major contribution to the success of the cruise. Additionally, the local knowledge provided by the crew of *African Queen*, in particular Captain Nick Dollolasa, was invaluable, and was much appreciated.

Excellent logistic support from Supply Oilfield Services Inc. and from Harrisons & Crosfield, Skyfix navigation support from Racal, and administrative support from both the Philippine Office of Energy Affairs and from the Australian embassy in Manila were all unstintingly provided, and are thankfully acknowledged.

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Appendix 1 : LIST OF CONSULTATIVE OIL COMPANIES

In the Philippines

1. Anglo-Philippines Oil & Mining Corporation
2. Alcorn Petroleum & Mineral Corporation
3. Balabac Oil Exploration Company
4. Basic Petroleum & Mineral Inc.
5. Oriental Petroleum & Mineral Corporation
6. Petrofields Exploration & Development Company, Inc.
7. Philex Mining Corporation
8. The Philodrill Corporation
9. San Jose Oil & Mining Corporation
10. Seafront Petroleum & Mineral Resources, Inc.
11. Trans-Asia Oil & Mineral Development Corporation
12. Ultrana Nuclear & Mineral Corporation
13. Unioil Exploration & Mineral Development Company, Inc.
14. Vulcan Industrial & Mining Corporation

In Australia

1. Ampol Exploration Ltd.
2. Austin Oil NL
3. Australian Worldwide Exploration Pty. Ltd.
4. Australasian Oil Exploration Ltd.
5. Bligh Philippines, Inc.
6. Bridge Oil Philippines, Inc.
7. BHP Petroleum Pty. Ltd.
8. Claremont Petroleum NL
9. Command Petroleum Holdings NL
10. Crusader Ltd.
11. MIM Petroleum Exploration Pty. Ltd.
12. SANTOS Ltd.
13. Woodside Petroleum Ltd.

Appendix 2: SCIENTIFIC EQUIPMENT IN USE

General

Raytheon echo sounder: 12 kHz (2 kW maximum output power)
Geometrics G801 magnetometer
Bodenseewerk Geosystem KSS-31 marine gravity meter

Navigation

RACAL SKYFIX satellite-link differential GPS (2 independent systems: one normally taking corrections from Manila, the other from Miri, in Sabah)
Magnavox T-set Global Positioning System
Magnavox MX1107RS and MX1142 TRANSIT satellite receivers
Magnavox MX610D and Raytheon DSN450 dual axis sonar dopplers (part-time)
Arma Brown and Sperry gyro-compasses; plus Ben paddle log (part-time)

Seismic streamer

Fjord Instruments, transformerless coupling
Maximum of 288 seismic channels, 12 auxiliary channels
10 Teledyne T-1 hydrophones per 6.25 metre group
Nominal sensitivity 44 Volts/Bar for 12.5 m group
6.25, 12.5, (18.75), and 25.0 metre groups available
Maximum towable length 6000 metres; 4800 m available

Recording instrumentation & recording options

Low noise charge-coupled preamplifiers
Preamplifier gain from 1 to 128 in 6 dB steps
Maximum of 320 channels including seismic and auxiliaries
LC filters : 8, 12, 24 and 48 Hertz at 18 dB/octave
HC filters : 64, 128, 256 and 512 Hertz at 72 dB/octave
Sampling rates : 0.5, 1, 2, and 4 millisecs
Record lengths : 2 secs to 20 secs
SEG-Y recording format
IFP operating at 200 kHz with special floating point format
Data recorded as 4-bit binary exponent and 12-bit mantissa

Water-column Geochemical equipment

The Direct Hydrocarbon Detection (DHD) method continuously analyzes C_1-C_8 hydrocarbons within seawater. Thermogenic hydrocarbons migrating up faults from source rocks and/or hydrocarbon reservoirs debouch into the seawater at the seafloor, producing higher concentrations of light hydrocarbons within the water column. These seep gases have molecular compositions that are distinctively different from that of the biogenically-produced hydrocarbons which are mainly produced by *in situ* processes in seawater. If the hydrocarbons are present in sufficient amounts, the molecular composition of the thermogenic hydrocarbons may be used to infer whether the primary source of the seep was oil, condensate or dry gas. The method used on the RV *Rig Seismic* is as follows. Seawater is continuously delivered into the geochemical laboratory onboard the ship via a submersible fish (which is towed approximately 10 m above the seafloor). The seawater is degassed in a vacuum chamber and the resulting headspace gas is injected into three gas chromatographs which sequentially sample the flowing gas stream and measure a variety of light hydrocarbons. Total hydrocarbons (THC) are measured every thirty seconds, light hydrocarbons (C_1-C_4) are measured every two minutes, and C_5-C_8 are measured every 8 minutes. These data, as well as fish altitude (above the seafloor), the depth of the fish, hydrographic (temperature and salinity) and navigation data are recorded on computer. All these data are recorded and displayed continuously so that any hydrocarbon anomalies in the water column can be quickly recognised and additional measurements can be made when appropriate. Detection sensitivity is approximately 10 parts per billion in the stripped headspace sample. At a ship speed of 5 knots, the measurement of THC is made every 80 m, C_1-C_4 every 310 m, and C_5-C_8 every 1240 m.

Appendix 3: SEISMIC RECORDING PARAMETERS

The following geometry and recording parameters were used for the Philippines seismic survey:

Streamer geometry

Fjord Instruments transformerless: 2400 m active length
192 seismic channels plus 5 WBs plus 13 DTs
Group interval 12.5 m
Nominal depth 8 m
Near offset nominally 180 m
Far offset nominally 2567 m
(see cable diagram over)

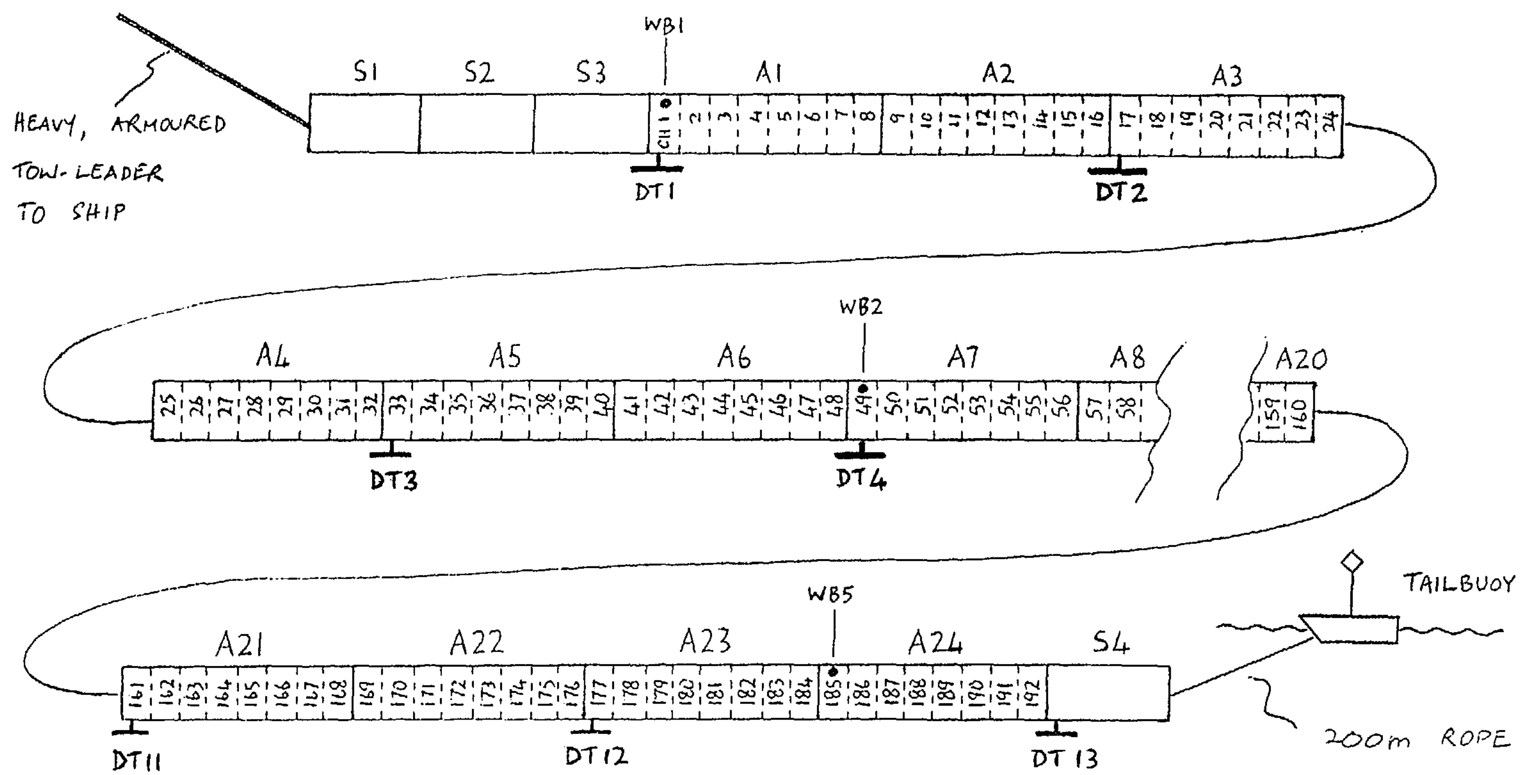
Energy Source

16 x 110 cu.in. HGS sleeve gun per array; 2 arrays of 10 guns each in 4, 3, 2, 1 groups used
Pressure 2000 psi nominal; 1800 psi minimum
Gun depths 6 m nominal

Recording parameters

8 Hz - 128 Hz passband
2 ms demultiplexed
7 sec record length
48 fold at a nominal 5 knots (shot rate = 9.7 sec = 25 m)
Seismic data recorded in SEG-Y format, special floating point format: 4 bit binary exponent, 12 bit mantissa.

CABLE CONFIGURATION



Appendix 4: NON-SEISMIC DATA ACQUISITION CHANNELS

The following is a list of channel allocations for the non-seismic data of Survey 109.

The main data set is saved on magnetic tape every minute in blocks of 128 x 6 floating point words. This represents 128 data channels of 6 records per block.

1	Survey and day number from DAS computer clock	(sss.ddd)
2	Acquisition GMT from DAS computer clock	(.hhmmss)
3	Acquisition GMT from master clock	(.hhmmss)
4	Latitude, best estimate	(radians)
5	Longitude, best estimate	(radians)
6	Speed, best DR estimate	(knots)
7	Course, best DR estimate	(degrees)
8	Magnetometer # 1	(nT)
10	Depth from 12 kHz echo sounder	(metres)
12	F/A Magnavox sonar doppler	(3920 counts/nm)
13	P/S Magnavox sonar doppler	(3920 counts/nm)
14	F/A Raytheon sonar doppler	(193.5 counts/nm)
15	P/S Raytheon sonar doppler	(193.5 counts/nm)
18	Instrument room Sperry gyro heading	(degrees)
19	SG Brown gyro heading	(degrees)
20	Bridge Sperry gyro heading	(degrees)
25	Racal dGPS #2 UTC time	(hhmmss)
26	Racal dGPS #2 latitude	(radians)
27	Racal dGPS #2 longitude	(radians)
28	Racal dGPS #2 height	(m)
29	Racal dGPS #2 course	(degrees)
30	Racal dGPS #2 speed	(knots)
31	Racal dGPS #2 number of satellites	
32	Racal dGPS #2 PDOP	
33	Racal dGPS #2 HDOP	
34	Racal dGPS #2 3-D position error	(m)
35	Racal dGPS #2 2-D position error	(m)
36	Racal dGPS #2 differential quality	(see below)
37	Racal dGPS #2 flag	(see below)
39	T-Set north std dev.	(m)
40	T-Set east std dev.	(m)
41	T-Set satellite numbers	
42	T-Set GMT time	(seconds)
43	T-Set DOP	
44	T-Set latitude	(radians)
45	T-Set longitude	(radians)
46	T-Set height above geoid	(m)
47	T-Set speed	(knots)
48	T-Set course	(degrees)
49	T-Set frequency bias	
51	Latitude from Dead Reckoning System 1	(radians)
52	Longitude from Dead Reckoning System 1	(radians)

53	Speed from Dead Reckoning System 1	(knots)
54	Course from Dead Reckoning System 1	(degrees)
55	Latitude from Dead Reckoning System 2	(radians)
56	Longitude from Dead Reckoning System 2	(radians)
57	Speed from Dead Reckoning System 2	(knots)
58	Course from Dead Reckoning System 2	(degrees)
67	GMT from Magnavox MX1107	(seconds)
68	Dead reckoned time from MX1107	(seconds)
69	MX1107 latitude	(radians)
70	MX1107 longitude	(radians)
71	MX1107 speed	(knots)
72	MX1107 heading	(degrees)
73	GMT from Magnavox MX1142	(seconds)
74	Dead reckoned time from MX1142	(seconds)
75	MX1142 latitude	(radians)
76	MX1142 longitude	(radians)
77	MX1142 speed	(knots)
78	MX1142 heading	(degrees)
79	Gravity	($m/sec^2 \times 10^{-3}$)
80	ACX	($m/sec^2 \times 10^{-4}$)
81	ACY	($m/sec^2 \times 10^{-4}$)
82	Sea state	
83	AGRF magnetic anomaly #1	(nT)
86	Shot time	(hhmmss)
87	Shot point number	
88	Northerly set/drift	(radians/10 seconds)
89	Easterly set/drift	(radians/10 seconds)
110	Racal #1 dGPS UTC time	(hhmmss)
111	Racal #1 dGPS latitude	(radians)
112	Racal #1 dGPS longitude	(radians)
113	Racal #1 dGPS height	(m)
114	Racal #1 dGPS course	(degrees)
115	Racal #1 dGPS speed	(knots)
116	Racal #1 dGPS number of satellites	
117	Racal #1 dGPS PDOP	
118	Racal #1 dGPS HDOP	
119	Racal #1 dGPS 3-D position error	(m)
120	Racal #1 dGPS 2-D position error	(m)
121	Racal #1 dGPS differential quality	(see below)
122	Racal #1 dGPS flag	(see below)

The **Transit satellite fix information** from both the MX1107 and MX1142 is saved in blocks of 20 floating point words when the fix data become available. The data from each satnav are in a similar format, each being identified by the first word.

1 1107 or 1142
2 Day number (1107) or date (1142)
3 GMT

4	Latitude	(radians)
5	Longitude	(radians)
6	Used flag	(0 = not used, 1 = used)
7	Elevation	(degrees)
8	Iterations	
9	Doppler counts	
10	Distance from DR	(nautical miles)
11	Direction from DR	(degrees)
12	Satellite number	
13	Antenna height	(metres)
14	Doppler spread flags (1107 only)	
.	" " "	
.	" " "	
20	" " "	

Racal dGPS "flag" is a 5 digit number [n1,n2,n3,n4,n5] as follows:

n1: Operating Mode	0 = no solution
	1 = 4 SV
	2 = 3 SV + altitude aiding
	3 = 3 SV + clock aiding
	4 = 2 SV + altitude aiding + clock aiding
	5 = all-in-view
n2: Receiver Code	7 = C/A, L1 only, carrier aided
n3: Receiver Dynamics	0 = static, 1...9 represents low...high
n4: Position Quality	0...9 represents bad...good
n5: Differential Quality	0 = no corrections, 1...9 represents bad...good

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
NE Palawan Shelf								
109/01	SOL from SW	09 34.50	118 42.75	09 34.486	118 42.839			
	DUMARAN WELL	10 19.598	119 56.370	10 19.525	119 56.459			
	EOL at NE	10 38.25	120 26.25	10 38.176	120 26.339	117	210.6	210.6
109/02	SOL from NE	10 35.70	120 27.70	10 35.626	120 27.789			
	PALY WELL	10 25.962	120 12.464	10 25.888	120 12.464			
	ROXAS WELL	10 04.708	119 38.678	10 04.636	119 38.767			
	EOL at SW	09 57.40	119 27.40	09 57.329	119 27.489	69	124.2	334.8
109/03	SOL at SE	09 55.50	119 18.70	09 55.429	119 18.789			
	EOL at NW	10 02.70	119 14.10	10 02.628	119 14.189	8	14.4	349.2
109/04	SOL at SE	09 52.50	119 14.10	09 52.429	119 14.189			
	EOL at NW	10 00.90	119 08.80	10 00.828	119 08.889	9.7	17.46	366.66
109/05	SOL at SE	09 50.00	119 09.50	09 49.929	119 09.589			
	EOL at NW	09 59.30	119 03.70	09 59.229	119 03.789	10.3	18.54	385.2
109/06	SOL at SE	09 45.00	119 05.90	09 44.930	119 05.989			
	EOL at NW	09 54.87	118 59.60	09 54.796	118 59.689	11.3	20.34	405.54
109/07	SOL at SE	09 40.00	119 02.60	09 39.930	119 02.689			
	EOL at NW	09 49.30	118 56.60	09 49.229	118 56.689	10.8	19.44	424.98
109/08	SOL at SE	09 40.00	118 56.10	09 39.930	118 56.189			
	EOL at NW	09 47.00	118 51.60	09 46.929	118 51.689	8.1	14.58	439.56

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance in n. mile	Distance in kilometre	Total in kilometre
		Latitude	Longitude	Latitude	Longitude			
109/09	SOL at SE	09 38.00	118 50.40	09 37.930	118 50.489			
	EOL at NW	09 43.00	118 47.30	09 42.930	118 47.389	5.9	10.62	450.18
109/10	SOL at SE	09 32.40	118 47.50	09 32.331	118 47.589			
	EOL at NW	09 37.50	118 44.20	09 37.430	118 44.289	5.9	10.62	460.8
109/11	SOL at SE	09 40.35	118 47.46	09 40.280	118 47.549			
	EOL at NW	10 10.15	119 35.00	10 10.078	119 35.089	56	100.8	561.6
109/12	SOL at SE	10 02.60	119 40.00	10 02.528	119 40.089			
	ROXAS WELL	10 04.708	119 38.678	10 04.636	119 38.767			
	Mid-point	10 10.15	119 35.00	10 10.078	119 35.089			
	EOL at NW	10 12.30	119 33.53	10 12.228	119 33.619	11	19.8	581.4
			Total in NE Palawan Shelf		**581.4**			
Cuyo Platform								
109/13	SOL at SE	10 10.15	119 35.00	10 10.078	119 35.089			
	EOL at NW	11 07.00	121 03.00	11 06.923	121 03.090	105	189	770.4
109/14	SOL at NE	11 14.00	120 53.50	11 13.923	120 53.590			
	EOL at SW	10 44.50	120 00.00	10 44.425	120 00.089	61	109.8	880.2
109/15	SOL at SW	10 53.00	119 59.25	10 52.925	119 59.340			
	Mid-point	11 15.85	120 42.75	11 15.773	120 42.840			
	EOL at NE	11 20.30	120 46.95	11 20.223	120 47.040	55	99	979.2

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
109/16	SOL at NW	11 20.00	120 35.75	11 19.923	120 35.840			
	EOL at SE	10 56.50	120 50.00	10 56.424	120 50.090	27	48.6	1027.8
109/17	SOL at SE	10 48.00	120 41.30	10 47.925	120 41.389			
	EOL at NW	11 20.00	120 22.25	11 19.923	120 22.340	37	66.6	1094.4
109/18	SOL at NW	11 11.50	120 13.75	11 11.423	120 13.840			
	EOL at SE	10 42.50	120 32.00	10 42.425	120 32.089	34	61.2	1155.6
109/19	SOL at SE	10 34.00	120 28.10	10 33.926	120 28.189			
	EOL at NW	11 10.50	120 05.50	11 10.423	120 05.590	43	77.4	1233
109/20	SOL at NW	11 05.00	119 55.75	11 04.924	119 55.840			
	EOL at SE	10 27.75	120 18.00	10 27.676	120 18.089	43	77.4	1310.4
			Total in Cuyo Platform		**729**			
		Total in Survey Area !			**1310.4**			
Tayabas Bay								
109/21	SOL at NW	13 46.50	121 54.50	13 46.413	121 54.590			
	Mid-point	13 32.75	122 11.00	13 32.663	122 11.090			
	EOL at SE	13 15.30	122 29.25	13 15.214	122 29.340	46.5	83.7	1394.1
109/22	SOL at SW	13 17.00	122 20.50	13 16.914	122 20.590			
	EOL at NE	13 23.60	122 27.50	13 23.514	122 27.590	9.3	16.74	1410.84

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
109/23	SOL at SW	13 20.25	122 15.30	13 20.164	122 15.390			
	EOL at NE	13 28.00	122 24.50	13 27.914	122 24.590	10.2	18.36	1429.2
109/24	SOL at SW	13 24.50	122 10.50	13 24.414	122 10.590			
	EOL at NE	13 31.50	122 19.70	13 31.413	122 19.790	12	21.6	1450.8
109/25	SOL at E	13 32.60	122 17.50	13 32.513	122 17.590			
	EOL at W	13 35.60	121 50.80	13 35.513	121 50.890	26.4	47.52	1498.32
109/26	SOL at W	13 38.00	121 51.50	13 37.913	121 51.590			
	EOL at E	13 36.75	122 10.40	13 36.663	122 10.490	18.4	33.12	1531.44
109/27	SOL at E	13 39.15	122 08.10	13 39.063	122 08.190			
	EOL at W	13 40.15	121 52.25	13 40.063	121 52.340	15.5	27.9	1559.34
109/28	SOL at W	13 42.75	121 53.15	13 42.663	121 53.240			
	EOL at E	13 41.75	122 06.40	13 41.663	122 06.490	12.9	23.22	1582.56
109/29	SOL at NE	13 43.75	122 04.35	13 43.663	122 04.440			
	EOL at SW	13 34.00	121 54.70	13 33.913	121 54.790	13.7	24.66	1607.22
109/30	SOL at NW	13 29.60	122 11.60	13 29.513	122 11.690			
	EOL at SE	13 05.00	122 38.25	13 04.915	122 38.340	35.8	64.44	1671.66
			Sub-total in Tayabas Bay		361.26			

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
Ragay Gulf								
109/31	SOL at SW	13 05.15	122 34.00	13 05.065	122 34.090			
	EOL at NE	13 27.70	123 05.50	13 27.613	123 05.590	38	68.4	1740.06
109/32	SOL at N	13 26.50	123 07.50	13 26.413	123 07.590			
	EOL at S	13 03.70	123 07.90	13 03.615	123 07.990	22.8	41.04	1781.1
109/33, 35	SOL at SE	12 58.67	123 18.20	12 58.582	123 18.288			
	EOL at NW	13 43.40	122 33.75	13 43.312	122 33.840	56.7	102.06	1883.16
109/34	SOL at SW	13 28.30	122 42.25	13 28.214	122 42.340			
	EOL at NE	13 35.60	122 51.60	13 35.514	122 51.690	10.8	19.44	1902.6
109/36	SOL at NW	13 47.75	122 37.75	13 47.662	122 37.840			
	EOL at SE	13 13.69	123 11.14	13 13.605	123 11.229	47	84.6	1987.2
109/37	SOL at E	13 25.75	123 08.80	13 25.663	123 08.890			
	EOL at W	13 24.90	122 42.25	13 24.814	122 42.340	26	46.8	2034
109/38	SOL at SW	13 22.60	122 44.50	13 22.514	122 44.590			
	EOL at NE	13 32.00	122 55.70	13 31.913	122 55.790	14.3	25.74	2059.74
109/39	SOL at E	13 17.60	123 11.50	13 17.514	123 11.590			
	R-2 Prospect	13 16.93	123 02.60	13 16.844	123 02.690			
	B-2 Prospect	13 15.90	122 46.60	13 15.814	122 46.690			
	EOL at W	13 15.70	122 43.50	13 15.614	122 43.590	27.4	49.32	2109.06

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
109/40	SOL at SW	13 21.10	122 44.75	13 21.014	122 44.840			
	EOL at NE	13 31.10	122 57.00	13 31.013	122 57.090	15.5	27.9	2136.96
109/41	SOL at N	13 29.50	122 59.80	13 29.413	122 59.890			
	EOL at S	13 13.40	123 00.00	13 13.314	123 00.090	16	28.8	2165.76
109/42	SOL at S	13 14.40	123 02.65	13 14.314	123 02.740			
	R-2 Prospect	13 16.93	123 02.60	13 16.844	123 02.690			
	EOL at N	13 28.60	123 02.30	13 28.513	123 02.390	14.2	25.56	2191.32
109/43	SOL at N	13 27.75	123 05.00	13 27.663	123 05.090			
	EOL at S	13 07.75	123 05.30	13 07.665	123 05.390	20.1	36.18	2227.5
109/44	SOL at E	13 19.30	123 11.25	13 19.214	123 11.340			
	R-1 Prospect	13 18.90	123 03.60	13 18.814	123 03.690			
	EOL at W	13 18.00	123 43.25	13 17.914	123 43.340	27.5	49.5	2277
109/45	SOL at W	13 21.70	122 44.75	13 21.614	122 44.840			
	EOL at E	13 22.40	123 10.80	13 22.314	123 10.890	25.5	45.9	2322.9
109/46	SOL at SW	13 12.25	122 57.50	13 12.164	122 57.590			
	EOL at NE	13 20.25	123 11.00	13 20.164	123 11.090	15.2	27.36	2350.26
109/47	SOL at E	13 12.70	123 11.70	13 12.614	123 11.790			
	EOL at W	13 12.70	122 43.30	13 12.614	122 43.390	27.7	49.86	2400.12
109/48	SOL at SW	13 14.70	122 43.20	13 14.614	122 43.290			
	EOL at NE	13 28.70	123 01.30	13 28.613	123 01.390	22.7	40.86	2440.98

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
109/49	SOL at NE	13 11.80	123 13.35	13 11.714	123 13.440			
	EOL at SW	13 06.25	123 05.75	13 06.165	123 05.840	9.3	16.74	2457.72
109/50	SOL at SW	13 09.10	123 03.80	13 09.015	123 03.890			
	EOL at NE	13 14.50	123 11.80	13 14.414	123 11.890	9.5	17.1	2474.82
109/51	SOL at NE	13 16.50	123 11.60	13 16.414	123 11.690			
	EOL at SW	13 11.30	123 03.50	13 11.214	123 03.590	9.3	16.74	2491.56
109/52	10 n. miles after SOL at SW							
(patch for	EOL at NE	13 20.25	123 11.00	13 20.164	123 11.090	5		
109/46)								
109/53	SOL at E	13 17.60	123 11.50	13 17.514	123 11.590	10		
(patch for	10 n. miles after SOL							
109/39)								
109/54	SOL at NE	13 02.00	123 16.20	13 01.915	123 16.290			
	EOL at SW	12 58.50	123 11.75	12 58.415	123 11.840	5.7	10.26	2501.82
109/55	SOL at SW	13 00.90	123 09.60	13 00.815	123 09.690			
	EOL at NE	13 05.00	123 15.40	13 04.915	123 15.490	7	12.6	2514.42
109/56	SOL at NE	13 06.75	123 14.30	13 06.665	123 14.390			
	EOL at SW	13 02.60	123 08.50	13 02.515	123 08.590	7	12.6	2527.02

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
109/57	SOL at E	13 12.70	123 11.70	13 12.614	123 11.790			
(patch for	EOL at 12 n. miles					12		
109/47)								
109/58	SOL at E	13 19.30	123 11.25	13 19.214	123 11.340			
(re-shoot for	R-1 Prospect	13 18.90	123 03.60	13 18.814	123 03.690			
109/44)	EOL at W	13 18.00	122 43.25	13 17.914	122 43.340	27.5		
109/59	SOL at W	13 21.70	122 44.75	13 21.614	122 44.840			
(patch for	EOL at 15 n. miles					15		
109/45)								
109/60	SOL at NE	13 38.10	122 47.40	13 38.013	122 47.490			
	EOL at SW	13 31.30	122 39.80	13 31.213	122 39.890	10.2	18.36	2545.38
109/61	SOL at SW	13 33.25	122 38.25	13 33.163	122 38.340			
	EOL at NE	13 40.10	122 45.50	13 40.013	122 45.590	9.8	17.64	2563.02
109/62	SOL at N	13 36.40	122 46.50	13 36.313	122 46.590			
	EOL at S	13 03.50	122 46.50	13 03.415	122 46.590	32.7	58.86	2621.88
			Total in Ragay Gulf		**950.22**			
Tayabas Bay								
109/63	SOL at S	13 07.00	122 26.60	13 06.913	122 26.690			
	EOL at N	13 24.30	122 26.80	13 24.213	122 26.890	17.2	30.96	2652.84

Appendix 5 List of Seismic Way-point for Philippine Cruise 109

Line No	Position & Well	Way-point in Clarke System		Way-point in WGS-84 System		Distance	Distance	Total
		Latitude	Longitude	Latitude	Longitude	in n. mile	in kilometre	in kilometre
109/64	SOL at SE	13 21.55	122 28.00	13 21.463	122 28.090			
	EOL at NW	13 33.20	122 15.63	13 33.113	122 15.720	16.7	30.06	2682.9
109/65	SOL at NE	13 33.10	122 17.25	13 33.013	122 17.340			
	EOL at SW	13 27.00	122 09.25	13 26.914	122 09.340	10	18	2700.9
109/66	SOL at SW	13 34.75	121 59.30	13 34.663	121 59.390			
	EOL at NE	13 41.20	122 05.90	13 41.113	122 05.990	9	16.2	2717.1
109/67	SOL at NE	13 38.85	122 07.80	13 38.763	122 07.890			
	EOL at SW	13 34.10	122 02.40	13 34.013	122 02.490	7.2	12.96	2730.06
109/68	SOL at NW	13 28.50	122 08.75	13 28.413	122 08.840			
	EOL at SE	13 20.00	122 17.50	13 19.913	122 17.590	11.8	21.24	2751.3
			Sub-total inTayabas Bay		129.42			
			Total in Tayabas Bay		490.68			
		Total in Survey Area II			1440.9			
	Total kilometres				2751.3			

Appendix 6 : LIST OF GEOCHEMISTRY WAY-POINTS

Line No	Position	Way-point in Clarke System Latitude	Longitude
Sniffer 1			
C	NE	13 20.30	123 05.30
D	SW	13 14.70	122 59.20
E	SW	13 14.00	123 00.00
F	NE	13 19.40	123 05.80
G	NE	13 20.50	123 04.60
H	SW	13 15.40	122 59.20
I	SW	13 14.80	123 00.00
J	NE	13 20.00	123 05.70
Sniffer 2			
1	SOL	13 23.25	122 55.25
2	EOL	13 14.70	123 03.80
3	SOL	13 15.85	123 05.00
4	EOL	13 19.40	123 01.60
5	SOL	13 17.90	122 59.75
6	EOL	13 14.60	123 03.00
7	SOL	13 15.70	123 04.10
8	EOL	13 19.40	123 00.60
9	SOL	13 16.70	122 57.60
10	EOL	13 14.20	123 00.00
Sniffer 3			
11	SOL	13 26.25	122 56.50
12	EOL	13 12.60	123 10.00
13	SOL	13 10.80	123 08.30
14	EOL	13 24.75	122 54.75
Sniffer 4			
15	SOL	13 08.25	123 13.40
16	EOL	13 21.50	123 00.30
17	SOL	13 22.60	123 01.30

18	EOL	13 12.20	123 11.60
19	SOL	13 16.25	123 07.60
20		13 15.00	123 06.30
21	EOL	13 21.25	123 00.00
Sniffer 6			
30	SOL	13 27.00	123 00.00
31	EOL	13 19.50	123 07.60
32	SOL	13 20.20	123 08.25
33	EOL	13 27.10	123 01.30
34	SOL	13 27.75	123 02.20
35	EOL	13 21.00	123 09.00
Sniffer 7			
36	SOL	13 19.30	123 01.10
37	EOL	13 26.80	122 53.70
38	SOL	13 28.75	122 55.75
39	EOL	13 19.80	123 04.75
Sniffer 8			
40	SOL	13 12.60	122 59.30
41		13 22.10	122 59.30
42	EOL	13 35.25	122 46.30
43	SOL	13 36.30	122 47.50
44	EOL	13 23.70	123 00.00
Sniffer 9			
45	SOL	13 23.70	122 54.75
46	EOL	13 35.75	122 42.75
47	SOL	13 34.50	122 41.25
48	EOL	13 21.40	122 54.15
49	SOL	13 23.30	122 56.50
50	EOL	13 36.50	122 43.50
Sniffer 10			
51	SOL	13 15.00	123 00.00
52	EOL	13 18.50	123 00.00
VP-1	Station	13 16.95	123 00.00

Sniffer 11			
53	SOL	13 18.76	123 01.00
54	EOL	13 18.76	123 04.00
VP-2	Station	13 18.76	123 02.57
VP-3	Station	13 18.75	123 03.75
VP-4	Station	13 18.25	123 02.57
Sniffer 12			
55	SOL	13 20.25	122 45.75
56	EOL	13 25.00	122 44.50
Sniffer 13			
57	SOL	13 25.00	122 45.50
58	EOL	13 20.25	122 47.75
Sniffer 14			
59	SOL	13 20.25	122 48.25
60	EOL	13 25.00	122 46.50
VP-5	Station	13 22.49	122 47.39
VP-6	Station	13 29.00	122 48.10
VP-7	Station	13 27.50	123 00.00
VP-8	Station	13 23.60	123 00.00
Sniffer 15			
61	SOL	13 20.00	123 03.00
62	EOL	13 15.00	123 01.70

Appendix 7: GRAVITY TIE

Gravity ties were performed at the beginning and at the end of the survey in Puerto Princesa, Palawan. A station with an absolute gravity value had previously been established at the Puerto Princesa airport terminal. This building has since been demolished, but the concrete slab was identifiable. Measurements were taken, using a Worden portable gravity meter, in the proximity of the gravity station. Another station was established at the new terminal building for future reference. Further readings were taken on the wharf adjacent to the ship to allow the transfer of absolute gravity values to the ship's Bodenseewerk gravity meter.

The following pages show the meter readings at both ties, and diagrams of the locations where the readings were taken, both at the airport and at the wharf.

OBSERVER	SURVEY No	DAY	
TH + TM.	109	86	**GRAVITY**

AREA	TRAV	DATE	FIELD METER	SCALE FACTOR	
Philippines Puerto Princesa		26.03.92	WORDEN No. 140	0.1021	Geophysical Branch, Bureau of Mineral Resources Geology and Geophysics

STATION	TIME	READING	INSTR TEMP °C	LATITUDE	LONGITUDE	REMARKS
A. Wharf	0125	591:50				Wharf ht = 1.88 m
B. Pt. Authority	0140	592:50				
C New Terminal	0201	560:90				
D Old Terminal	0214	554:50				
A. Wharf.	0300	589:70				wharf ht = 2.04 m.
B. Pt. Authority	0309	595:30				
C. New terminal	0325	560:30				
D. Old terminal	0334	557.·0				
	Times is U.T.C.					

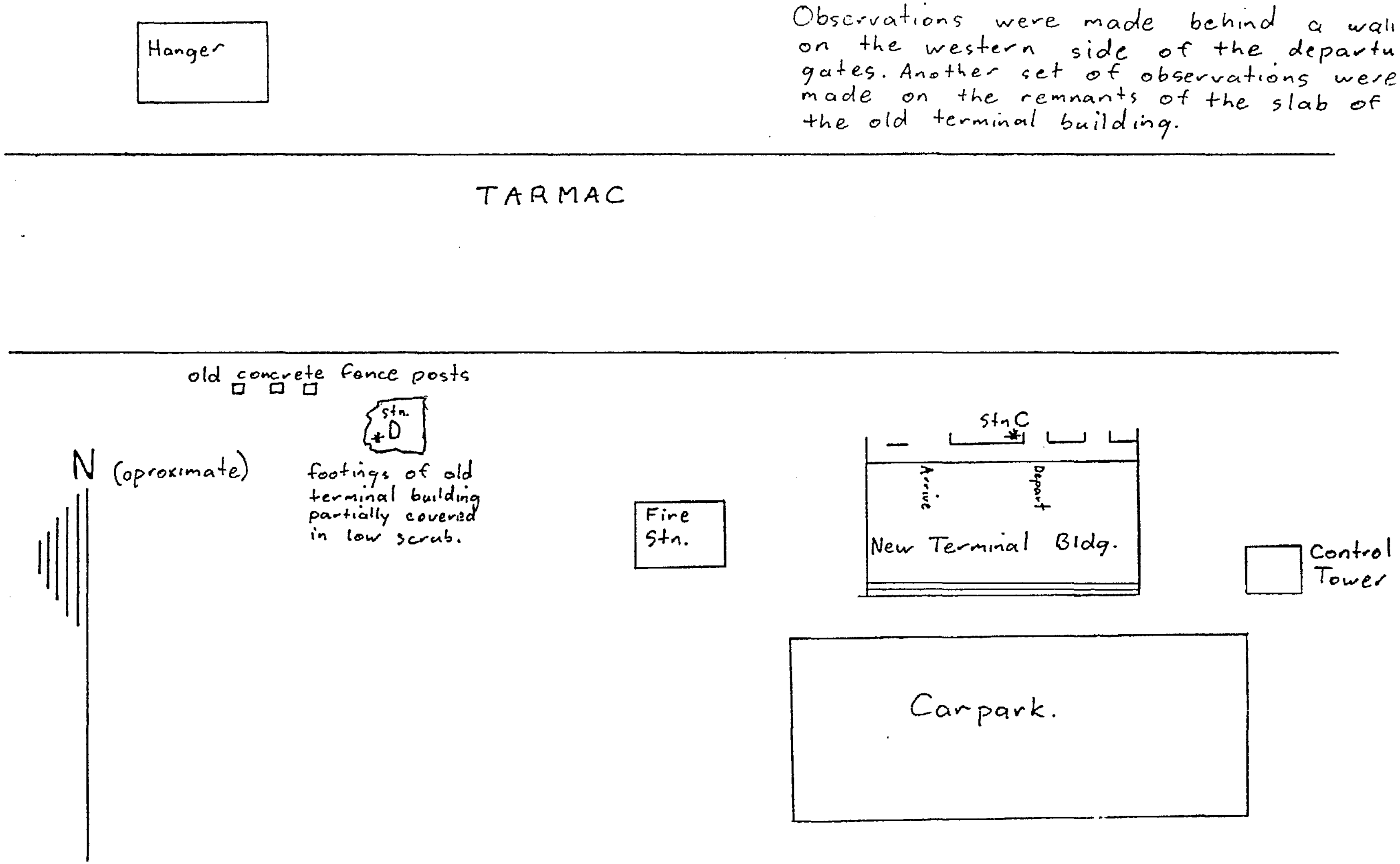
OBSERVER	SURVEY No	DAY	
TMcN	109	126	**GRAVITY**

AREA	TRAV	DATE	FIELD METER	SCALE FACTOR	
Philippines Puerto Princesa		05.05.92	WORDEN 146	0.1021	Geophysical Branch, Bureau of Mineral Resources Geology and Geophysics

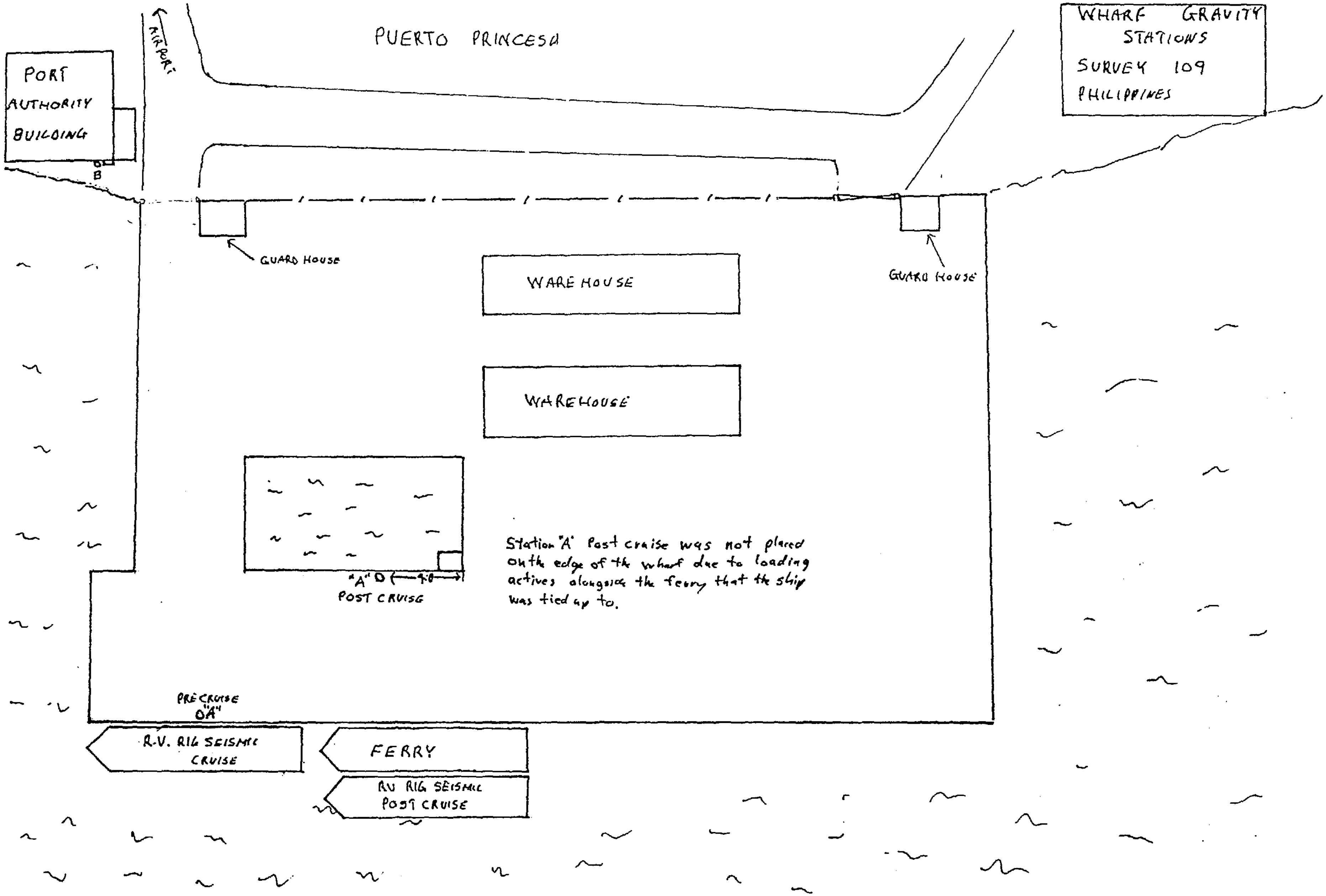
STATION	TIME	READING	INSTR TEMP °C	LATITUDE	LONGITUDE	REMARKS
A. Wharf.	0701	636:30				2.4 m. wharf ht.
B. Pt. Authority	0711	636:80				
C New terminal	0732	604:20				Puerto Princesa Airport
D Old terminal	0745	603:80				Puerto Princesa Airport
A. Wharf	0805	635:00				2.4 m. wharf ht.
B. Pt. Authority	0812	636:90				
C. New Terminal	0825	603:30				
D. Old Terminal	0832	602:20				
A. Wharf.	0854	633:30				3.2 m. Wharf ht
B. Pt. Authority	0902	635:50				

PUERTO PRINCESA AIRPORT

Observations were made behind a wall on the western side of the departu gates. Another set of observations were made on the remnants of the slab of the old terminal building.



Distances Aproximate


WHARF GRAVITY STATIONS
SURVEY 109
PHILIPPINES
PUERTO PRINCESA
AIRPORT
PORT AUTHORITY BUILDING
B
GUARD HOUSE
GUARD HOUSE
WAREHOUSE
WAREHOUSE
"A" POST CRUISE
Station "A" Post cruise was not placed on the edge of the wharf due to loading actives alongside the ferry that the ship was tied up to.
PRE CRUISE "A"
R.V. RIG SEISMIC CRUISE
FERRY
RV RIG SEISMIC POST CRUISE

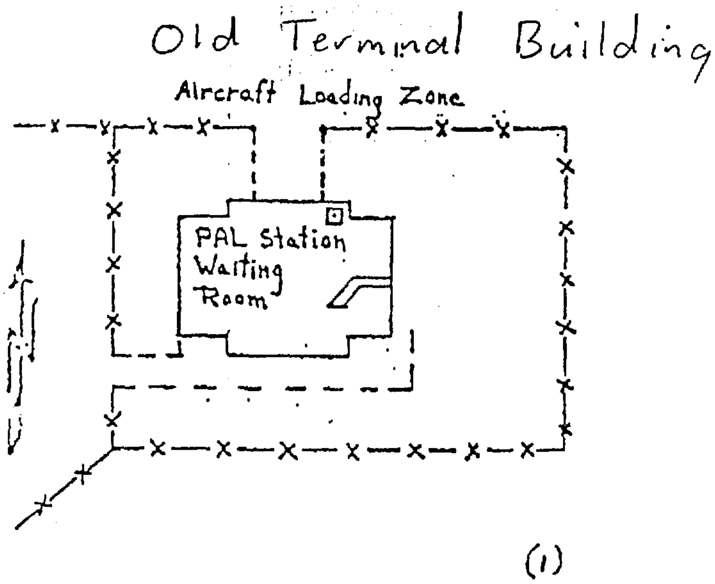
GRAVITY BASE STATION

TUDE 09° 45'N (1)	STATION DESIGNATION
ITUDE 118° 45'E (1)	PUERTO PRINCESA
ATION 6.1 METERS (1)	COUNTRY/STATE Philippines
REFERENCE CODE NUMBERS	ADOPTED GRAVITY VALUE
3705-1	g= 978 236.64 mgals
02598J	IGSN-71 978 223.00
	ESTIMATED ACCURACY ± 0.3 mgals
	DATE MONTH/YEAR 7/70

IPTION AND/OR SKETCH

IGSN-71 978 223.00.

rvations were made at Puerto Princesa Airport at the north entrance to the station in line with the north wall, on the concrete floor, about 0.5 foot e ground level. (1)



Appendix 8: CREW LIST

A. Codrington	Master
T. Walters	Mate
M. Gusterson	2nd Mate
C. Hellier	extra 2nd Mate
R. Thomas	Chief Engineer
I. McCarthy	2nd Engineer
P. Jiear	Electrician
T. Dale	A.B.
D. Kane	A.B.
G. Pretsel	A.B.
P. Morcombe	E.R.A.
B. Fowler	Chief Steward
G. Conley	Cook
M. Perrett	Steward
M. Cumner	Steward/Seaman
C-S. Lee	Chief Scientist
D. Ramsay	Co-Chief Scientist
H. Miller	Systems Scientist
L. Kalinisan	Systems Scientist
J. Bishop	Geochemist
C. Tindall	T.O. Science
T. McNamara	T.O. Science
J. Bedford	T.O. Science
F. Stradwick	T.O. Science
A. Hunter	T.O. Science
L. Hatch	T.O. Science
D. Holdway	T.O. Electronics
C. Saroch	T.O. Electronics
M. James	T.O. Mechanical
B. Dickinson	T.O. Mechanical (till 23 April)
A. Radley	T.O. Mechanical
C. Dyke	T.O. Mechanical
J. Vickery	Technical Specialist (Mechanical)
R. Apostol	Filipino Scientist (OEA)
E. Guazon	Filipino Scientist (OEA)
N. Trinidad	Filipino Scientist (OEA)
D. Panganiban	Filipino Scientist (OEA)
D. Carlos	Filipino Scientist (Basic Petroleum, till 11 April)
I. Hawkshaw	AIDAB Representative (11 - 23 April)