A preliminary result of the Ragay Gulf survey in the Philippines

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Abstract: During March-May 1992, the Australian Geological Survey Organisation and the Philippine Office of Energy Affairs conducted a cooperative marine seismic, gravity, magnetic, bathymetry and geochemical "sniffer" survey in four offshore Philippine basins: NE Palawan, Cuyo Platform, Tayabas Bay and Ragay Gulf. The project was funded by the Australian International Development Assistance Bureau. The survey work was conducted using the Australian Government's geoscientific vessel, *Rig Seismic*.

The cruise achieved all its objectives and was a major success. Of the four survey areas, the Ragay Gulf is of particular interest, with complex structures, multi-phase tectonism and massive sediment infill. It was in this region that many geochemical "sniffer" seeps were located.

The geochemical "sniffer" data and its C-13 and C-14 isotope analyses have indicated the presence of significant source rocks. These seeps are thermogenic in origin and have reached sufficient maturity to generate significant quantities of hydrocarbons. In the near future, the geochemical data will be integrated with the seismic data to provide clues for hydrocarbon migration.

The preliminary seismic interpretation have revealed the existence of five sedimentary sub-basins with 2.5 - 5 seconds of Eocene to Recent sediments. Several types of potential traps were documented.

No well has been drilled in the offshore Ragay Gulf. Onshore well log information and stratigraphy have assisted in the correlation and interpretation of offshore seismic data. In addition, the importance of the carbonate and clastic reservoirs was recognised.

Overall, the oil and gas potential in the Ragay Gulf area looks most encouraging.

INTRODUCTION

The Philippines is currently energy deficient but recent studies and exploration results (i.e. the discoveries of West Linapacan, Malampaya and Octon oil/gas fields) indicate potential oil and gas reserves exist in offshore Philippine basins. The Government of the Philippines has decided to actively promote oil and gas exploration activity in the country. They have identified the tectonic complexity and the lack of geoscientific information as contributing to the low level of petroleum exploration in the majority of the 13 identified offshore basins. As the result, the Philippine Government has requested the Australian Government to assist in the form of a comprehensive offshore seismic survey in selected potential oil-bearing basins.

The Philippine Marine Seismic Survey Project is being conducted by the Australian Geological Survey Organisation (AGSO, formerly the Bureau of Mineral Resources) in conjunction with the Philippine Office of Energy Affairs (OEA) under the funding from the Australian International Development Assistance Bureau (AIDAB).

The project has two main objectives:

1) to upgrade the knowledge of petroleum prospectivity of selected areas in the Philippines and to promote potential opportunities for future Philippines-Australia joint venture exploration; and
2) to assist the Philippine Government to acquire the skills to obtain and interpret seismic data and other petroleum source-related information, and use these to focus future petroleum exploration in Philippine waters.

A joint consultative group consisting of 15 Australian and 15 Philippine companies was formed to provide the project with technical advice. This group has had, and will continue to have, a significant input into the technical aspects of the project.

During March-May 1992, the AGSO in conjunction with OEA have conducted a geophysical and geochemical survey in the Philippines using the Australian research vessel, *Rig Seismic* (Fig. 1). This ship has a unique capability to simultaneously collect seismic, gravity, magnetic, bathymetry and bottom-water geochemical "sniffer" (direct hydrocarbon detection) data; the ship also has the capacity to conduct various forms of geological sampling.

A total of 2,950 km of seismic and magnetic data was obtained during a 45-day cruise in the Philippines. In addition, some 5,000 km of geochemical, gravity and bathymetry data were obtained. The work was undertaken in four areas: the NE Palawan Shelf, Cuyo Platform, Tayabas Bay and Ragay Gulf (Fig. 2).

Overall the cruise achieved all its objectives and was a major success (Lee and Ramsay, 1992). The seismic records indicate good quality data was obtained in most areas. The Ragay Gulf is of particular interest, with complex structures and sedimentary deposition centres of up to 5,000 m thick. It was in this region that many geochemical "sniffer" seeps were located (Bishop *et al.*, 1992; Evans *et al.*, 1992).

The newly acquired data are being processed at AGSO, integrated with existing seismic and well data, and interpreted and analysed for petroleum potential. The final analysis, together with basic data, will first be presented in the Philippines and Australia and later internationally, to promote further exploration. This report is one of the promotional papers and deals with the preliminary results of the Ragay Gulf survey.

STRATIGRAPHY

The Ragay Gulf is bounded to the east by the Bicol Peninsula and to the west by the Bondoc Peninsula (Fig. 3). The stratigraphy of Bondoc Peninsula has the greatest relevance to the sequence underlying Ragay Gulf and Tayabas Bay.

Our knowledge of the stratigraphy is based on limited number of maps and reports from oil and mineral companies as well as data from the wells drilled in the peninsula. Despite 25 wells having been drilled on the peninsula, 16 are less than 1,000 m deep, only five exceed 1,500 m and two exceed 2,000 m deep. Just four wells, Katumbo Creek 1, San Francisco 1, 2 and Mayantok 1, have a complete suite of logs. Two wells, Aurora 1, 2,088 m and Aurora 2, 1,103 m, which were drilled in 1970, probably had a modern suite of logs run but no logs or reports on either well have been located. These wells, together with San Francisco 1 and 2, were drilled less than 1 km apart and would have provided a good measure of stratigraphic lateral continuity.

From the lithological descriptions of the field outcrops (Antonio 1961; Yap, 1972; Poblete and Ferrer, 1990) and the information from the World Bank Report (BED, 1986), a description of lithology has been assembled. The stratigraphy is summarised in Fig. 4.

Basement

The basement consists of hornblende schists with scattered quartz veins. These are locally foliated. Alteration to chlorite and epidote is common. No estimation of thickness has been possible. Age is pre-Miocene to possibly pre-Tertiary.

Unisan Formation

Unconformably overlying the basement schists is the Unisan Formation. It consists of volcanoclastic carbonate breccia composed of fine-grained porphyritic volcanics and tuffs together with penecontemporaneous tuffaceous silty carbonates containing rich foraminifera. The thickness of the unit is unknown. In Katumbo Creek well, it shows close petrographic affinities in composition, texture and alteration to the outcrop samples from northern Bondoc (BED, 1986). The age is late Eocene to late Oligocene, probably in range P15-P19.

Panaon Limestone

The Panaon Limestone unconformably overlies the Unisan Formation. It consists of limestone which varies from dense crystalline with coralline relics to completely recrystallised limestone. Toward the south of the Peninsula this carbonate unit, if present, is deeply buried and beyond economically drillable depths. However its age equivalent, the Malakawang Limestone, crops out over Burias and Templo Islands. It is, therefore, highly probable that the facies extends along, and adjacent to, the Alabat-Burias Ridge, under Ragay Gulf, at economically drillable depths.

Thickness is estimated to be 500-1,000 m. It is thought to be highly variable in thickness and locally lenticular. It was deposited in shallow marine conditions in the Late Oligocene to Early Miocene N3/P22-N7.

Vigo Formation

The Vigo Formation (Gumaca Formation of Antonio, 1961; Yap, 1972) outcrops along the length of the axis of Bondoc Peninsula. It has been subdivided into upper and lower parts. Relations with the underlying Panaon Limestone vary from conformable to unconformable. Geochemical analyses (BED, 1986) of well cuttings and outcrop samples show the Vigo to have significant hydrocarbon source potential.

The *Lower Vigo Formation* consists predominantly of alternating sandstone and shale with, especially near its base, lenses of limestone up to 10 m thick, conglomerates and volcanic interbeds apparently in up to five separate horizons. Locally, carbonaceous silts, shales and coal seams occur. The conglomerates contain pebbles of schists, volcanic rocks and limestone.

Figure 1. Australian geoscientific research vessel, Rig Seismic.

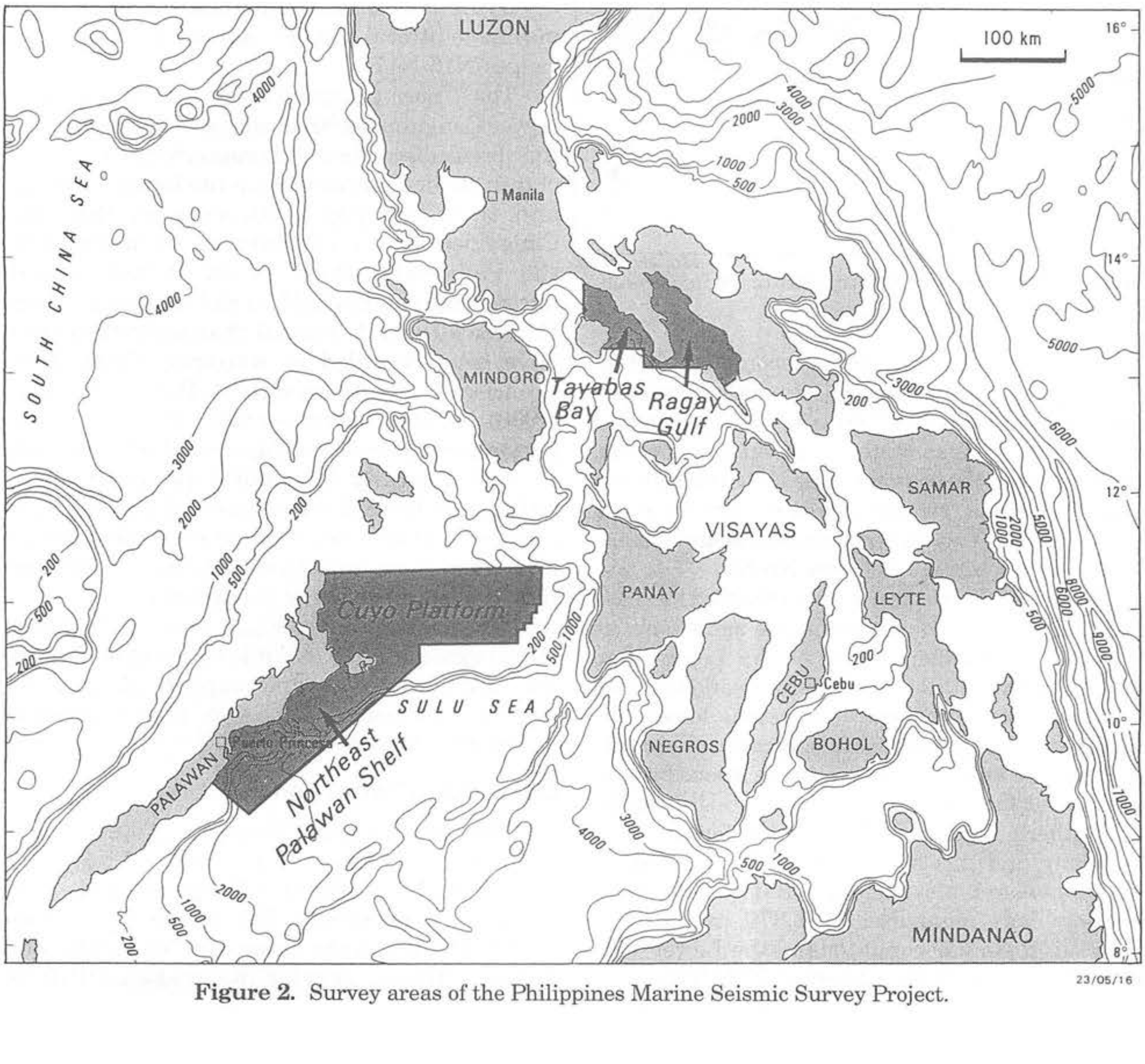


Figure 2. Survey areas of the Philippines Marine Seismic Survey Project.

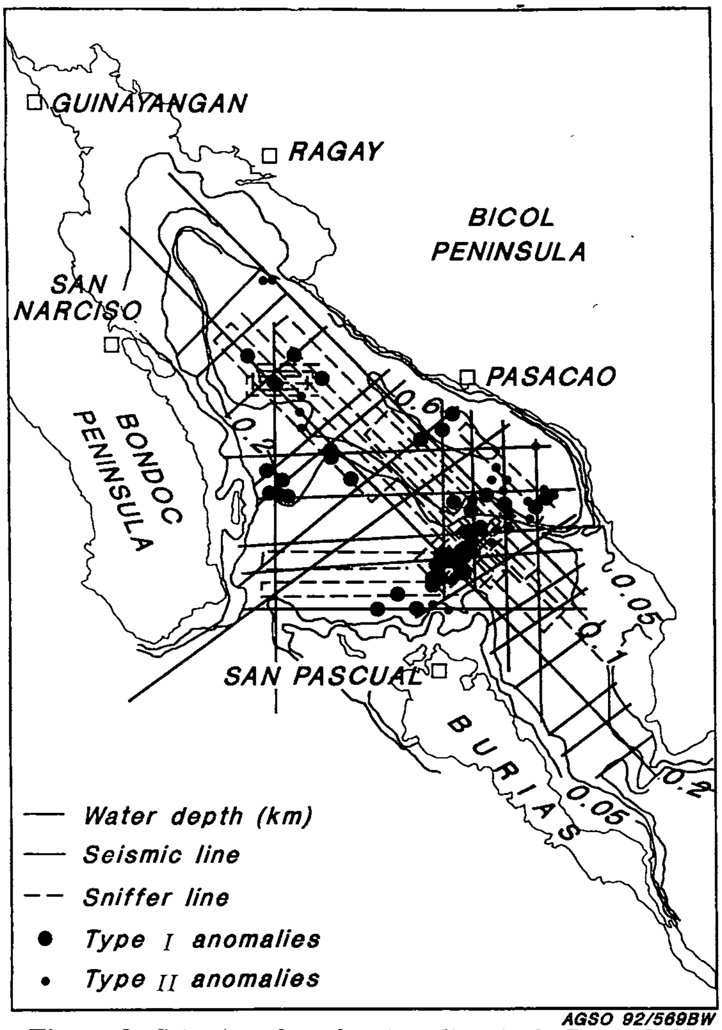


Figure 3. Seismic and geochemistry lines in the Ragay Gulf. Location of geochemical "sniffer" anomalies.

Thickness of the unit in its incomplete section is 2,840 m but the total thickness was estimated at 3,000-4,000 m (Antonio, 1961). It was deposited in an environment that varied from shallow marine, as evident from the common limestone throughout, to coastal paludal swamps, as is evident from the thin coal seams and carbonaceous silts and shales. Age is earliest Middle Miocene N8-N9.

Upper Vigo Formation shows a marked increase in the proportion of conglomerate-sandstone as compared to sandstone-shale of the Lower Vigo Formation. Individual conglomerate-sand beds are commonly over 1 m thick. Limestone lenses are scattered throughout the section. Volcanic interbeds are known from several locations but are restricted to the northwest near Pitago-Unisan. In the Southern Bondoc Peninsula, the formation is less sandy and has been termed the Vigo Shale (Hashimoto and Matsumaru, 1981). Maximum thickness was measured at 1,870 m. It was deposited in similar conditions to the Lower Vigo Formation in the Middle Miocene N10-N14.

Canguinsa Formation

The Canguinsa Formation overlies the Vigo Formation with a marked angular unconformity. It is subdivided into an upper and lower part (Lopez and Hondagua Formations respectively of Antonio 1961; Yap, 1972).

The lower part of the *Lower Canguinsa Formation* consists of cross-bedded sandstone and poorly sorted conglomerate with interbedded grey shale, siltstone and dark coloured sandstone. Carbonaceous streaks occur throughout. The conglomerate contains quartz, schists, igneous rocks, limestone, some hard siltstone and sandstone with finer grains of quartz schist and igneous rock fragments. In the upper part, the conglomerate is lighter in colour, calcareous and contains mica flakes but little carbonaceous materials.

Maximum recorded thickness is 1,490 m in Bondoc 3 but similar thicknesses have been measured in the field in northern Bondoc. As with the Vigo Formation the presence of limestones and thin coals and carbonaceous silts and shales indicate a varying depositional environment from shallow marine to littoral-paralic. Age is Late Miocene and ranges N16-N17.

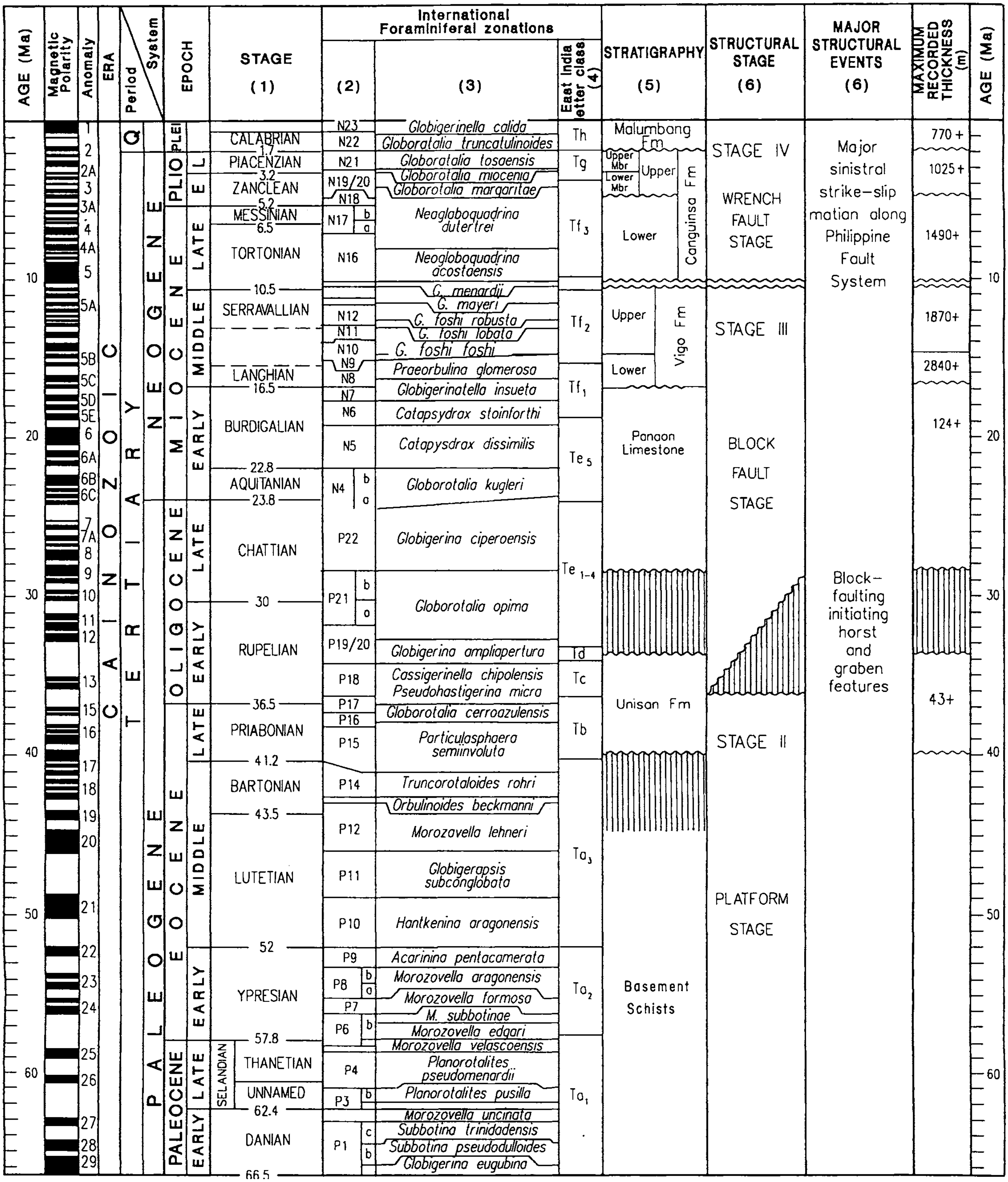
The *Upper Canguinsa Formation* overlies the Lower Canguinsa with no angular unconformity. A time break disconformity is suggested by the absence of thin shelled megafossils in the Lower Canguinsa and their common occurrence in the Upper Canguinsa. South of Buenavista, on the east side of the Peninsula, there is an obvious angular unconformity in the field as well as changes in San Francisco 1 and 2. Faunal changes in the cuttings have been recorded in Katumbo Creek 1, San Francisco 1, 2 and Mayantok 1. Poblete and Ferrer (1990) believe the provenance of the Canguinsa Formation was from the Tayabas-Marinduque area.

Lithologically it consists predominantly of indistinctly bedded calcareous and micaceous, buff coloured siltstone interbedded with thin mudstone layers and some limestone. There are conspicuous thin shelled megafossils throughout.

The maximum thickness claimed by Antonio (1961) exceeds 1,025 m but is believed to thicken to the southeast. The unit appears to have been deposited exclusively in shallow marine conditions during the Pliocene N18-N21.

Malumbang Formation

The Malumbang Formation (Catanauan Limestone of Antonio, 1961; Yap, 1972) unconformably overlies the Canguinsa and all older units as a relatively flat drape. It consists predominantly, in the *lower part*, of chalky white, porous, dense, crystalline megafossiliferous



1. Berggren *et al.* (1985a, b), Burger (in prep., a & b)
2. Blow (1969, 1979), Berggren (1969)
3. Bolli (1957a & b, 1966), Stainforth *et al.* (1975), Bolli & Premoli-Silva (1973), Caron (1985)
4. Adams (1984), Adams *et al.* (1986), Chaproniere (1981, 1983), Jenkins *et al.* (1985)
5. Antonio (1961), Yap (1972), OEA (1988)
6. BED (1986)

Figure 4. Stratigraphy of Bondoc Peninsula.

limestone. In the *middle part* there is a sequence of silty to shaly calcareous sandstone with limestone interbeds. In the *upper part* it consists of porous, gently dipping limestone. In the south, this threefold subdivision is not evident. The Malumbang Formation is generally a very shallow marine carbonate complex with the lithology varying from reefal limestone to detrital carbonates and some clastic facies.

Maximum recorded thickness is about 770 m and age is Pleistocene, N22-N23.

LITHOLOGY IDENTIFICATION FROM WELL LOGS

There is a major problem in interpreting the original logs because of the high proportion of clay, volcanogenic rock fragments and Fe-Mg minerals together with the lack of quartz and radioactive minerals. This results in the gamma ray only varying in the range 15-45 API units with no consistent pattern of variation between sands, shales and coals. Only minimal variation is recorded on the resistivity logs and FDC-CNL logs do not follow the pattern on variation which characterises rocks derived from a more mature granitic or quartzose provenance. Attempts to match calliper, gamma, SP, DT, FDC and CNL responses with lithology using conventional methods has shown no apparent consistency.

In an attempt to identify lithologies from the logs, the logs were digitised and redisplayed at magnified scales as follows:

- the calliper was displayed at 6-16 inches together with the gamma ray which was displayed at 1-50 API units;
- the induction or short normal was displayed at logarithmic 0.6-10 or 0.5-20 together with the DT displayed at 260-60 or 250-50, and;
- the NPHI was redisplayed in porosity units and at 0.5-0.1 together with the FDC which was also redisplayed in porosity units 0.65-0.05.

This allowed identification, especially in the San Francisco wells, of:

1) Limestones and carbonate cemented sands which showed low gamma values, high resistivity, high sonic, and low neutron and density porosity. The carbonate cemented sands were particularly evident in the Vigo Formation of the San Francisco wells.
2) Non-carbonate cemented sands showed low gamma, moderate resistivity, very low neutron porosity and low density porosity. The relatively lower neutron porosity was thought to be due to the high content of clay, unstable basic igneous material and Fe-Mg rich minerals.
3) Siltstones and fine to very fine sands could not be differentiated, presumably due to the high clay, basic rock fragments and Fe-Mg mineral content.
4) No coals were identified which was presumed to be due to coal and coaly intervals being thinner than resolution of the logging tools.

In the Canguinsa interval of San Francisco 1 and 2 and the Canguinsa and Vigo intervals of Katumbo Creek 1 and Mayantok 1, thin limestone was evident from spikes on the resistivity and DT but little other lithological differentiation could be recognised. This was thought to be due to the high clay and carbonate content. This was despite, in the case of the Canguinsa section of the San Francisco wells, the mudlog clearly showing fine-medium and fine-coarse sandstone in 10-60% of each logged interval.

RESERVOIRS

Evaluating the reservoir potential of the sequence is essentially conjectural as only four fully logged wells were available. Both carbonate and clastic reservoirs with suitable porosities are to be expected beneath Ragay Gulf. Outcrop geology of Bondoc Peninsula shows that carbonate sequences of significant thickness are present in the Panaon Limestone, the base of the Lower Vigo Formation and in the Malumbang Formation. Thinner carbonates are present in the Vigo and Canguinsa Formations. Clastic reservoirs are possible in the Lower Canguinsa and Lower Vigo Formations.

Carbonate Reservoirs

1) The *Panaon Limestone* occurs overlying the basement outcrops near Lian Point of the Northwest Ragay Gulf and the Panaon equivalent, the Malakawang Limestone, is known to exist on Burias and Templo Islands. Seismic evidence shows a high amplitude event at shallow to moderate depth along the length of the Alabat-Burias Ridge and adjacent. The Panaon-Malakawang Limestone can be followed throughout much of Ragay Gulf where it is characterised by a high amplitude event that underlies the comparatively bland Vigo interval. The Panaon event is variable in thickness but consistently characterised by a high amplitude event. It is found at 0.8-1 second depth along the crest and 1-1.5 seconds down the flanks of the Alabat-Burias Ridge where it is at readily drillable depth. Careful analysis of the seismic, including specialised processing may produce events that reflect variation in porosity within the carbonate.

2) The *Vigo Formation* carbonates that are around 10 m thick in outcrop may also occur offshore but have not yet been identified with confidence on

the seismic.

3) The *Upper Canguinsa Formation* carbonates, although very young, and not overlain by seals onshore, may provide sealed reservoirs offshore where the thickness of the Canguinsa increases and is overlain by up to a half a second of sediments. These have optimum attraction in deeper parts of the trough where the thickness of cover is greatest.

Clastic Reservoirs

From the outcrop geology and well data, clastic reservoirs are likely to be found in the Lower Canguinsa and Lower Vigo Formations. Despite outcrop descriptions of quartz rich sands, well data indicates these are generally volcano-clastic Fe-Mg rich reservoirs with only about 10-15% quartz. Furthermore where encountered in the San Francisco wells, they were all too often carbonate cemented with high resistivity and sonic values. In Mayantok 1, maximum sand grain size is only very fine to fine but Mayantok did not test the whole Vigo section and may not have drilled into the Lower Vigo. If the source of the Vigo and Canguinsa sediments was from the west, then beneath Ragay Gulf, cleaner sands may be present. However, from the geochemical evidence, the numerous seeps and the many fluorescing side wall cores in the exploration wells, it would seem highly likely that any porous sand with an effective seal could be oil or gas filled. Any drilling should be done with muds that are least likely to react with the unstable mineralogy of the clastic sands so that porosity is not occluded.

SEISMIC INTERPRETATION

Tying the stratigraphy to the onshore seismic and then linking with the offshore seismic of Ragay Gulf was done using the Mayantok 1 well and the 1988 Ran Ricks seismic. The well data was tied to the NE-SW seismic line (B-105) that passed through the Mayantok 1 well location, then correlated to the set of NW-SE tie lines that ran to the northwest toward the Bigol River area. The quality of the seismic was such that the outcrop geology had to be constantly plotted on the seismic sections to ensure the validity of the seismic interpretations. There are five SW-NE cross lines to which the seismic picks were transferred then, where possible, transferred to the offshore seismic by skip correlation.

Several vintages of lines were used in the initial offshore data interpretation, including preliminary stacks of the newly acquired AGSO/OEA lines. The overall data quality can be described as fair to good, specially the recent lines which clearly show better internal reflector characteristics of the identified major horizons. However, the quality of data greatly diminishes in areas where diapirism has taken place and in zones of extensive faulting. In both, seismic reflectors are extremely poor if not completely obliterated. Similar conditions can be observed onshore where available seismic and radar imagery data suggest a northwest-southeast trend of fault-related flower structures in Bondoc Peninsula.

No offshore well has been drilled in Ragay Gulf. The horizons were based on the general reflector characteristics and were interpreted across major structures such as faults, grabens and horst blocks which are the predominant features in the east Ragay Gulf. Six horizons were identified and tied with the onshore stratigraphy.

The *Blue horizon,* a fairly consistent deep event, appears as strong, low frequency and continuous reflection. Although generally mappable throughout the gulf area, this event is barely recognisable in reflection-free diapir zones in east of Ragay Gulf. This event is initially described here as equivalent to top of Unisan volcanics of probable Late Eocene to Early Oligocene age.

The *Green horizon,* above the blue, is equivalent to the top of the Late Oligocene-early Miocene Panaon Limestone encountered in the onshore Katumbo Creek well. Reflections are characterised by a thin chaotic event in the central ridge and a moderately divergent pattern which progressively thickens towards the deep trough. In zones of extensive step-faulting (near south tip of Bondoc Peninsula and in north of Ragay Gulf), the event is obscured.

The *Orange horizon,* a distinct event above the green, is clearly evident in some of the new AGSO/OEA data. Where it is mappable such as in the deeper part of the Ragay Gulf, this sequence is prognosed to be the equivalent to the top of the Middle Miocene Lower Vigo Formation.

The *Red horizon,* a major unconformity, separates the Middle Miocene Upper Vigo from the overlying Late Miocene Lower Canguinsa Formation. This unconformity differentiates two depositional sequences which show similar internal stratal configurations although the red event overlies a discontinuous sequence which becomes progressively continuous toward the troughs. As with the underlying green event, the red event onlaps the blue in the central ridge, close to where the sediments outcrop as shallow reefs and islets.

The *Yellow horizon* represents the internal boundary between the Upper and Lower members of the Canguinsa Formation but there is little distinction between the two sequences. Both are characterised by very continuous, high amplitude and medium to high frequency reflections although the lower event appears less continuous in some part. This event is conspicuously absent over structural highs. Its absence farther south of the Bondoc Peninsula suggests that the formation is confined to Ragay Gulf and onshore Bondoc.

The top *Pink horizon* which is confined in the deep Ragay Gulf separates the Canguinsa from the recent sedimentary accumulation with materials probably derived from the regional uplift and erosion during the Pleistocene. This is interpreted as the top of the Upper Canguinsa and the base of Malumbang Formation.

OFFSHORE SEDIMENTARY BASINS

Five sedimentary sub-basins have been identified (Fig. 5), occurring on both sides of the Alabat-Burias Ridge that passes northwest-southeast through the middle of Ragay Gulf. This ridge is bounded on both sides by the Philippine fault system. The Capuluan, Ragay and Burias sub-basins form a major elongate depositional terrace west of the central ridge. On the other side, the shallow Peris sub-basin joins the much deeper Bondoc sub-basin to the south, forming the other major depositional centre that extends to onshore Bondoc Peninsula.

The *Bondoc Sub-basin* contains possible Eocene to Recent sediments with up to 3 seconds of fill south of Alibijaban Island. This sedimentary basin thickens onshore toward the southeast part of the Bondoc Peninsula and pinches out in area adjacent to the wrench fault-related flower structures along the major Philippine fault system passing through the peninsula. These flower structures can be observed in radar imagery data (ARCI, 1988) although not clearly visible in the Landsat 5 satellite imagery data. Here the Panaon Limestone (green horizon) is very thick (Fig. 6) which is suggestive of considerable subsidence during the Oligocene time The Malumbang Formation (pink horizon) is missing, indicating a major period of uplift and erosion during the Pliocene-Pleistocene time when movement along the Philippine fault system had shifted to the south (Bischke *et al.*, 1989; Sarewitz and Lewis, 1991).

The entirely offshore *Ragay Sub-basin* covers more than 150 km of the deep trough along the east of the Alabat-Burias Ridge. To the north, it is separated from the Capuluan Sub-basin by a ridge and to the south, it pinches out near the edge of the Bicol Peninsula. Sediments thicken to about 5 seconds towards the middle of the deep trough. Here the interpreted Oligocene Panaon Limestone is relatively thin compared to that in Bondoc sub-basin (Fig. 7), suggesting a major shift in regional tectonics and subsequent sedimentation during late Oligocene to Early Miocene. Carbonate build-ups appear to have been developed within the Panaon Limestone, as is evident from the reef-like patterns. In the deeper part of the trough, there exists a series of diapir structures composed mainly of low velocity materials (i.e. clay or mud). Distinguishing the low velocity reflectors from the sea bottom multiples in velocity analysis for processing is difficult and nearly all the processing techniques done so far have failed to identify and remove the multiples.

The *Burias Sub-basin*, a relatively smaller basin northeast of the Burias Island, has maximum sediments of up to 2 seconds. The Oligocene Panaon Limestone varies in thickness and depth with probable carbonate build-ups observable within.

North of Ragay Gulf, the *Capuluan Sub-basin* extends onshore with maximum measured thickness of up to 2.5 seconds. Complex tectonics have resulted in a series of tilted fault blocks in the sub-basin. The interpreted structural high, possibly a sub-branch of the Philippine fault system, separates it from the *Peris Sub-basin* to the west. Tectonics and sediment infill are similar in both. Wrench related flower structures are present onshore where the Peris sub-basin truncated.

The entire Ragay Gulf was classified as a back-arc basin modified by strike-slip wrenching along the Philippine fault system which cuts through its central portions (BED, 1986). It consists of elongate NW-trending ridges and sub-basins formed by several phases of tectonic evolution. Early studies done on the area have indicated a two phase tectonism for Ragay Gulf: block faulting in the Oligocene to Middle Miocene and wrench deformation in the Late Miocene and younger. The seismic interpretation supports a more complicated geohistory.

GEOCHEMISTRY RESULTS

Field observations of geochemical "sniffer" program on board the R/V *Rig Seismic* showed minor oil/gas seeps over the NE Palawan Shelf and major ones in Ragay Gulf (Lee and Ramsay, 1992). Those in Ragay Gulf appear to be related to major faulting and/or deep diapiric structures. Some of these structures (i.e. Alibijaban, R-1 and R-2 prospects) were originally identified in previous reports by exploration companies and in the World Bank Report (BED, 1986), while new structures and seeps have been identified by the current program (Fig. 3).

Two types of geochemical anomalies have been observed (Bishop *et al.*, 1992). Type I is characterised by high concentrations of methane, ethane and propane with traces of butanes and

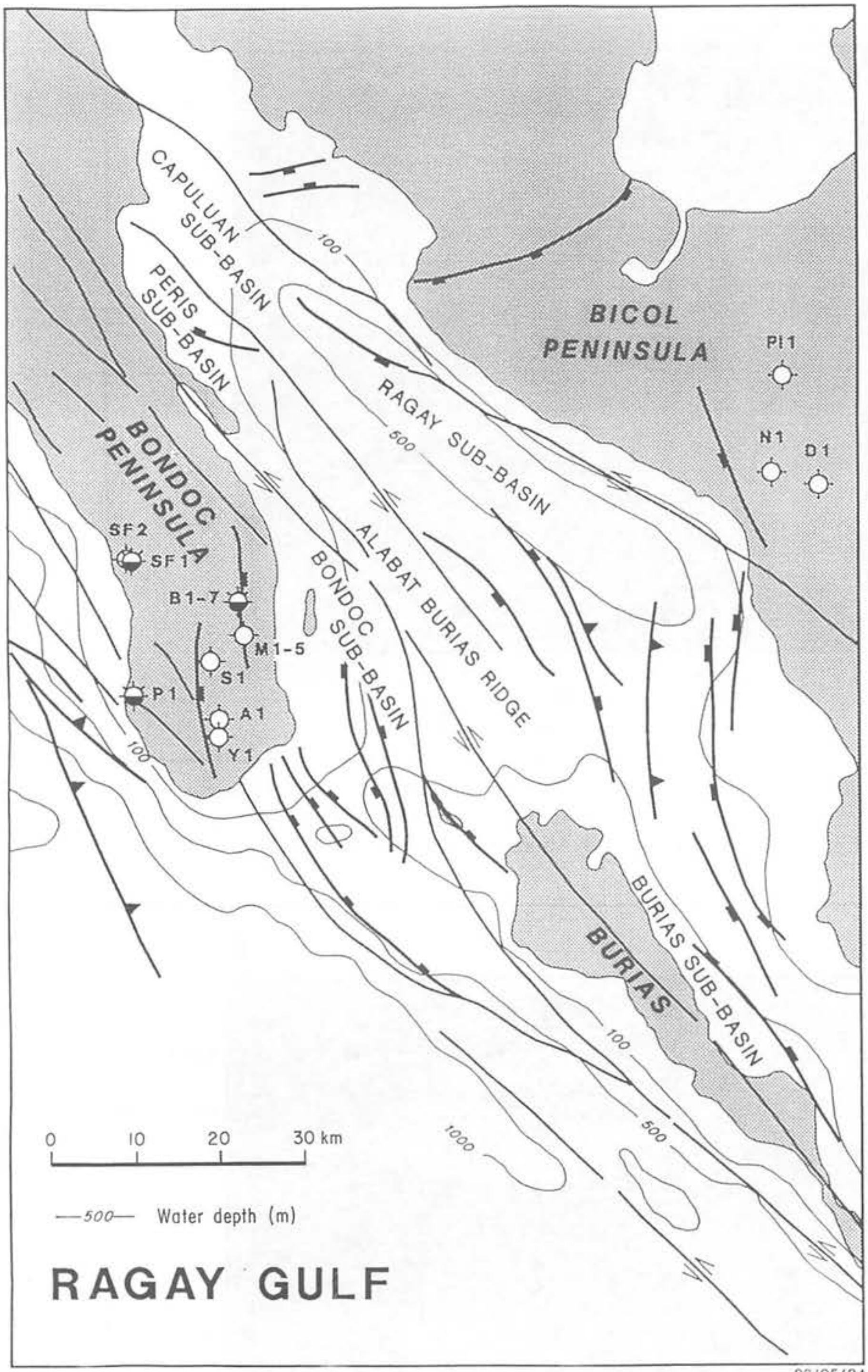


Figure 5. Structural framework of Ragay Gulf showing location of 5 sedimentary sub-basins and the Alabat-Burias ridge. Bendoc Peninsula well names are: Amoguis, A; Bondoc, B; Maglihi, M; San Francisco, SF; Sapa, S; Yeeban, Y. Bicol Peninsula well names: Pili, Pl; Sto Domingo, D; Sto Nino, N.

pentanes. Hydrocarbon wetness values (% wetness= (C2+C3+C4)/ (C1+C2+C3+C4) x 100) are 1-1.5%. These are referred to as wet gas anomalies. Type II, known as dry gas anomalies, are characterised by high concentrations of methane, with only traces of ethane. Hydrocarbon wetness values are <0.5%.

The differences between these two types of anomalies are shown in cross-plots of percent hydrocarbon wetness versus methane concentration (Fig. 8). The trends in these plots may be used to predict the hydrocarbon "source" (i.e. dry gas, gas-condensate and liquid prone), which produce the geochemical anomalies. Type I, increasing wetness with increasing methane, suggested the hydrocarbons are sourced from gas-condensate rocks or accumulations. Type II, decreasing wetness with increasing methane, are indicative of either dry thermogenic gas or biogenic hydrocarbons.

In order to help clarify the "origin", whether thermogenic or biogenic, 25 gas samples were sent to the New Zealand National Institute of Water and Atmospheric Research Limited for C-13 isotopic analyses and subsequently 8 of them were selected for additional C-14 analyses.

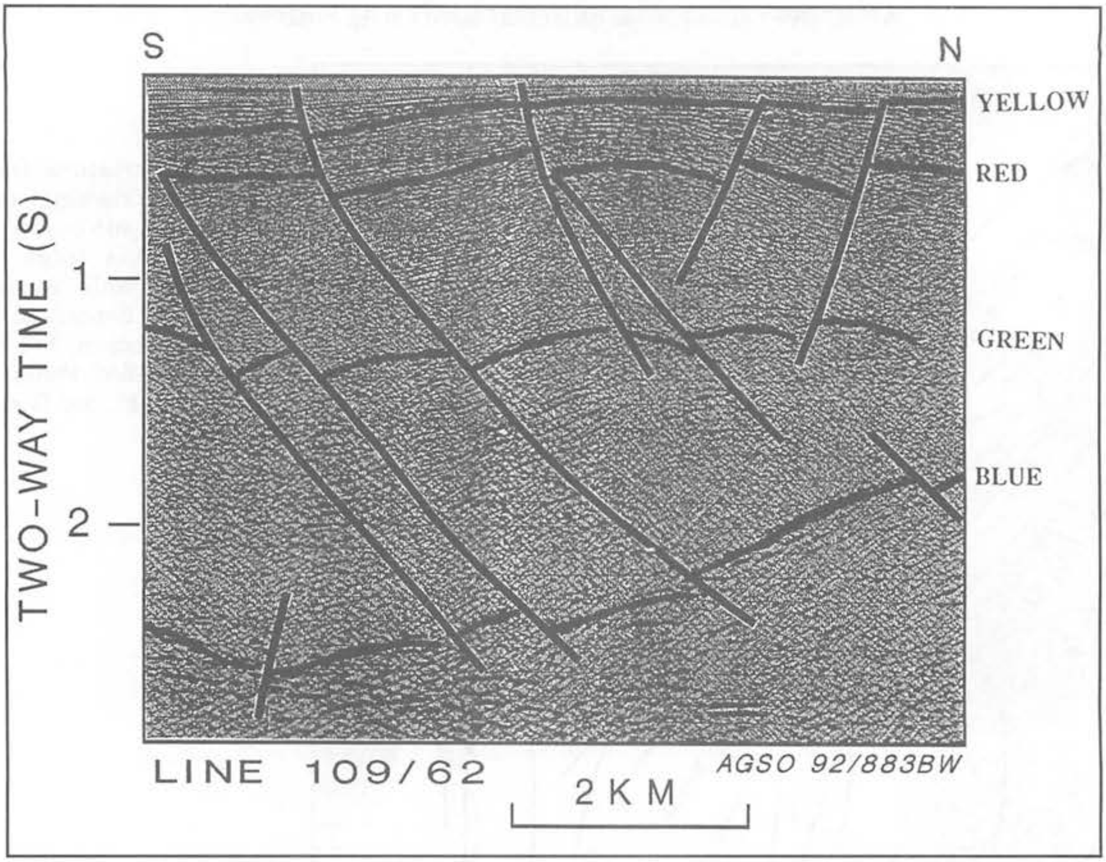


Figure 6. Seismic interpretation in the Bondoc Sub-basin, Line 109/62. Pink:Pliocene Upper Canguinsa Fm equivalent; Yellow:Late Miocene Lower Canguinsa Fm equivalent; Red:Middle Miocene Vigo Fm equivalent; Green:Late Oligocene-Early Miocene Panaon Lst equivalent; Blue:Eocene-Early Oligocene Unisan Fm.

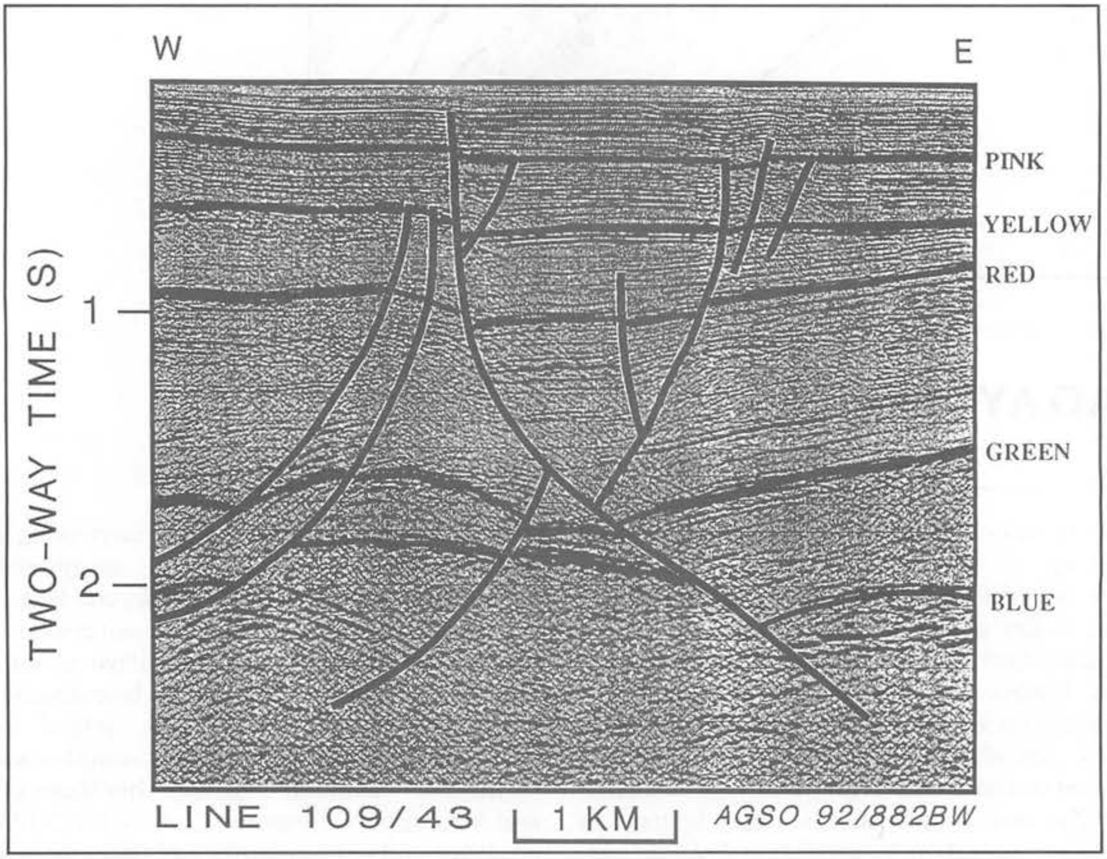


Figure 7. Seismic interpretation in the Ragay Sub-basin, Line 109/43. Pink:Pliocene Upper Canguinsa Fm equivalent; Yellow:Late Miocene Lower Canguinsa Fm equivalent; Red:Middle Miocene Vigo Fm equivalent; Green:Late Oligocene-Early Miocene Panaon Lst equivalent; Blue:Eocene-Early Oligocene Unisan Fm.

The C-13 analyses showed that most samples are of a thermogenic origin, ranging from -57 to -38% (Evans *et al.*, 1992). According to the Bernard model (Bernard *et al.*, 1977; Rice and Claypool 1981; Claypool and Kvenvolden, 1983), all Type I anomalies (8 samples) were found to be thermogenic in origin and the Type II indicate thermogenic (7 samples), mixed thermogenic-biogenic (9 samples) and biogenic (1 sample). The C-14 measurements have further supported the evidence for a "fossil" hydrocarbon source.

According to the Tissot and Welte model (1984), both the molecular and isotopes data suggested that the geochemical anomalies may be "sourced" from gas or condensate-prone source rocks (Evans *et al.*, 1992). It is interesting to note that the adjacent onshore wells, San Francisco1 and Bondoc3, have indicated a terrestrially derived, waxy kerogen source (BED, 1986). Further analyses of probable source rocks would help to clarify the actual kerogen type and composition of the source.

CONCLUSIONS

Processing of the recently acquired AGSO/OEA seismic data is ongoing. However, the preliminary interpretation of stack sections and previous industry data in conjunction with the geochemistry data have led to following conclusions:

1. The oil and gas potential in the Ragay Gulf area looks encouraging, with many of the petroleum occurrence criteria having been satisfied.
2. From seismic interpretation, we have observed several types of potential traps:
   - structural traps (i.e. B-1 prospect),
   - stratigraphic traps (i.e. R-1 and B-2 prospects),
   - combined structural/stratigraphic traps (i.e. R-2 and Alibijaban prospects), and
   - carbonate reefal build-ups (in Ragay and Burias sub-basins).
3. The geochemistry sniffer results and the isotopic analyses from the Ragay Gulf seeps indicated:
   - the presence of significant source rocks,
   - the source rocks are of thermogenic origin,
   - they probably have reached sufficient maturity, and
   - the geochemical data will be integrated with the seismic data to provide clues for hydrocarbon migration.
4. From onshore well information, we have suggested that the target for reservoir rocks:
   - the carbonate sequences are almost certainly the primary target for reservoirs,
   - the clastic sands, although a secondary target, may be cleaner beneath Ragay Gulf and should not be overlooked, especially as gas reservoirs.

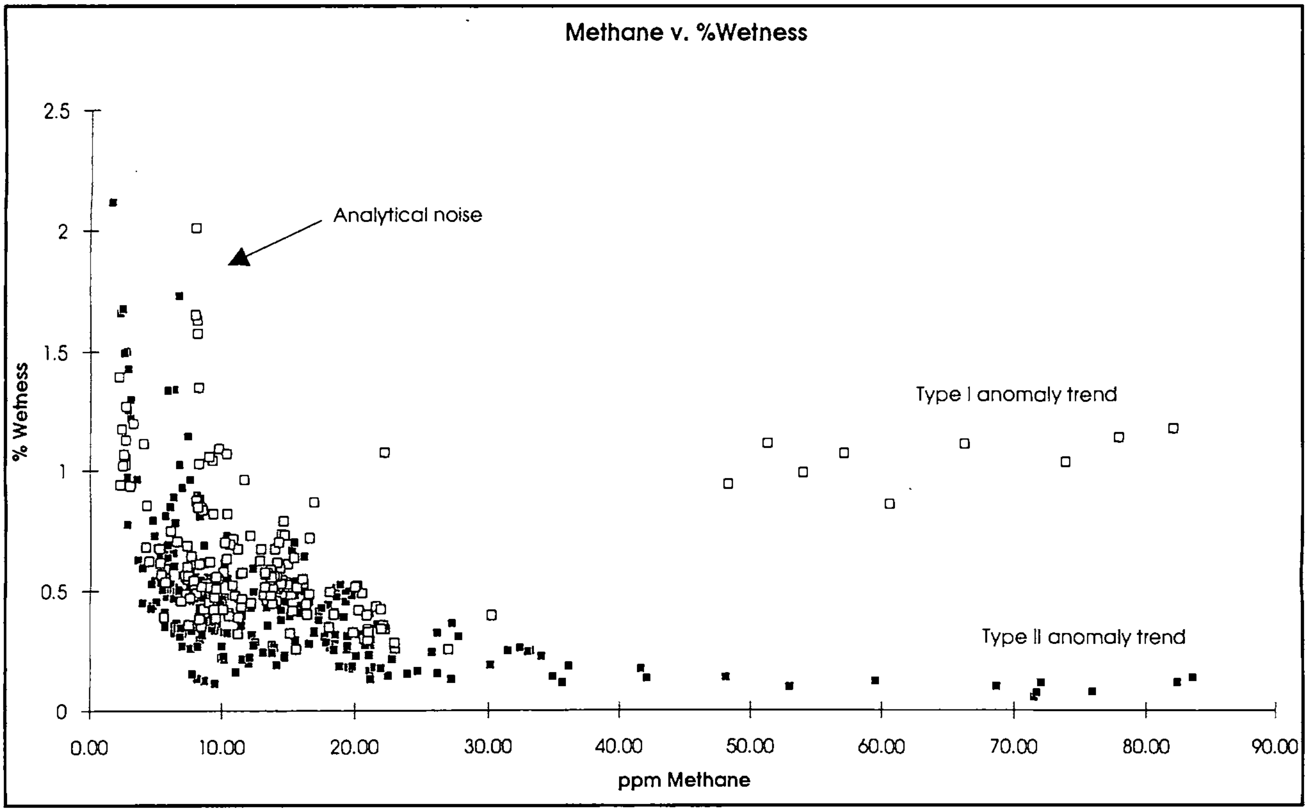


Figure 8. Methane concentration versus % wetness in the Ragay Gulf.

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