Geological Society of Malaysia – Circum-Pacific Council for Energy and Mineral Resources
Tectonic Framework and Energy Resources of the Western Margin of the Pacific Basin
November 27 – December 2, 1992, Kuala Lumpur, Malaysia

Oil, geology, and changing concepts in the Southwest Philippines (Palawan and the Sulu Sea)

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Abstract: The Southwest Philippines; Palawan, its offshore shelves, Reed Bank, and the southwestern Sulu Sea encompass 350,000 km^2 (126,000 mi^2). This region contains the better areas to search for significant oil and gas deposits in the Philippines.

The two largest oil fields yet found in the Philippines were discovered and confirmed in 1991-1992. West Linapacan field has more than 100 million barrels of recoverable oil. In June 1992, Shell Oil is reported in the Philippine press to have identified the possible occurrence of a 200 to 400 MMBO field at Camago-Malampaya about 30 km southwest of West Linapacan.

The Southwest Philippines' oil producing trend, about 40 km off the northwest coasts of Palawan and Busuanga is a northerly trending belt 200 km in length. Oil reservoirs in the Philippine fields are Oligocene to Lower Miocene platform limestones, reefs, and both silicic and carbonate turbidite sequences. A 540 km gap occurs between the Philippine production at Nido and the closest oil fields to the southwest in Sabah. Untested prospects and leads are present along the South China Sea coast of Palawan.

The southwest Sulu Sea overlies three poorly explored Tertiary sedimentary-structural basins (Balabac, Bancauan, and Sandakan basins). Geology and oil shows suggest the possible presence of commercial oil fields. Prospects and prospect leads are numerous. One well in the Malaysia sector of the Sulu Sea (Nymphe Norde 1) suggests economic potential.

Deep-water exploration targets (untested reefs and structural traps) are present in the South China Sea offshore Palawan. Large gas-condensate and oil reserves are indicated at Camago-Malampaya in 2400+ feet of water. A test of a major deep water reef prospect, Sarap-1, provided an exploration disappointment in 1991. Other major reef traps (e.g. Cliff Head) in deep water with better source rock association remain to be tested.

Besides economic interest, the Southwest Philippines has been the spawning ground of several concepts and theories about the origin and evolution of the overall region. Some theories and concepts are reviewed. The "Ulugan Bay fault" is disputed and recommended for elimination from future maps based on later field work and offshore geophysical studies. A major redefinition is an alternative.

Two schools of thought on the origin of much of Palawan are reviewed. Was continental crust from the South China Sea area subducted beneath Palawan, or is Palawan a complicated thrust pile composed in part of original crust types and early Tertiary sediments that have been thrust or emplaced to the northwest from the Sulu Sea region?

Some future exploration areas, plays, and prospects are illustrated.

INTRODUCTION

The region described herein as the Southwest Philippines (Fig. 1) encloses some 350,000 km^2 (126,00 mi^2). This region includes the principal islands of Mindoro, Palawan, and the Sulu Archipelago. It embraces a large part of the southeastern South China Sea and the Sulu Sea. Territorially, it is bounded on the southwest by Sabah, East Malaysia.

There are five general areas within the overall Southwest Philippines that are oil bearing, considered to be oil prospective, or have enough data to suggest the possibility for exploration exists (Bureau of Mines and Geosciences, 1982; Durkee, 1990). The areas are: 1) the shelf and deeper water off the northwest coast of Palawan; 2) Reed Bank in the South China Sea; 3) the shelf areas offshore Palawan and Sabah within the Sulu Sea; 4) Mindoro Island in part and adjacent marine areas to the east, south and west towards the Islands of Busuanga and Palawan; and 5) the little explored Cuyo Platform in the Sulu Sea southeast of northern Palawan.

The current oil productive part of the South China Sea, along the northwest coast of Palawan, is about 220 km (138 mi) in length (Fig. 2) (OEA,

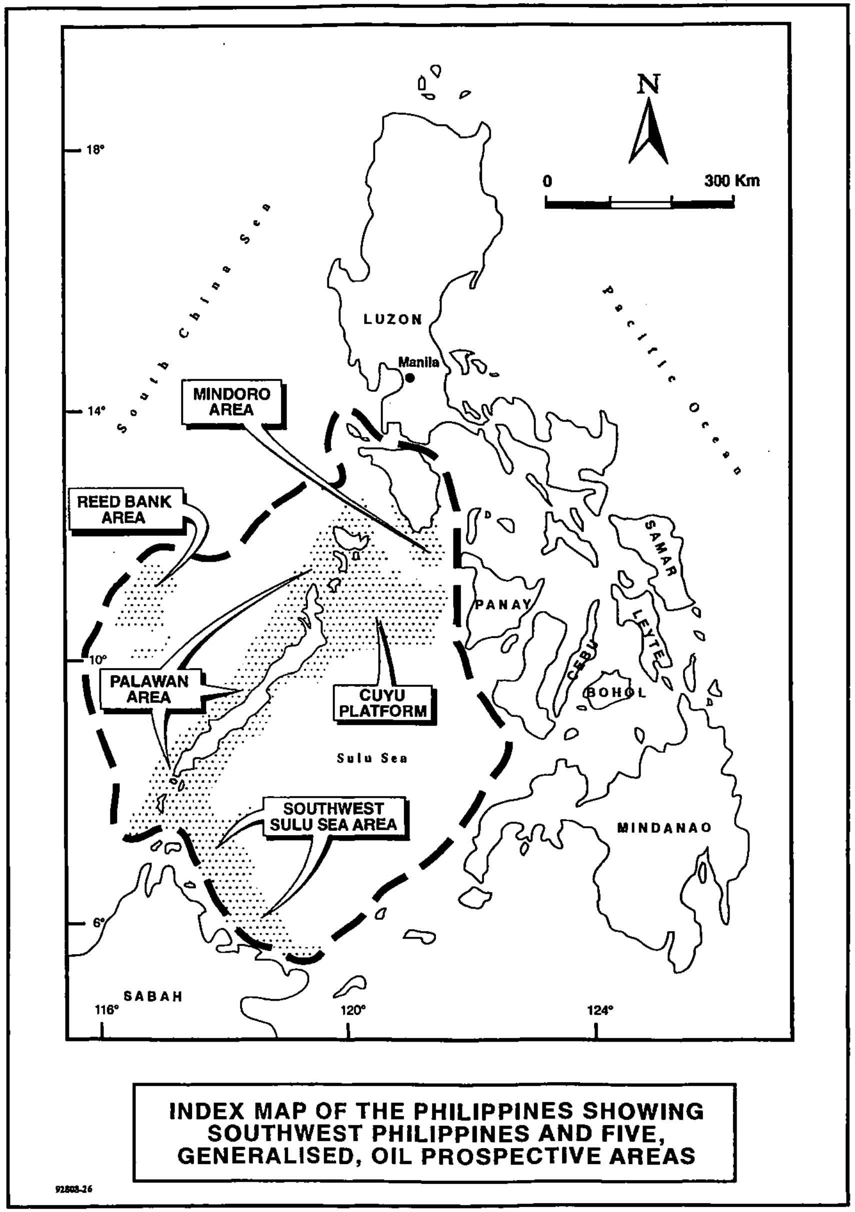


Figure 1. Index map of the Philippines showing Southwest Philippines and five, generalized, oil prospective areas.

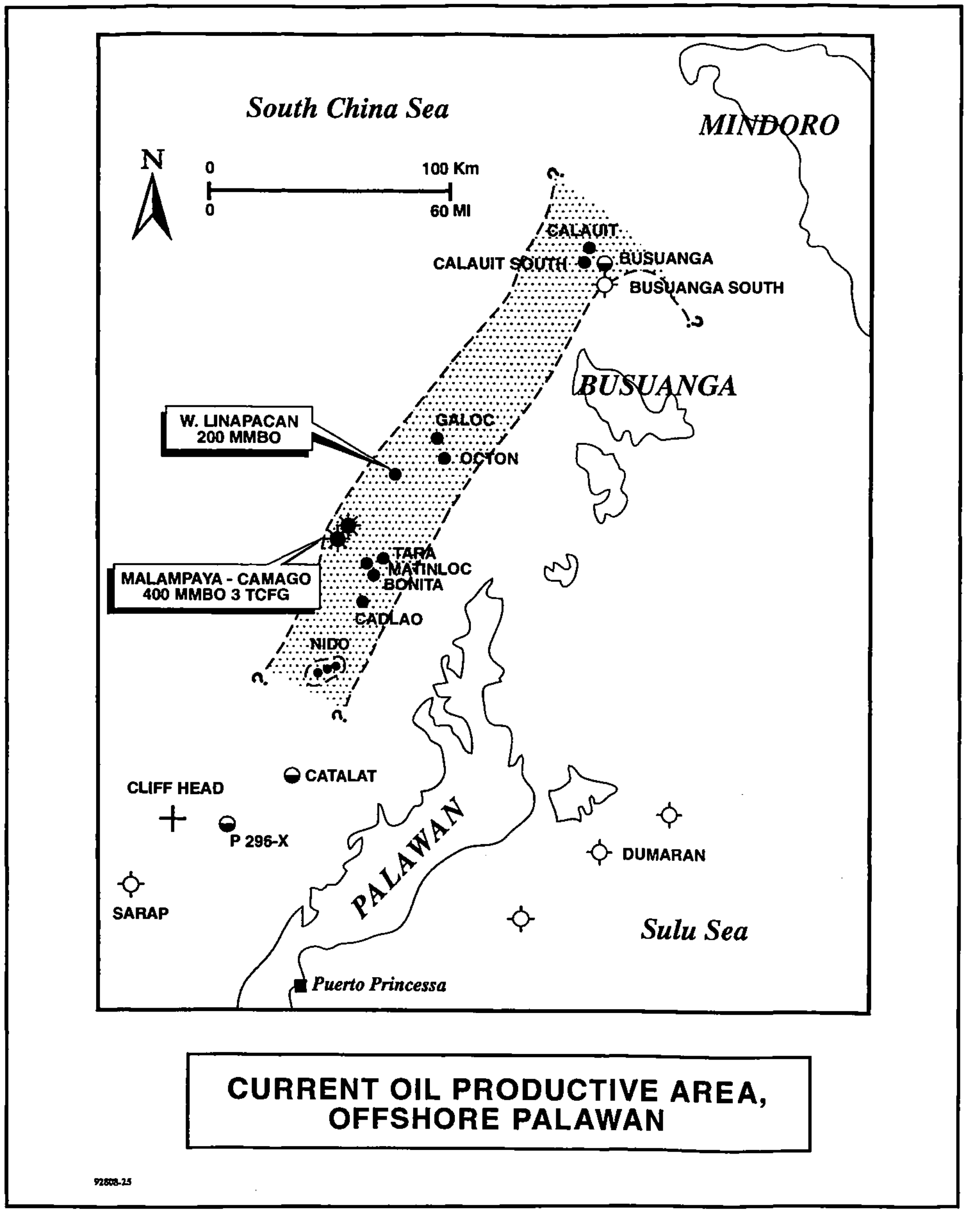


Figure 2. Current oil productive area, offshore Palawan.

1987). This includes the site of the Philippines first commercial oil discovery by Cities Services at Nido 1 in 1976 (Robertson Research, 1987).

There is a gap of 540 km between the existing Philippine oil production and the closest producing fields in Malaysia (South Furious field). In the sixteen years following the discovery of Nido 1, the southwest Philippines has been the site of tens of thousands of line kilometers of seismic work by industry and the German Geological Survey (BGR) (BGR, 1985-89) (Hinz and Schluter, 1985; Hinz *et al.*, 1989). There have been nearly 100 wells drilled throughout the area, mostly off northwest Palawan.

Another major sedimentary area discussed here lies in the southwest and northwest sectors of the Sulu Sea (Fig. 3). This sector of the Philippines affords three basins for exploration. These basins contain many good untested prospects, leads, and play types.

In January 1992, the largest oil field yet discovered in the Philippines, was confirmed at West Linapacan (Figs. 1 and 2). The field is reported to have a recoverable resource of about 100 million barrels. The field was officially inaugurated and placed on production at a rate of about 15,000 BOPD (barrels of oil per day) in June 1992.

West Linapacan field, midway along the Northwest Palawan oil producing trend, is about 365 km southwest of Manila. The field is 60 km offshore from the north tip the Island of Palawan about 100 km northeast of the 1976 discovery at Nido.

Subsequently, in June 1992, an even larger oil field discovery was indicated at the Shell-Oxy Malampaya-Camago deep water prospects 30 km (18 mi) southwest of West Linapacan. Press reports suggest areas of closure in the range of 30 km^2 and maximum pay thicknesses in a lower oil zone of 150 m and an upper gas condensate zone with a reported resource of one to three TCF (trillion cubic feet) of gas.

Besides being prospective for oil and gas, the Southwest Philippines has generated an abundance of tectonic concepts. Some which have had a negative impact on the search for oil are no longer tenable and should be erased, for example the Ulugan Bay fault (Hamilton, 1979; Gallagher, 1986).

GEOLOGY

General

The Philippines is in a region of contact between three major plates of the earth's crust (Fig. 4). This has given the subject area an interesting morphologic, topographic, and structural fabric.

The eastern Philippines from Northern Luzon to Mindanao is characterized by strong north to northwest structural and morphological trends (Santos, 1959). In contrast, the southwestern Philippines has a dominant northeasterly trend that appears to merge or be abruptly terminated by the eastern part of the archipelago.

The Southwest Philippines is a product of the mergence of sectors of the East Asia plate from the northwest and a northward or northwestward movement of the eastern Indonesian region from the south, and internal spreading (southeast Sulu Sea).

These movements in the Southwest Philippines involved rocks ranging in age from Permian to Recent. Some units are part of the East Asia plate as known in northeast Palawan, Mindoro, and Busuanga for example (Hashimoto and Sato, 1973 and 1981; Mitchell and Leach, 1991; Fontaine, 1979). Other rock types such as recent volcanics of the Sulu Sea ridge and Sulu archipelago are still being formed. The interaction of these varying terrains has taken place from Late Mesozoic up to the present time. Completing the picture in the southwestern part of the study area (Southwest Palawan and northwest Sulu Sea) has been the emplacement of chaotic rock strata or allochthonous masses, of late Mesozoic and early Tertiary age.

Tertiary sedimentary rocks include clastics and carbonates of platform and reef complex types which formed across the entire area. Eocene to Middle Miocene strata appear to be the most important in the search for oil and gas.

Stratigraphy

The stratigraphy of the region for the oil producing area of northwest Palawan, the offshore shelf of southwestern-most Palawan, and for the Sandakan basin of the southwest Sulu Sea region is shown on Figures 5, 6, and 7 respectively.

Northwest Palawan

In northwest Palawan the sedimentary section of interest to oil and gas exploration is confined to Oligocene and Miocene clastics and carbonates. These overlie in places a sequence of Lower to Upper Cretaceous that might be a possible source of hydrocarbons. The pre-Cretaceous consists of an indurate to metamorphosed sequence of Permian to Jurassic rocks. The older rocks are exposed in the northern one-third of the island of Palawan-Busuanga area.

The oldest rocks penetrated offshore Palawan are Upper Jurassic to Lower Cretaceous limestones and shales found near the base of Cadlao 1(Hinz and Schluter, 1985; Kudrass *et al.*, 1986; Rangin, 1989).

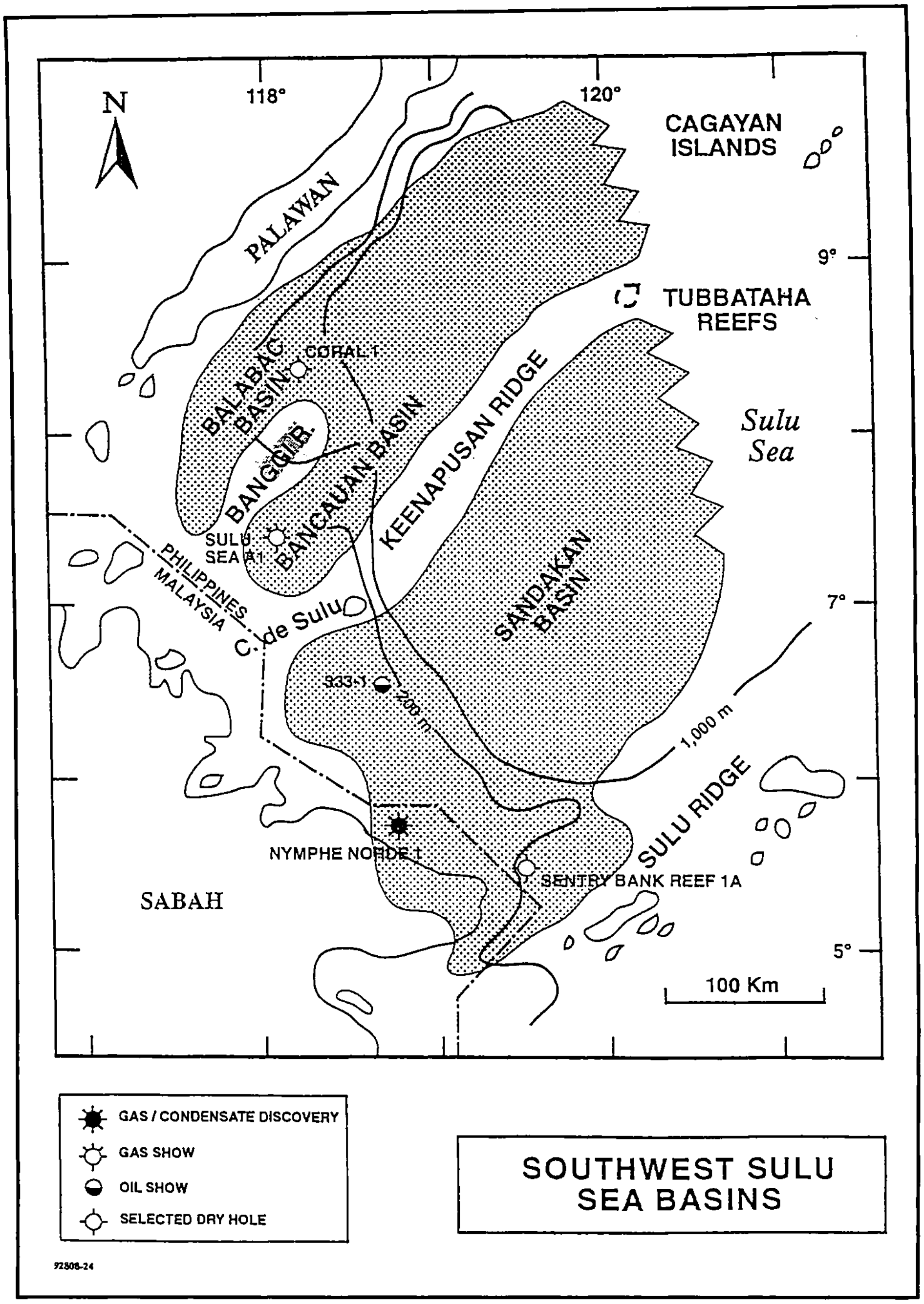


Figure 3. Southwest Sulu Sea basins.

In the offshore shelf area, the Oligocene to Lower Miocene limestones (The Nido Formation) that produce oil occur as platform type deposits and local reef accumulations. In the offshore overlying the Nido limestones are clastics that on the outer edge of the shelf have turbidite characteristics. These clastics are porous, and at Galoc Field provide an important oil reservoir. The carbonates can vary from a few tens of meters thick to more than a thousand meters thick (Catalat 1; Fig. 22 for various wells).

Southwest Palawan

In southwestern Palawan the stratigraphy has been complicated by the introduction of a northwestward thinning wedge of allochthonous rocks. Here, a chaotic wedge of Cretaceous to Eocene arkosic strata and ophiolites appear to be separating Upper Miocene clastics and a few limestones from the Nido equivalent strata, based on seismic correlation to the Sampaguita wells of the Reed bank area (Fig. 8).

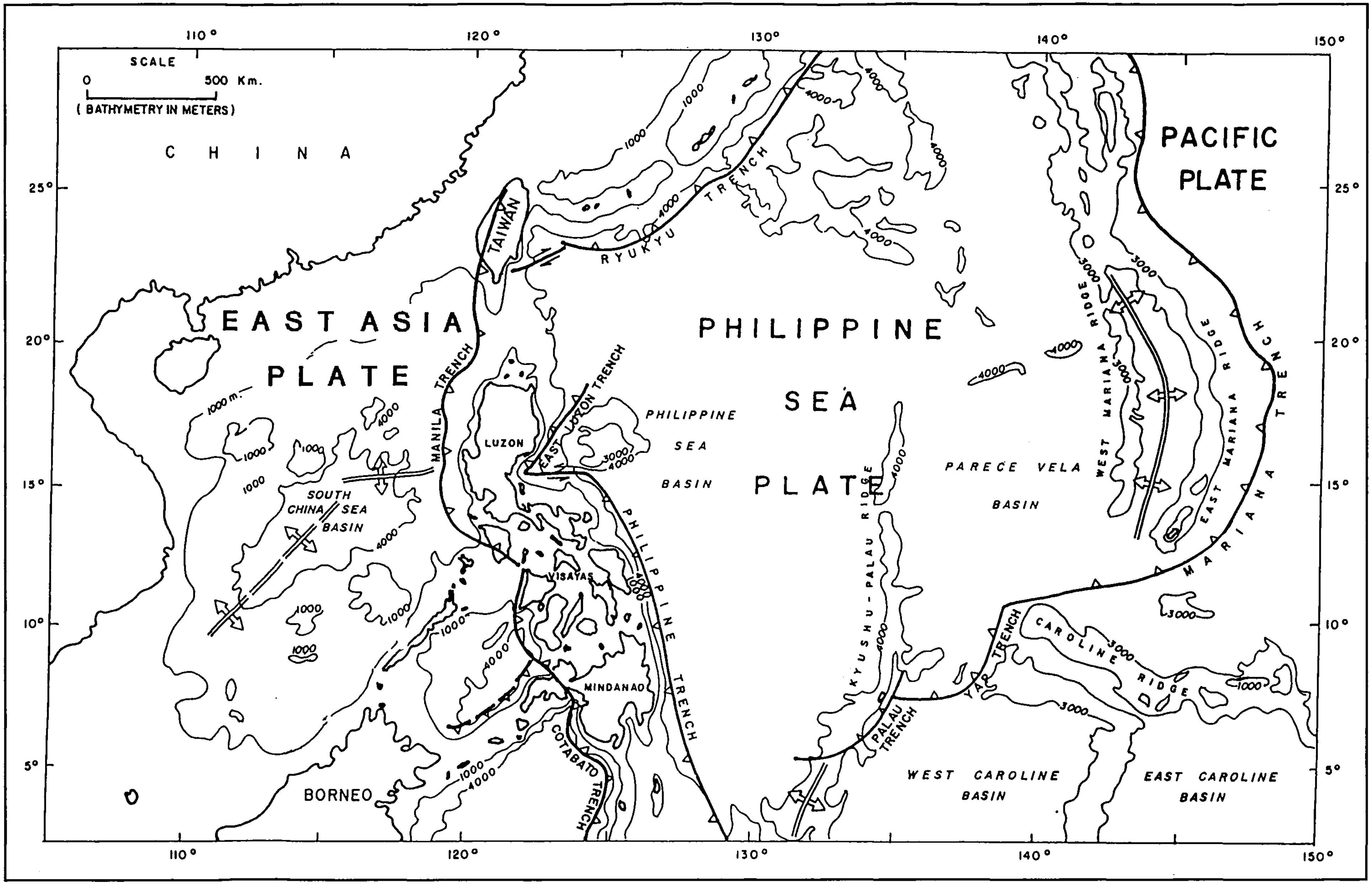


Figure 4. Crustal plates of the Philippine region.

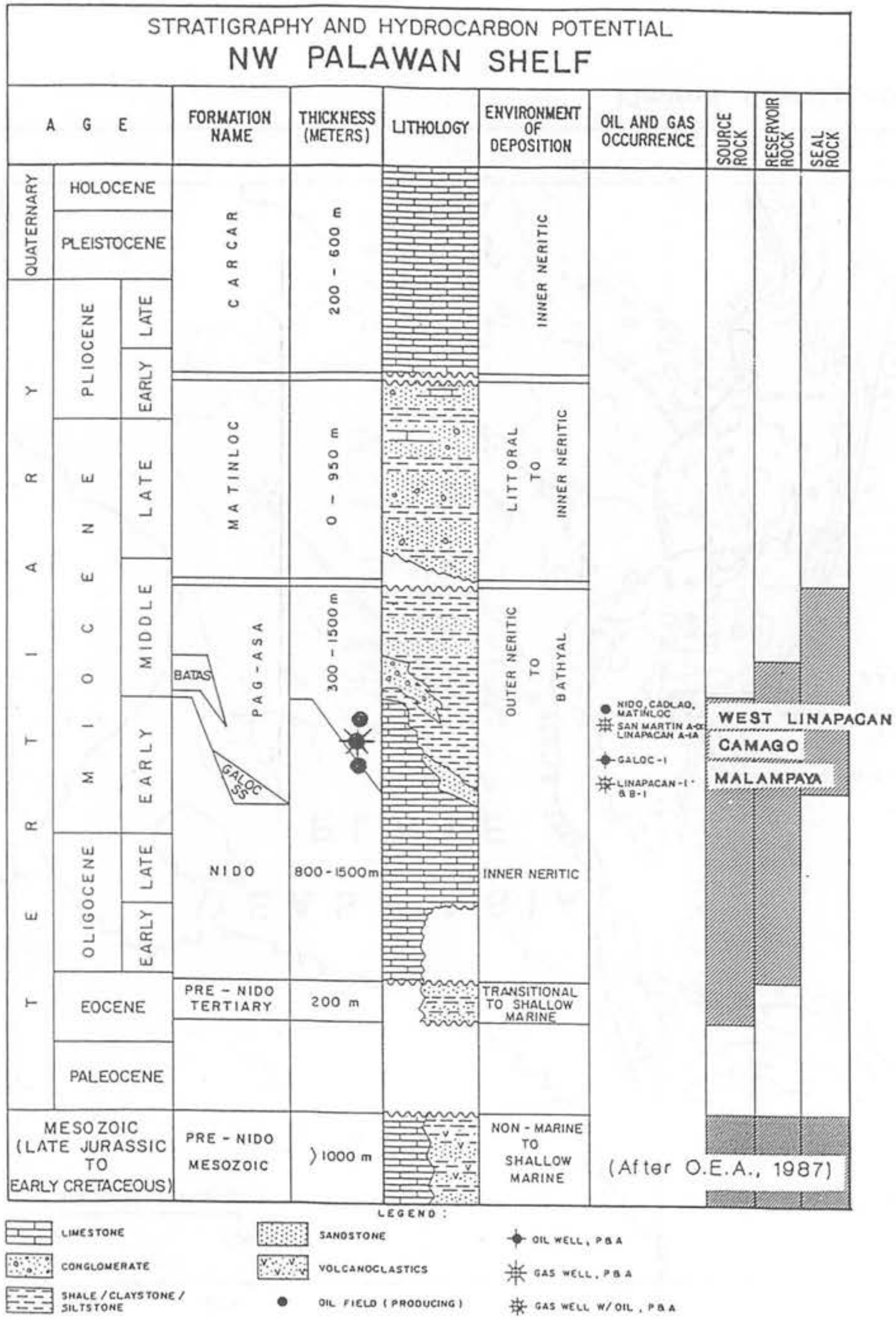


Figure 5. Stratigraphic chart, Northwest Palawan.

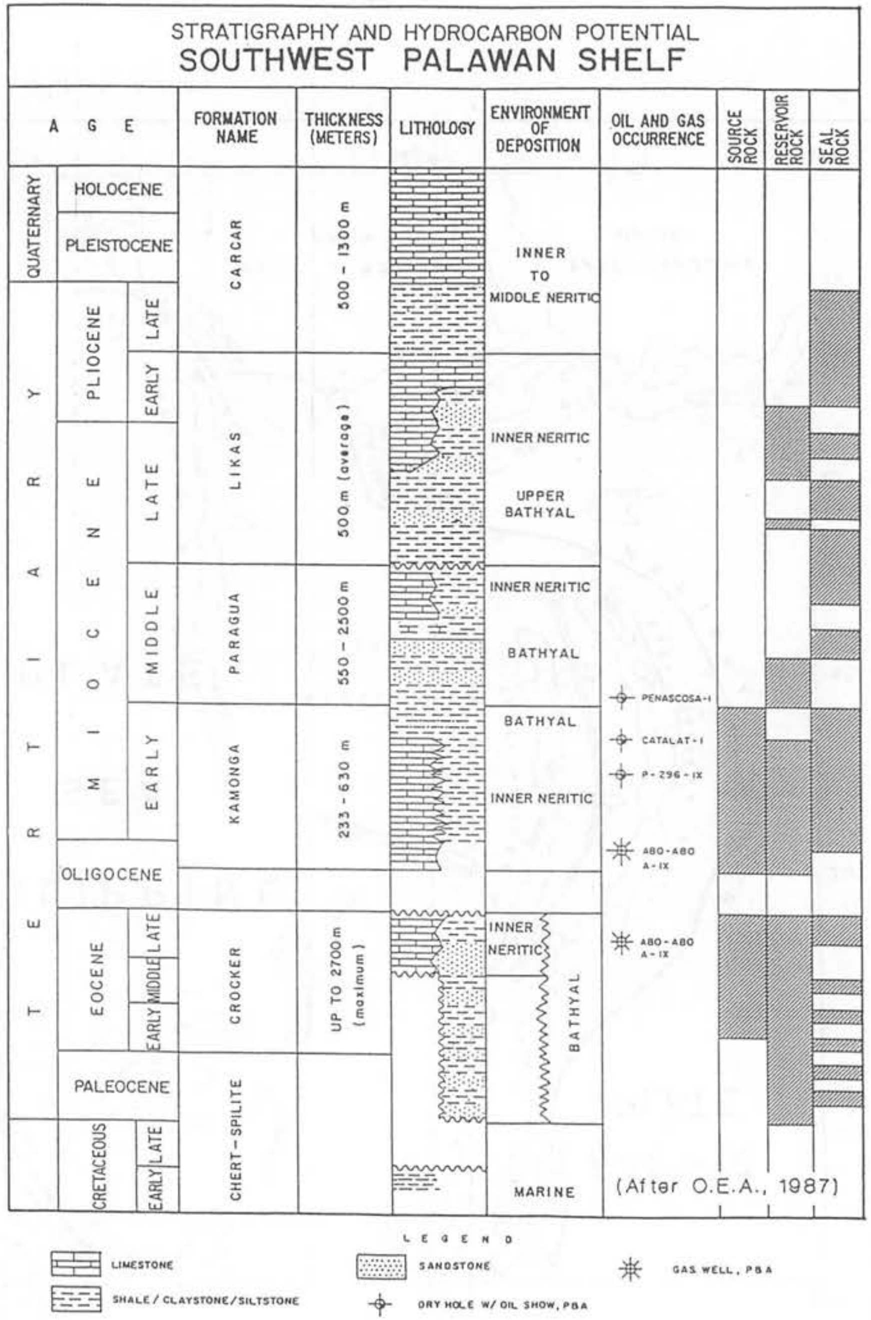


Figure 6. Stratigraphic chart, Southwest Palawan.

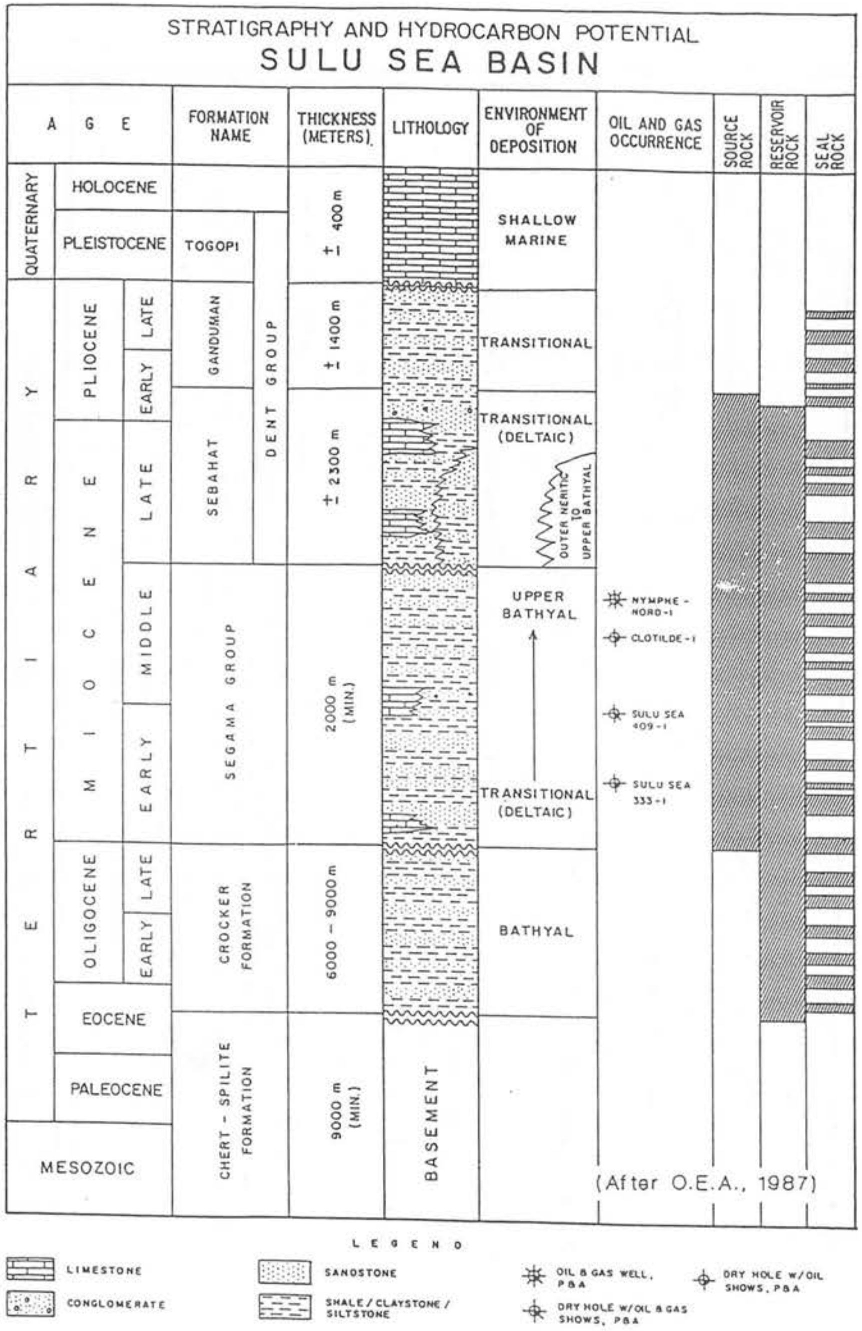


Figure 7. Stratigraphic chart, Southwest Sulu Sea.

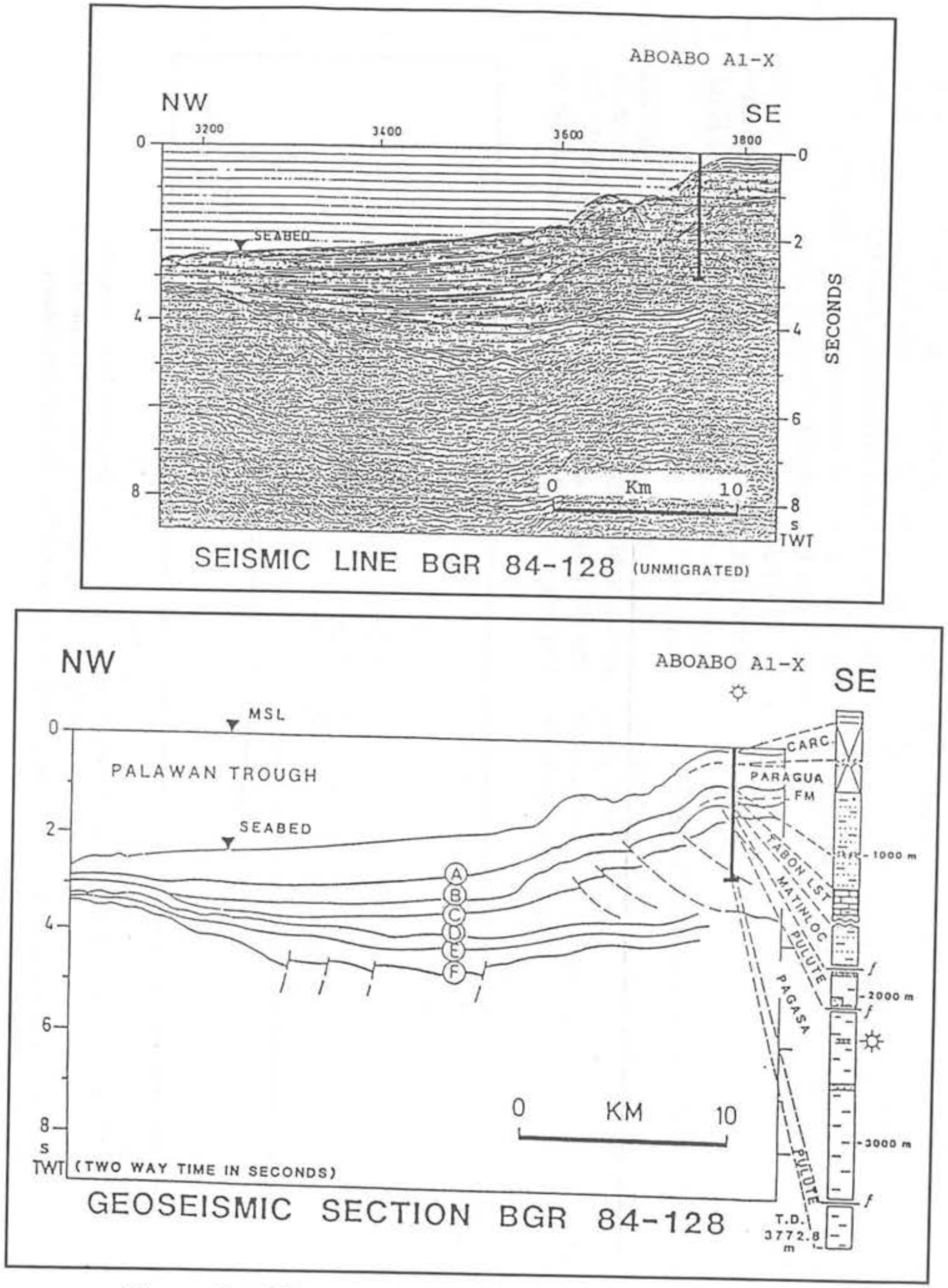


Figure 8. BGR seismic and geoseismic section, Aboabo A1-x.

Two figures by Letouzey and Sage (1988) that accompany the AAPG's East Asia maps show the general relation and differences between northwest Palawan and southwest Palawan (Included as Figures 9 and 10 of this paper).

Structure

Palawan, Reed Bank, and Cuyo Platform

Palawan, Reed Bank, and the Cuyo Platform had their inception as part of the East Asia continental plate. This segment of attenuated crust was dominated by a fabric of east-northeasterly trending rifts, grabens and half-grabens (Bosum, 1972; Hinz and Schluter, 1985; Kudrass *et al.*, 1986). The grabens and half grabens were the site of Lower Cretaceous to Paleocene synrift clastics as seen in the Reed Bank wells.

The northeast sector of this unit, or Calamian microplate, became further separated and rotated slightly to the southeast during Oligocene to Early Miocene (Taylor and Hayes, 1980).

The latter phase is represented by Oligocene through Miocene syndrift platform limestones on the Reed Bank and northwest Palawan shelf. The Palawan and Cuyo shelf area were modified by

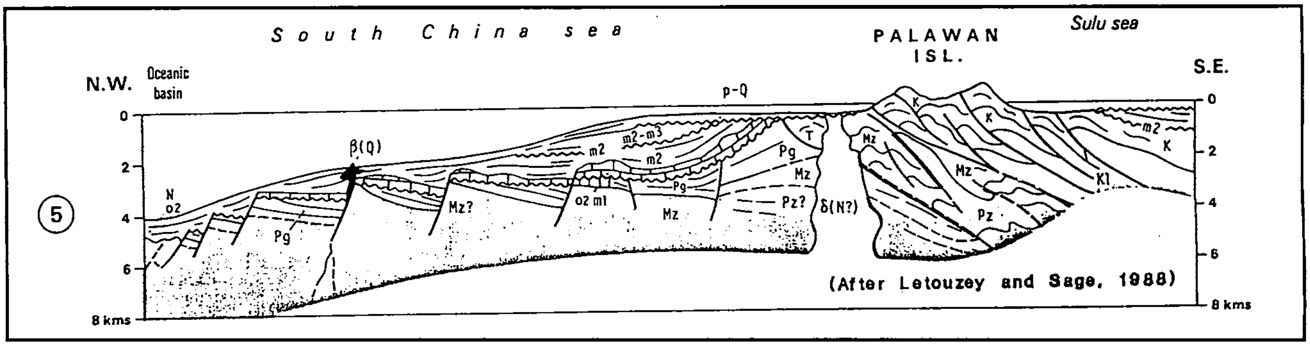
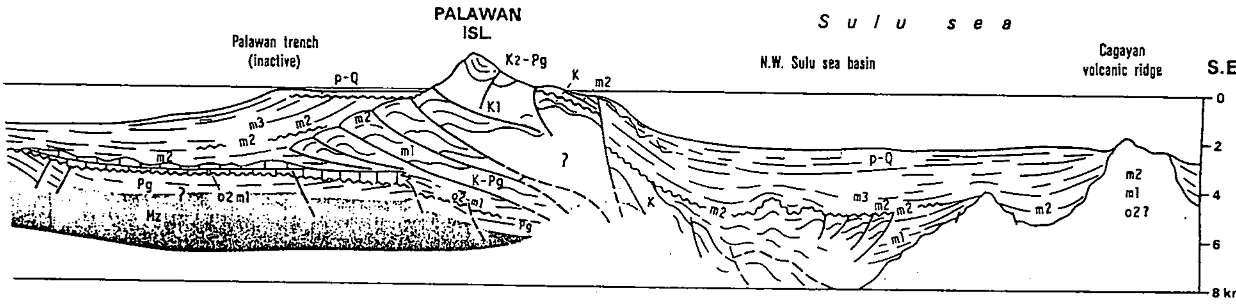


Figure 9. Generalized geologic cross-section, Northeast Palawan.
MZ — Mesozoic; K1/K2 — Lower/Upper Cretaceous; Pg — Paleogene; N — Neogene;
Q — Quaternary; O2 —Upper Oligocene; M1 — Lower Miocene; M2 — Middle Miocene;
M3 — Upper Miocene; T — Tertiary Undiff.; p — Recent; B — Quaternary Basalt.



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(After Letouzey and Sage, 1988)

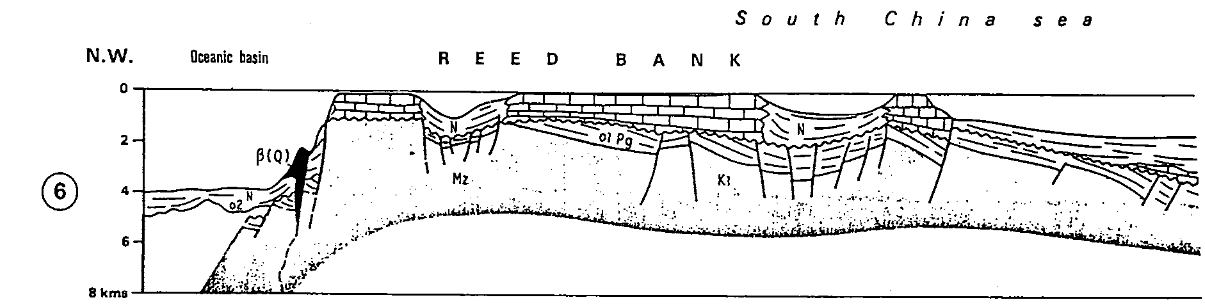


Figure 10. Generalized geologic cross-section, Southwest Palawan.

subsequent structural movements. These caused the depression of the Palawan trough and uplift and "ramping up" of the axial ranges of Palawan. In the northeast Palawan area, wrench faulting and attendant shear systems developed, having a northwesterly trend expressed in some coastlines of northern Palawan, Busuanga, and Mindoro.

The core of Palawan in the southern two thirds of the Island is largely ultramafic with abundant serpentinitic rocks and chaotic deposits (Mitchell and Leach, 1991). This has been described by some recent workers (Hinz *et al.*, 1989) to be part of an allochthonous tectonostratigraphic terrane inserted in the system from the Sabah region to the southwest (Figs. 8 and 11). There were perhaps two phases of such north moving masses. Northeast Palawan is composed of autothonous Paleozoic and Mesozoic metasediments and sedimentary rocks. The entire framework was then overlapped by Miocene and younger limestones, shales, and clastics.

These views and the BGR data (Hinz and Schluter, 1985; Hinz *et al.*, 1989) suggest that earlier workers' theories (Hamilton, 1979; Taylor and Hayes, 1980 and 1983; and Holloway, 1981) about Sabah and southern Palawan being underlain by southeastward subducted crust, is no longer tenable.

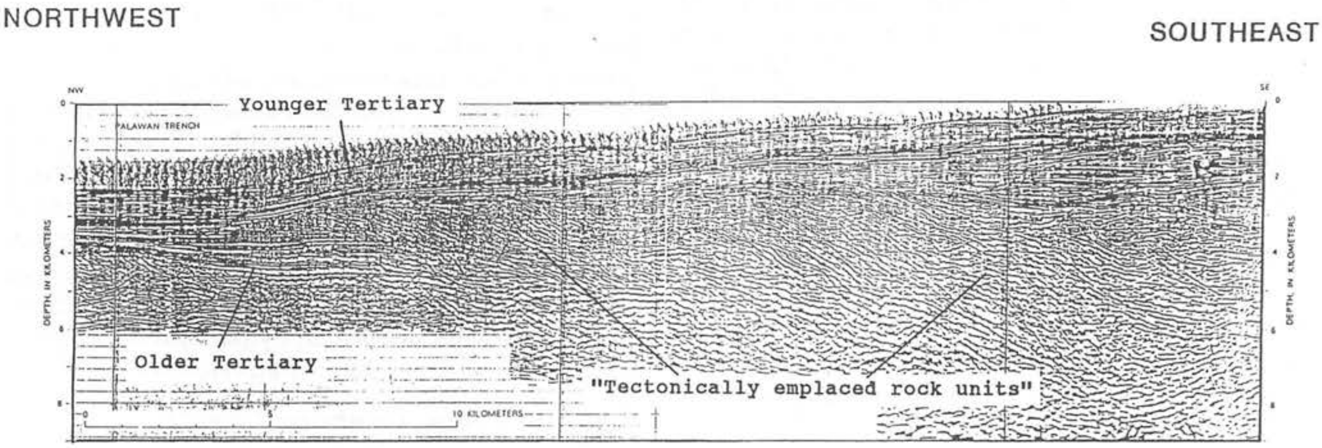
Reconnaissance seismic lines in the Cuyo region demonstrate the presence of large scale structural folding of possible early Tertiary to upper Mesozoic strata beneath platform Tertiary limestones and/or late Tertiary volcanics.

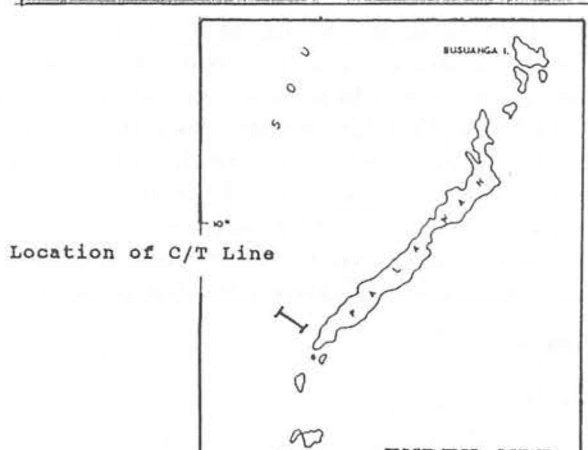
Along the coast of southwest Palawan there is an area of thrusting or ramping that could be important to oil and gas explorers ("Malabangan arc"). The importance of the area is demonstrated by the Phillips Aboabo 1 which cut several thrusts and tested in excess of 50 MMCFG/d (million cubic feet of gas per day) from a zone between 7,603 and 7,702 ft (Figs. 12 and 13).

At the far southwest end of Palawan, near the Island of Balabac, the structural trends in the surface geology have a marked change in strike to the southeast as the influence of Sabah comes into play (Basco, 1964; Beddoes, 1976).

Sulu Sea Basins

In the Southwest Philippines the Sulu Sea overlies a complex of three Tertiary structural and





This record section was used by Hamilton (1979) to illustrate evidence of a North Palawan subduction zone. Now, it is believed by the writer and others following extensive BGR studies (Hinz *et al.*, 1989) that this section illustrates a tectonic emplacement via a ramping or thrusting mechanism of older rock types from the south, between the Nido platform equivalents (Upper Oligocene–Lower Miocene and the Middle–Upper Miocene and younger strata over the top of disturbed strata.

Figure 11. Chevron-Texaco record section, Southwest Palawan.

stratigraphic basins (Bell and Jessop, 1974; Bow Valley, 1980; Hinz *et al.*, 1991; Hutchison, 1992; Rangin, 1989). These lie between the Palawan ridge on the northwest and the Sulu archipelago on the southeast. To the southwest they impinge upon the island mass of Borneo in northeastern Sabah, Malaysia (Fig. 3) (Stephen and Rangin, 1984).

The three basins are known from northwest to southeast as the Balabac, Bancauan, and Sandakan basins, respectively. These basins are separated by two northeast trending interbasin structural ridges; the Banggi ridge to the northwest separating the Balabac and Banggi basins and the Keenapusan ridge to the southeast separating the Bancauan basin from the Sandakan basin (Whittle and Short, 1978; Wilson, 1961). The Keenapusan ridge is coincident with a volcanic lineament that extends nearly the entire length of the Sulu Sea. Between the 1,000 meter bathymetric depth contour and the Philippine-Malaysia international boundary, there is an area of about 38,400 km^2 (15,000 mi^2).

Balabac Basin

There has been no oil or gas exploration work done in this basin of nearly 4,000 km^2 (1,500 mi^2) since the mid-1970's. Some seismic data was obtained later (1986-1988) by the BGR in connection with its crustal studies of the South China Sea region. This data needs to be integrated with earlier seismic data. The BGR data suggests that new work can obtain results significantly better than obtained by industry some 15 years earlier.

It should be noted that the Balabac basin has only one test, a well (Coral 1) reportedly drilled off-structure. Beddoes (1976) indicates at least 19 other anticlinal leads which could be investigated further. A single off structure well is a very inconclusive evaluation of the oil and gas potential of the Balabac Basin.

Bancauan Basin

Seismic interpretations involving more recent data demonstrate that the only two wells in the basin, Sulu Sea A-1 and Sulu Sea B-1, are in reality little more than stratigraphic tests.

Neither of the subject wells tested a significant, if any, four way dip closure, especially the B-1 well. An unevaluated, porous zone (gas kick which led to stuck pipe and termination of the A-1 well) was never tested.

A prospect with an areal closure of 3,300 ha (8,100 ac) with 300 m (1,000 ft) of vertical closure, is available to test on the upthrown side of a fault about 3 km (1.8 mi) northwest of the A-1 well location. There are more than 25 other prospect leads remaining to be evaluated in this basin of some 6,000 km^2 (2,340 mi^2).

Sandakan Basin

Although some new seismic data was collected in the Sandakan Basin during the late 1980's, the last two wells drilled still focused on prospect areas identified in the 1970's. There are other prospects to consider. Also, deeper prospect leads that could have a better spatial relation to mature oil source sediments need to be explored (Lee, 1970; Hinz *et al.*, 1991; Walker *et al.*, 1992).

The Superior Oil 333-1 well which has one of the better shows of oil in the Philippine sector of the Sulu Sea was likely not drilled at an optimum structural position. Nearby, 5.5 km (3.0 mi) to the south is a four way dip closure with 5,000 ha (12,800 ac) of areal closure which is 300 m (1,000 ft) structurally higher than the 333-1 well.

PETROLEUM OCCURRENCE

General Petroleum Setting

Figure 2 and Table 1 illustrate the principal oil fields that have been identified or indicated to date in the Palawan producing trend. Cumulative production from these fields totals not quite 40 million barrels of oil. This production was minuscule, relative to what now appears to be possible (West Linapacan and Malampaya).

Two major hydrocarbon reservoir zones occur in Northwest Palawan oil fields. These are the Upper Oligocene to Lower Miocene carbonates (Nido Limestone) with scattered bioherms and trends of carbonate banks ranging up into Middle Miocene. Lower Miocene turbidites (e.g. Galoc sands) and younger clastics overlie the Nido in other areas. These reservoirs are sealed by the Middle Miocene Pagasa Shale which later blanketed the region.

Types of Fields, Offshore Palawan

Oil is found in a variety of structural trap types as well as stratigraphic reservoirs and reefs. There are some sharp, high-relief wrench-fault related anticlines (West Linapacan); low relief undulating platform anticlines structurally higher on the Palawan rise (Calauit-Calauit South); pinnacle reefs along the outer edge of the Oligocene-Lower Miocene carbonate shelf (Nido complex); and turbidite fan deposits (Galoc field) overlying the carbonates.

Selected Fields

West Linapacan

As shown on Figures 14 and 15, the West Linapacan structure trends some eight km in a northwesterly direction. It has a maximum area of closure on the -6,400 foot contour on the Galoc Dolomite-Limestone horizon, above the Nido

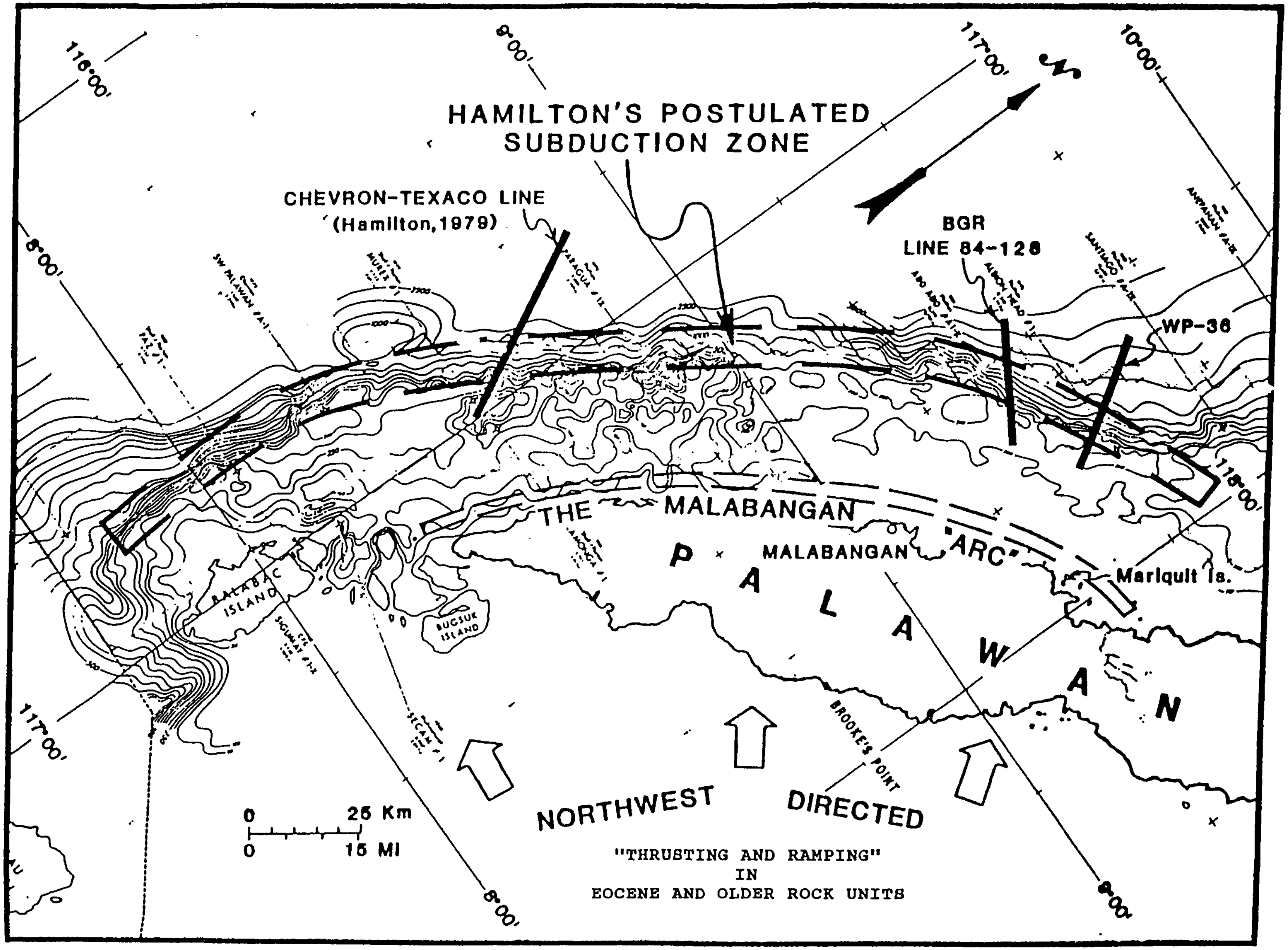


Figure 12. "Malabangan Arc", Southwest Palawan.

Table 1: Summary of Philippine Crude Oil Production. All Fields, 1979 through 1990 (in barrels)
Source: Office of Energy Affairs (OEA)

	Nido	Cadlao	Matinloc	North MatinlocL	Galoc	Tara	TOTAL
1979	8,569,916	0	0	0	0	0	8,569,916
1980	3,619,792	0	0	0	0	0	3,619,792
1981	1,069,638	788,697	0	0	0	0	1,858,335
1982	633,567	1,777,308	1,157,648	0	0	0	3,568,523
1983	562,491	1,975,063	2,336,799	0	0	0	4,874,353
1984	273,489	1,771,209	1,847,340	0	0	0	3,892,038
1985	284,397	1,229,524	1,377,103	0	0	0	2,891,024
1986	384,592	963,674	1,174,363	0	0	0	2,522,629
1987	236,530	780,413	1,003,022	0	0	19,078	2,039,043
1988	163,474	633,377	551,955	319,934	383,460	126,807	2,179,007
1989	258,614	527,368	416,477	602,983	0	72,366	1,877,808
1990	206,431	443,274	289,379	730,141	0	431	1,669,656
TOTAL	16,262,931	10,889,907	10,154,086	1,653,058	383,460	218,682	39,562,124

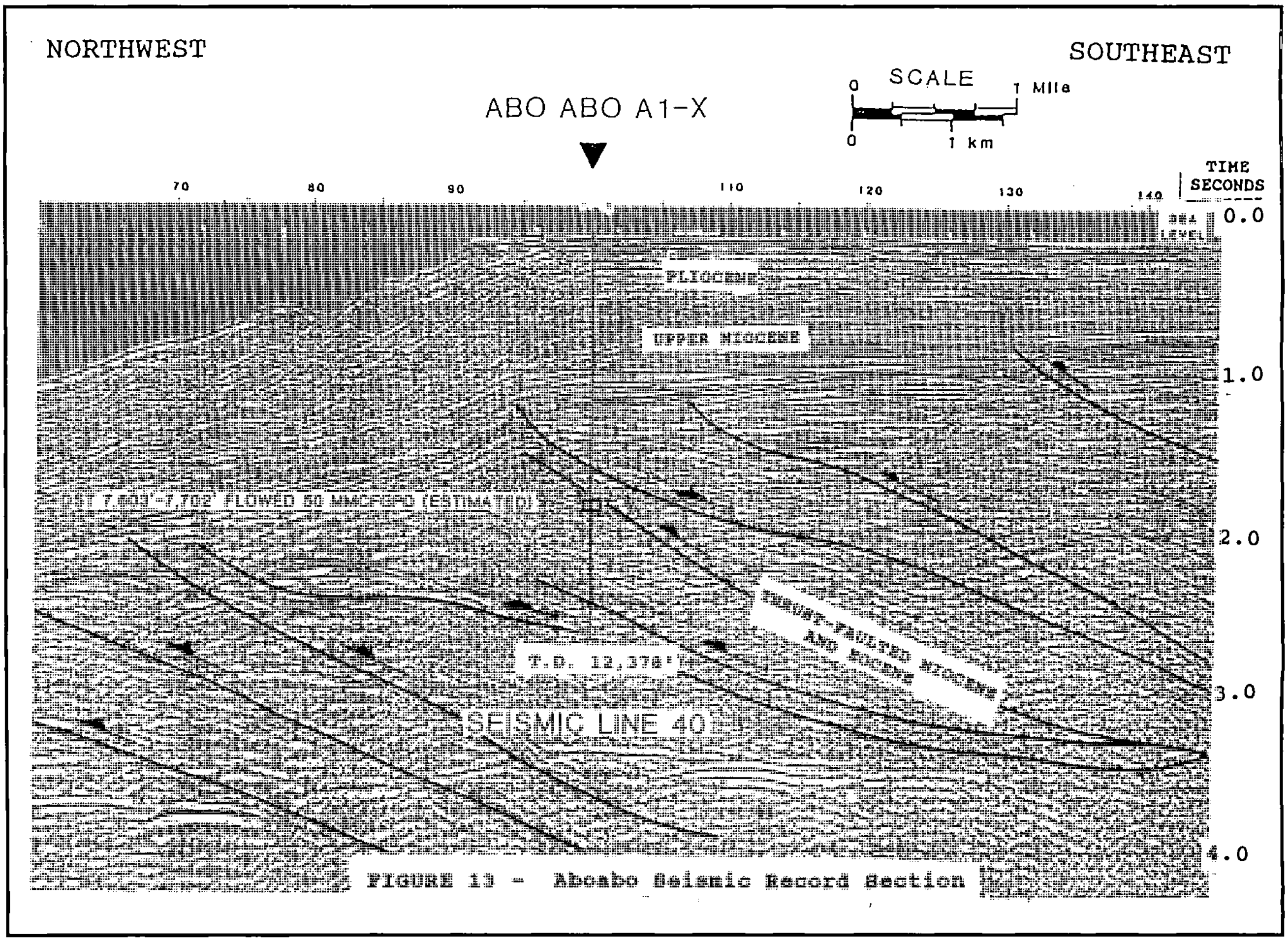


Figure 13. Aboabo seismic record section.

Limestone, of 4,130 acres. At this horizon the structure has about 1,000 feet of vertical closure. At the probable oil-water contact the areal extent is about 3,400 acres and a vertical oil column of 600 feet.

This field is in 1,150 feet of water. Its details of geology and history have been described by Walston and Osterle (1992). The field is reported to have between 100 and 200 million barrels of recoverable oil.

Calauit - Calauit South

The Calauit and Calauit South discovery wells were drilled on a broad, gentle, north-plunging anticlinal uplift that occurs about 50 km north of Busuanga Island. The discovery well, Calauit 1B, has a total depth of 2,220 m (7,282 ft). It is in water 292 feet deep.

The Calauit 1B tested a fault controlled, low relief structural closure on the overall Calauit-Busuanga uplift. As mapped seismically on the Nido carbonate sequence (Fig. 16) the Calauit structure has an areal closure of about 1,500 ha (3,706 ac) with a vertical fault controlled closure of 250 m (820 ft).

A 502 ft thick limestone, called the Calauit Limestone, was intersected from 5,241 to 5,743 ft. Testing over the interval 5,255 to 5,524 yielded 3,222 BO/d (barrels of oil per day), 26° API ($1^1/_2$-inch choke).

Expectations and hopes for a major-sized potential resource in this area were diminished following the drilling of the nearby, dry, Busuanga South Wildcat in 1991.

Octon Field

The Octon 1 discovery well is in 304 ft of water about 50 km northeast of West Linapacan. As shown on Figure 17, the Octon structure has an areal closure of about 763 ha (1,900 ac) and a vertical closure of 116 m (380 ft). This configuration is as mapped seismically on top of the "Galoc clastic unit". Octon 1 was drilled to a total depth of 8700 feet (Fig. 17).

On DST 4 (7,546-7,620 ft), the well flowed 12.5 MMCFG/d and 1,037 BC/d (barrels of condensate per day). Possible resource estimates (Balabac annual report, 1991) are up to 420 BCF (billion cubic feet) gas and about 35 million barrels of condensate. Octon 2, in April 1992, was reported (Manila press) to have flowed oil at a rate of 1,266 BO/d with 966 MCFG/d.

Reef Complex Fields

Nido Field

In mid-1976, the first significant oil in the Philippines, was discovered in the Southwest Philippines at the Cities Services *et al.* Nido 1. Nido 1 was designed to test what appeared to be a reef anomaly (Fig. 18). Hatley (1980) has described in much detail the discovery and development of Nido field.

A subsequent test, South Nido West 1, flowed oil at rates up to 9,880 BO/d. Initially the field was flowed at rates up to 40,000 BO/d. To date the field has yielded about 16 million barrels of 27° API crude oil.

Other Reef Fields

Other reef fields are known and many others likely remain to be found. One of the smaller pinnacle types is illustrated by Bonita 1 (See Fig. 2). Bonita 1 completed in a Nido pinnacle reef had an initial test rate of 2,100 BO/d. Its areal extend however is small and if it can be developed in a satellite facility in conjunction with other fields, then it might prove economic. As a stand alone field it is uneconomic. Reserves of 5 million barrels have been suggested.

Turbidite Clastic Reservoir Fields

Galoc Field

Galoc field (Fig. 2) is in 320 m (1,050 ft) of water. It is about 10 km (6 mi) north-northwest of Octon field and 28 km (17 mi) northeast of West Linapacan field. Galoc 1 tested a seismically mapped anomaly believed to be a reef-type carbonate mound feature. At the base of the proposed carbonate mound, oil bearing turbidite sandstones tested 1,828 BO/d (McGuinness and Branson, 1989). This was the first significant oil production from a clastic reservoir in the Philippines.

An extended test of Galoc 1 in 1988 yielded flow rates up to 5,000 BO/d after stimulation and through a one-inch choke. Reserves are estimated to be between 30 and 50 million barrels of recoverable oil.

Deep Water Fields

Camago-Malapaya

The Oxy Camago 1 discovery well drilled in 1990 is about 30 km (18 mi) southeast of the West Linapacan field. The Camago 1 was drilled in 2,416 ft of water (Fig. 2). Little published information about the field is available. Previous seismic sections published by Gallagher of Occidental Oil (1986) for the Malampaya deep water area perhaps provide a clue of the type of features that are present as oil or gas traps in deep water areas in the vicinity of the discovery (Fig. 19).

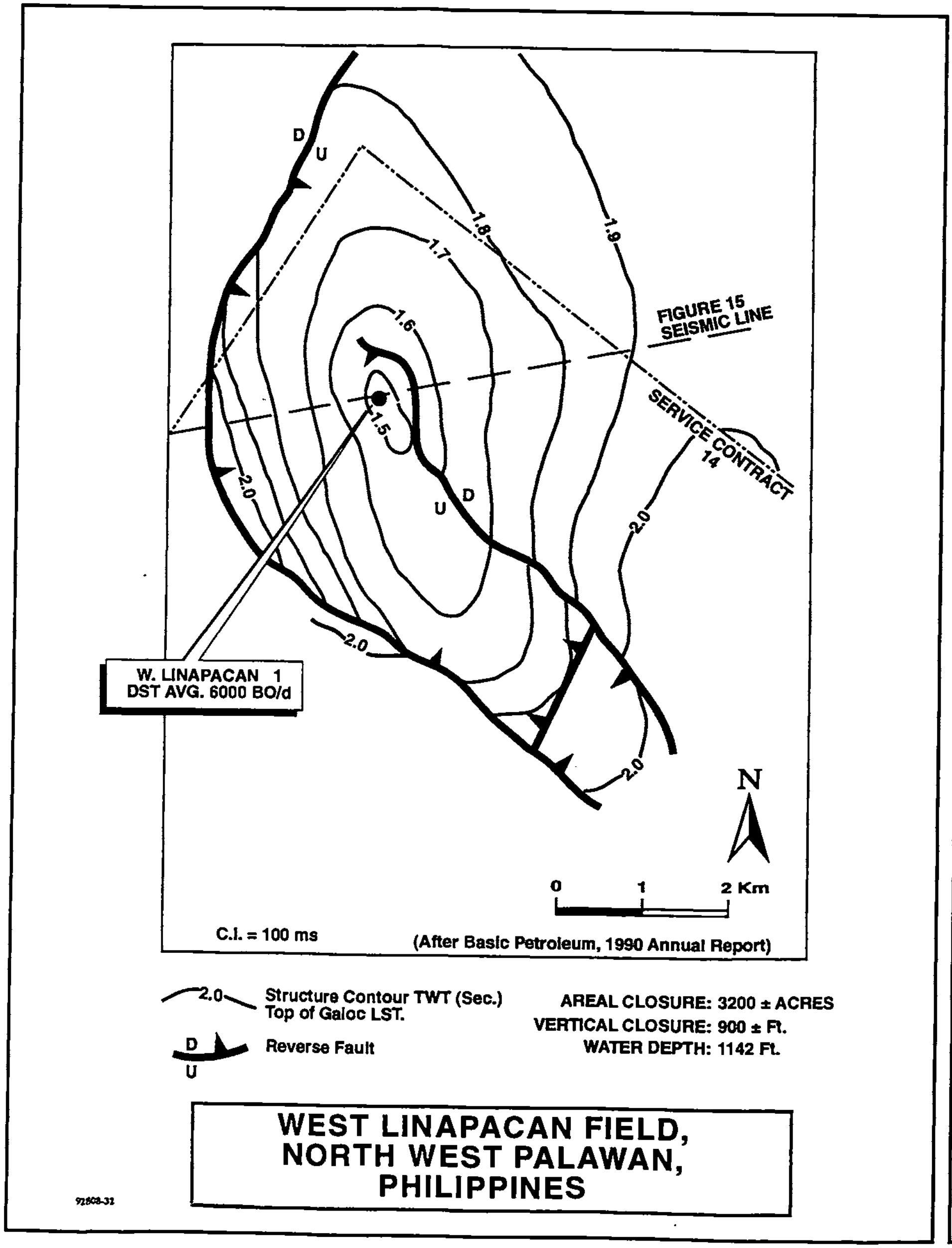


Figure 14. West Linapacan structure contour map.

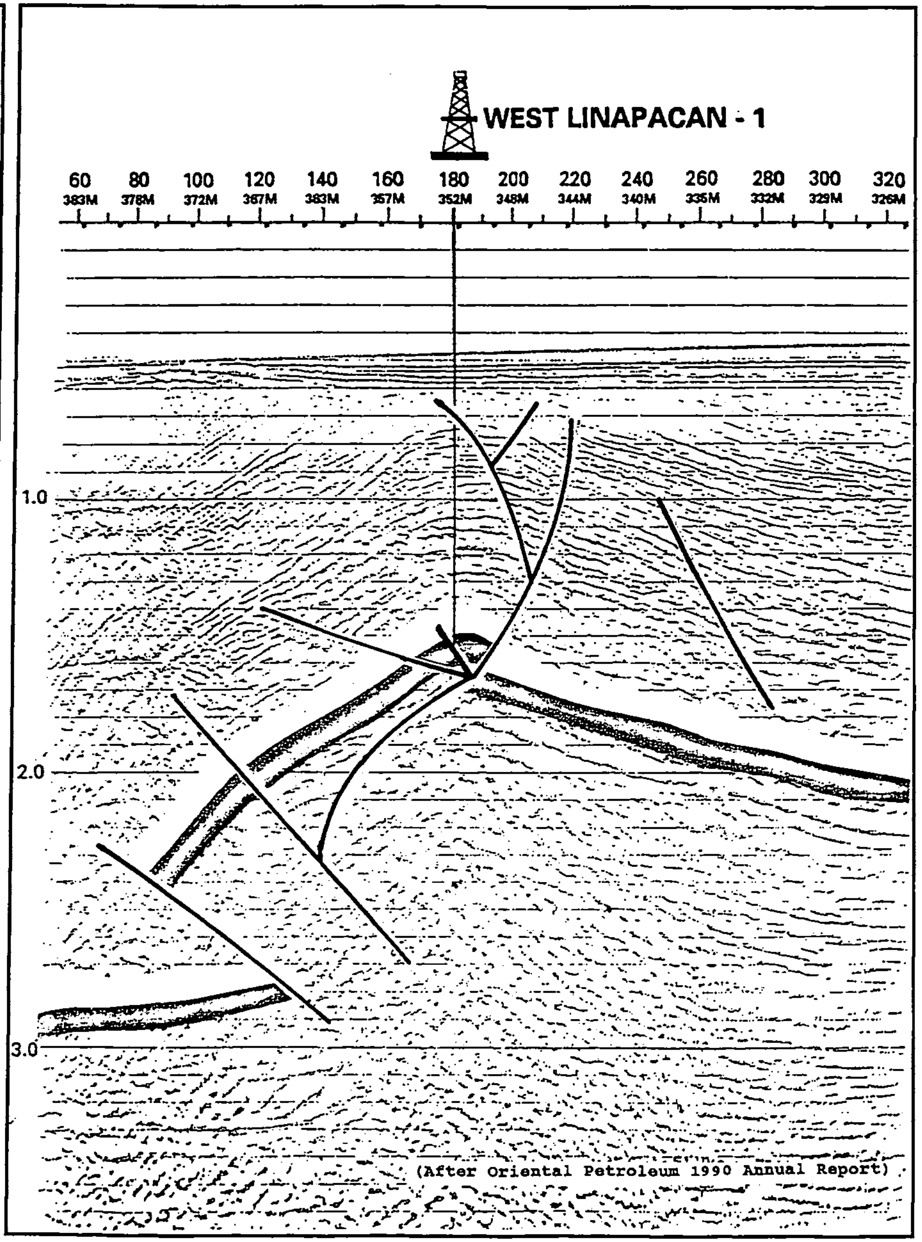


Figure 15. West Linapacan seismic record section.

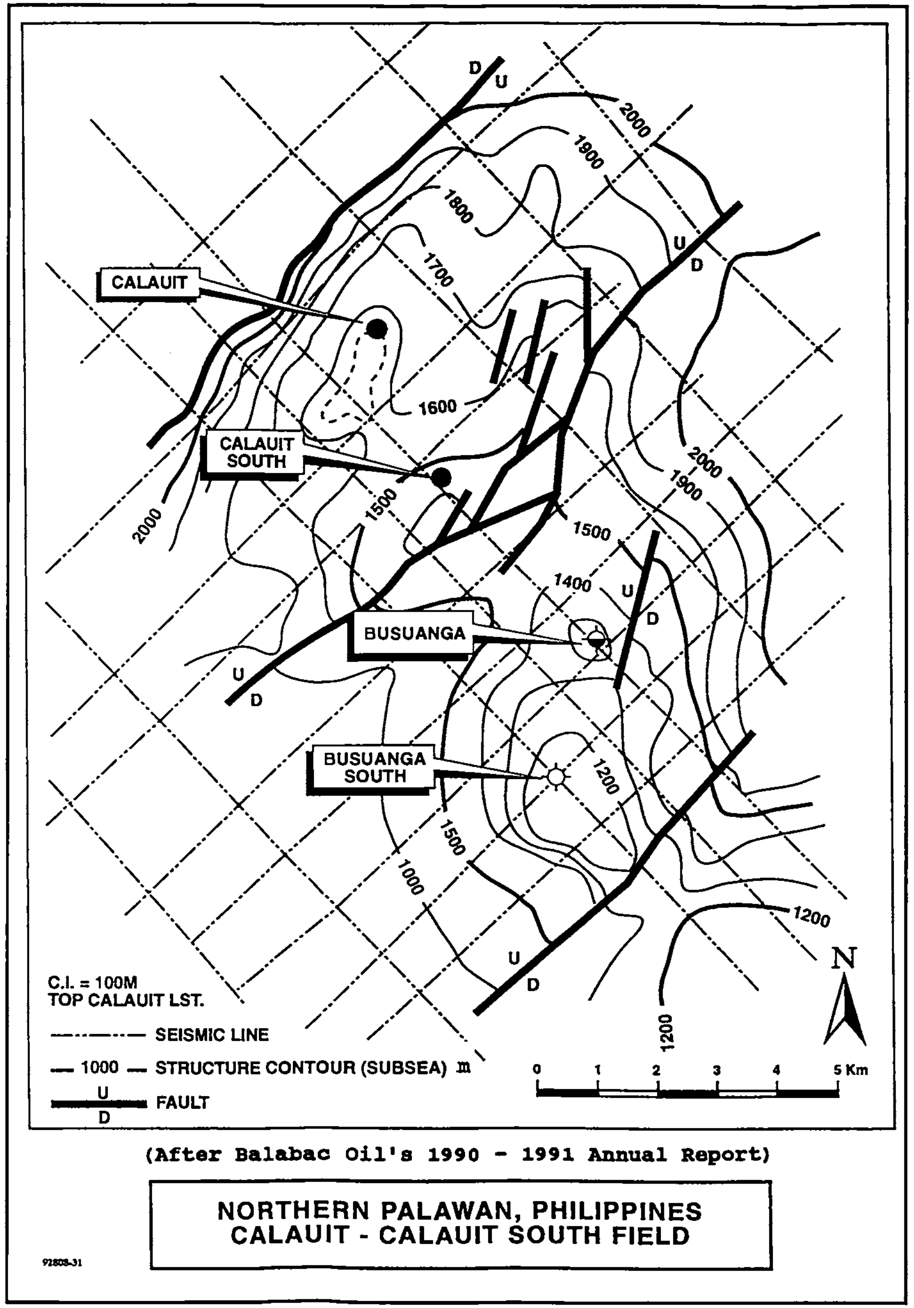


Figure 16. Calauit area structure contour map.

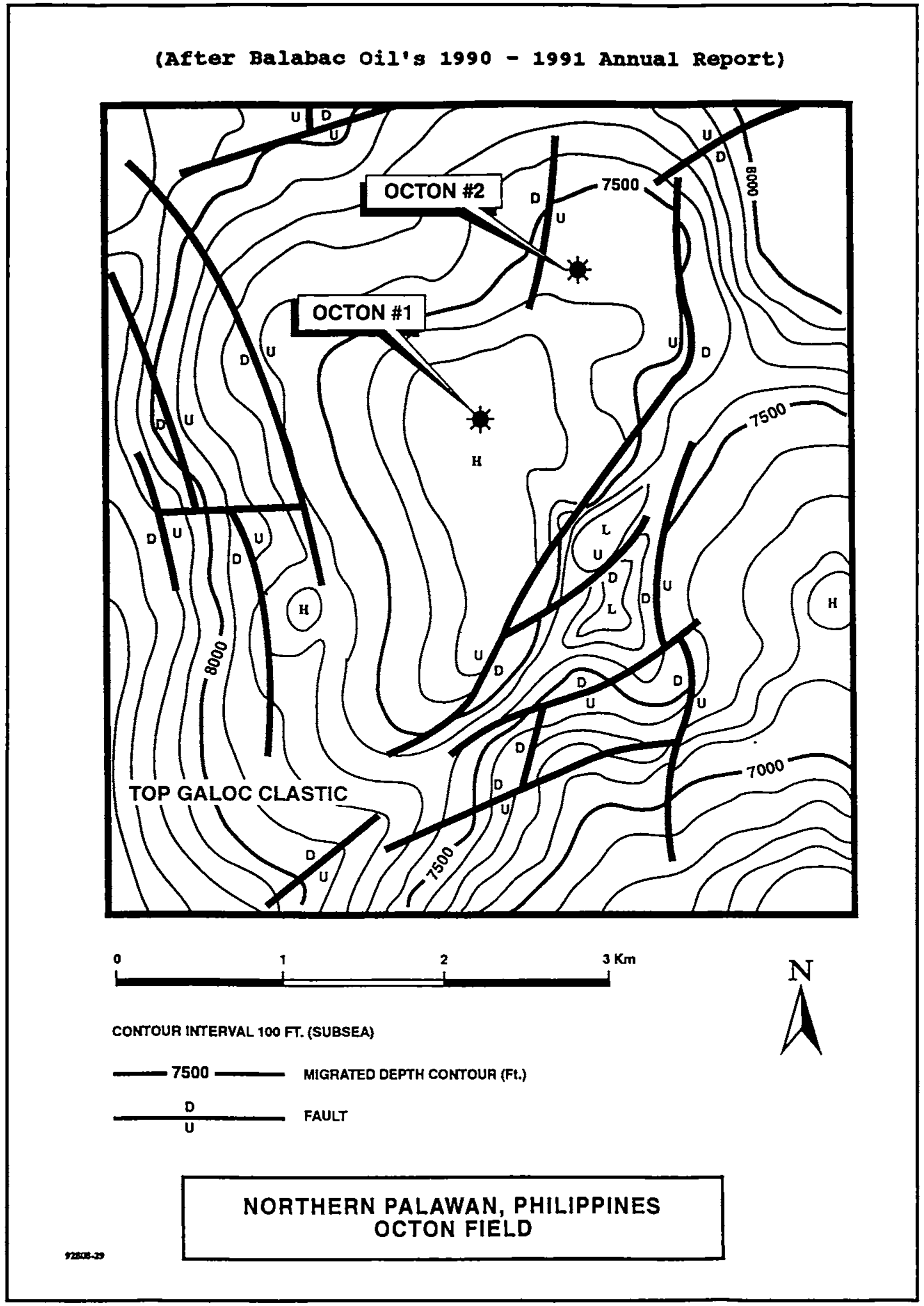


Figure 17. Octon field structure contour map.

The Camago 1 tested at rates of 12.3 MMCFG/d with traces of condensate from a sandstone section overlying the Nido (9,020 to 9,070 ft), while a deeper interval within the Nido Limestone (9,828 to 9,873 ft) flowed gas at the rate of 21 MMCFG/d with 730 BC/d (Oil and Gas Journal, 23 October 1989).

Shell subsequently joined Oxy to explore other deep water prospects within the permit area. Shell's third test (Malampaya 1) about 9 km northeast of Camago 1 appears to have located the largest oil and gas field yet found in the Philippines. Press reports suggest an area in excess of 30 km^2 with a resource potential in the range of 400 million barrels of oil and one to three TCF of gas.

Other Prospects

There are a number of known deep water reef seismic anomalies present along the south China Sea Coast of Palawan. Figures 20 and 21 illustrate an undrilled reef trap (Cliff Head prospect) in ex-GSEC 54, about 150 km (90 mi) southwest of Camago.

Significant Hydrocarbon Shows

Some significant hydrocarbon shows in non-producing sectors of the Southwest Philippine region are shown on Figure 22. Some wells and locations that lend encouragement to the hope of future discoveries are:

Catalat 1 — Palawan shelf, 4,000 ft of platform limestones with varying types and amounts of oil shows.

Aboabo 1 — offshore of central Palawan (Fig. 13) tested 50 MMCFG/d and had other untested oil and gas shows in thrust repeated Miocene and Eocene strata.

Reed Bank — The Reed Bank, Sampaguita 1 tested at rates of 3.7 MMCFG/d with 4.4 BC/MMCF (barrels of condensate per million cubic feet) from perforations between 10,335 and 10,364 feet. It also flowed 3.6 MMCFG/d with 25 BC/MMCF from the interval 10,282 to 10,301 ft. The well bottomed in Lower Cretaceous at 13,530 ft.

Tiga Papan 1 — In Sabah, 60 miles southwest of Philippine waters, along the China Sea Coast, the Tiga Papan 1 well flowed at rates up to 3,704 BO/d with 8.6 MMCFG/d.

Balabac Island — Basco (1964) described both seeps and solid hydrocarbons interbedded in Tertiary section on Balabac Island at the southwest tip of Palawan.

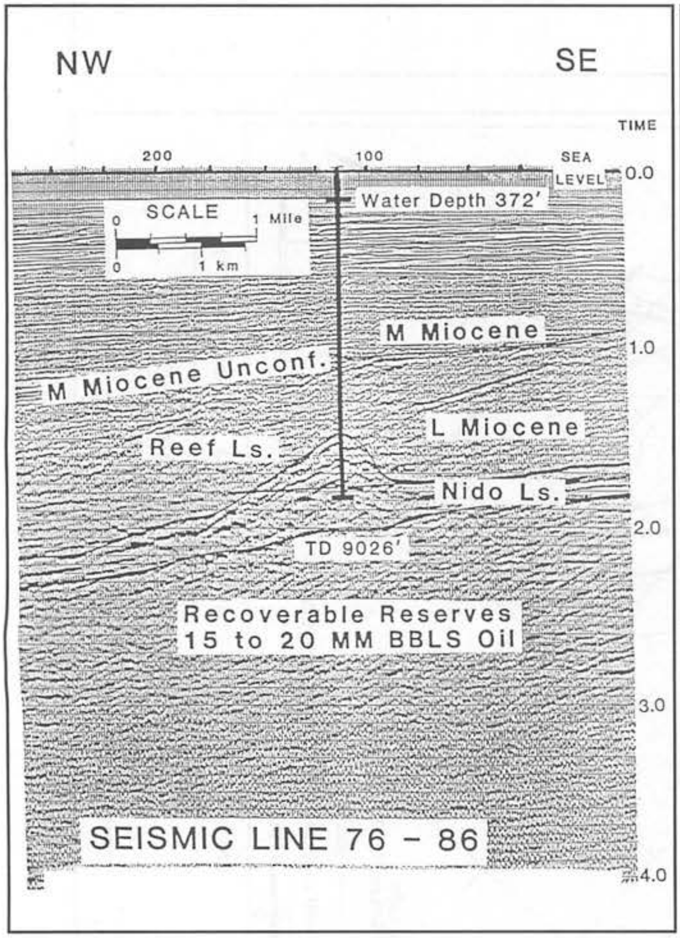


Figure 18. Seismic record section through Nido reef field.

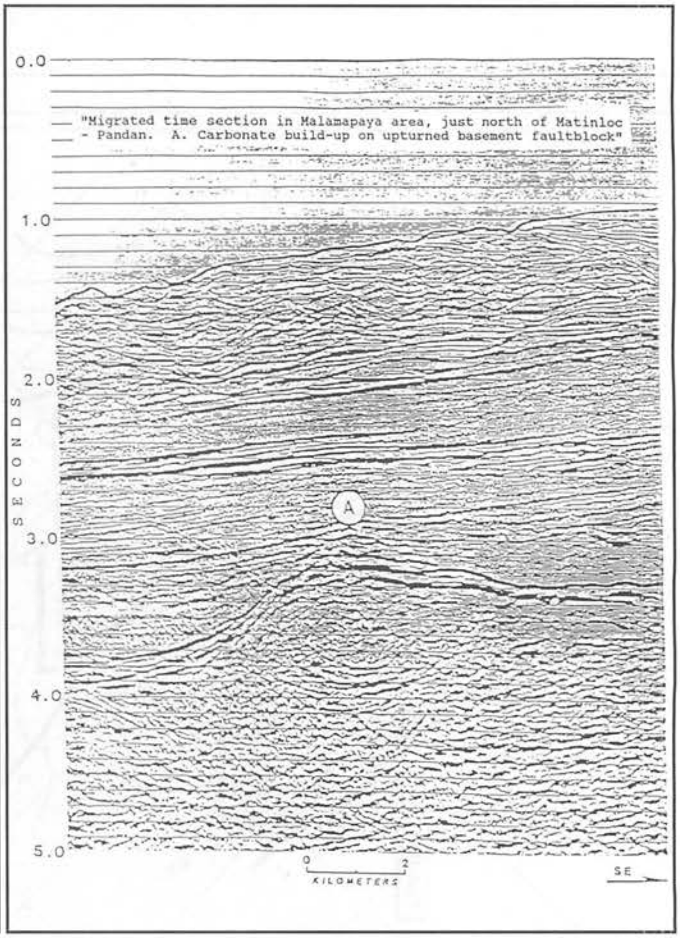


Figure 19. Seismic record section through Malampaya area.

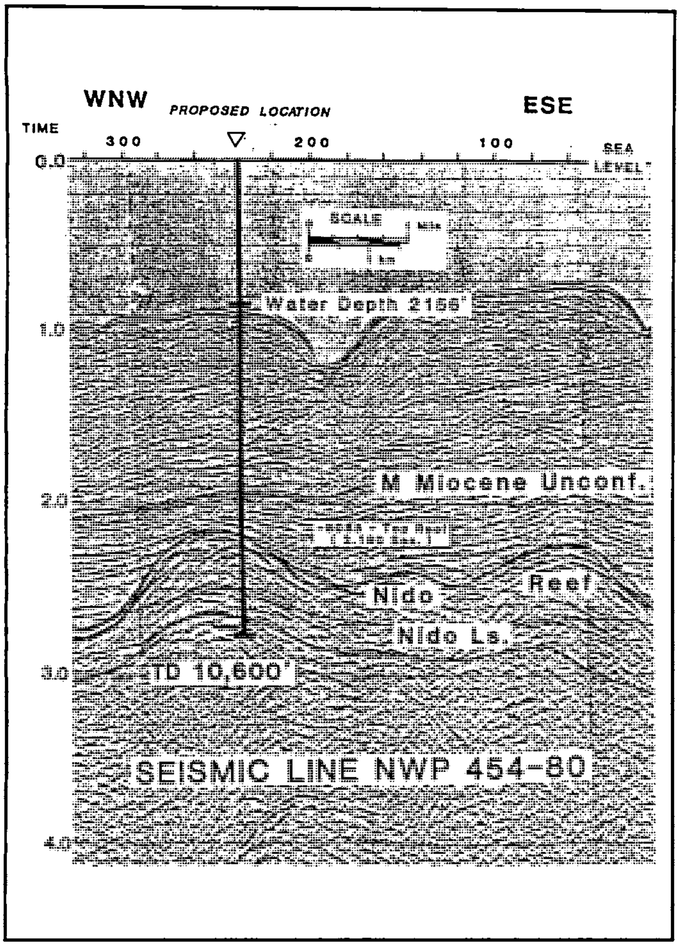


Figure 20. Cliff Head Prospect, seismic record section.

Sulu Sea-Nymphe Norde 1, Sabah — The Nymphe Norde 1 in the Sandakan basin sector of the Sulu Sea (Fig. 3), flowed 500 BC/d and 3.9 MMCFG/d from Lower Miocene reservoir sandstones.

Sulu Sea-Superior Oil 333-1 — Fluorescence and cut were noted in a sandstone at 10,560 ft drill depth. A core of the interval demonstrated oil staining and porosity of 20 percent in the top two feet of the core. A drill stem test of the interval 10,560 to 10,576 ft recovered 7,370 ft of water with one percent 27° API crude.

Mindoro — Oil and gas seeps are present onshore southern Mindoro. Oil or gas shows have been reported from four wells drilled offshore south of Mindoro Island (Maniguin 1, for example). Onshore, Progresso 1 had a gas blowout.

GEOLOGIC CONCEPTS; THEIR EVOLUTION, REVIEW, CHANGES

The origin of the Southwest Philippines has progressed through the trial and error of hypotheses designed by many workers during the past 20 years. The list is long, but certainly many key suggestions have come from authors through the years as follows: Hamilton (1979), Reyes (1971), Hashimoto and Sato (1973), Mascle and Biscarrat (1978), Taylor and Hayes (1980 and 1983), Holloway (1981), Hinz

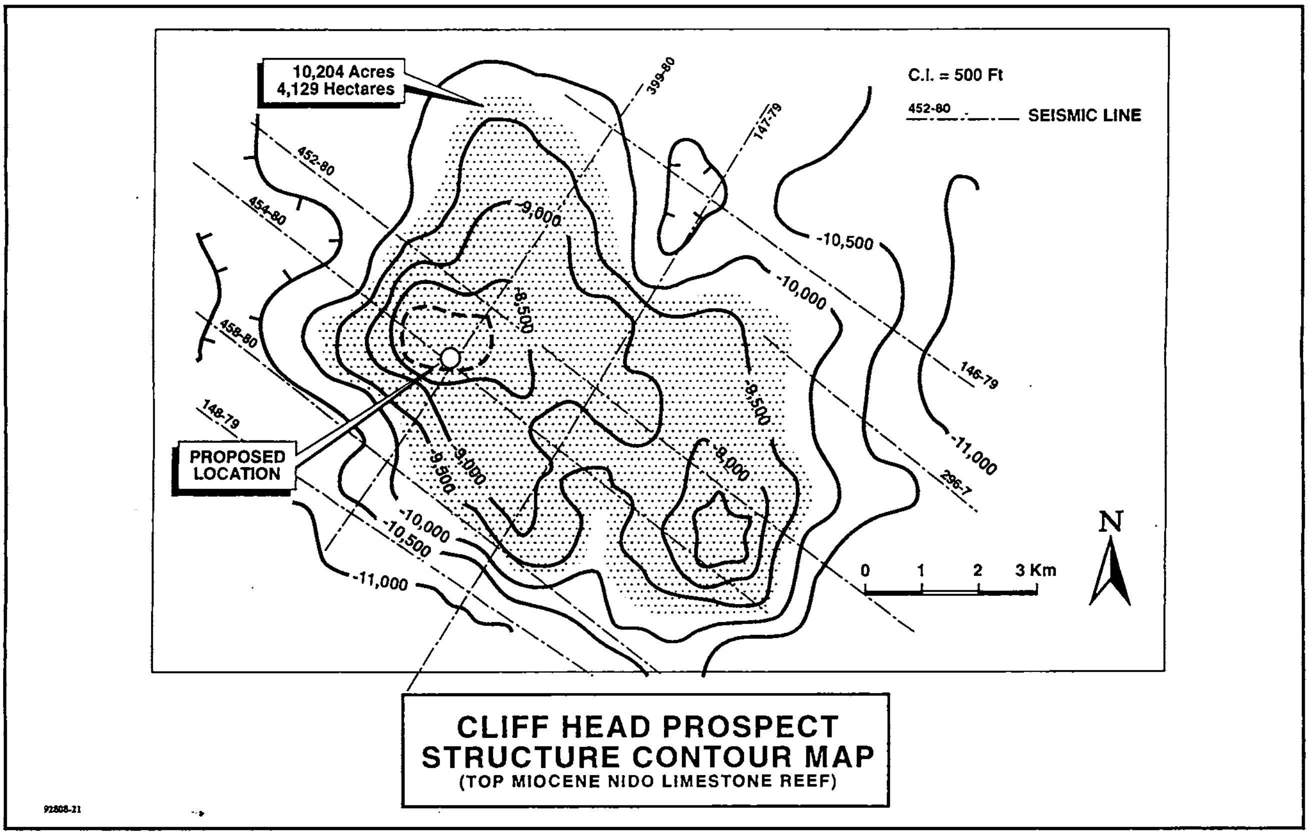


Figure 21. Cliff Head Prospect, structure contour map (Top Miocene Nido Limestone Reef).

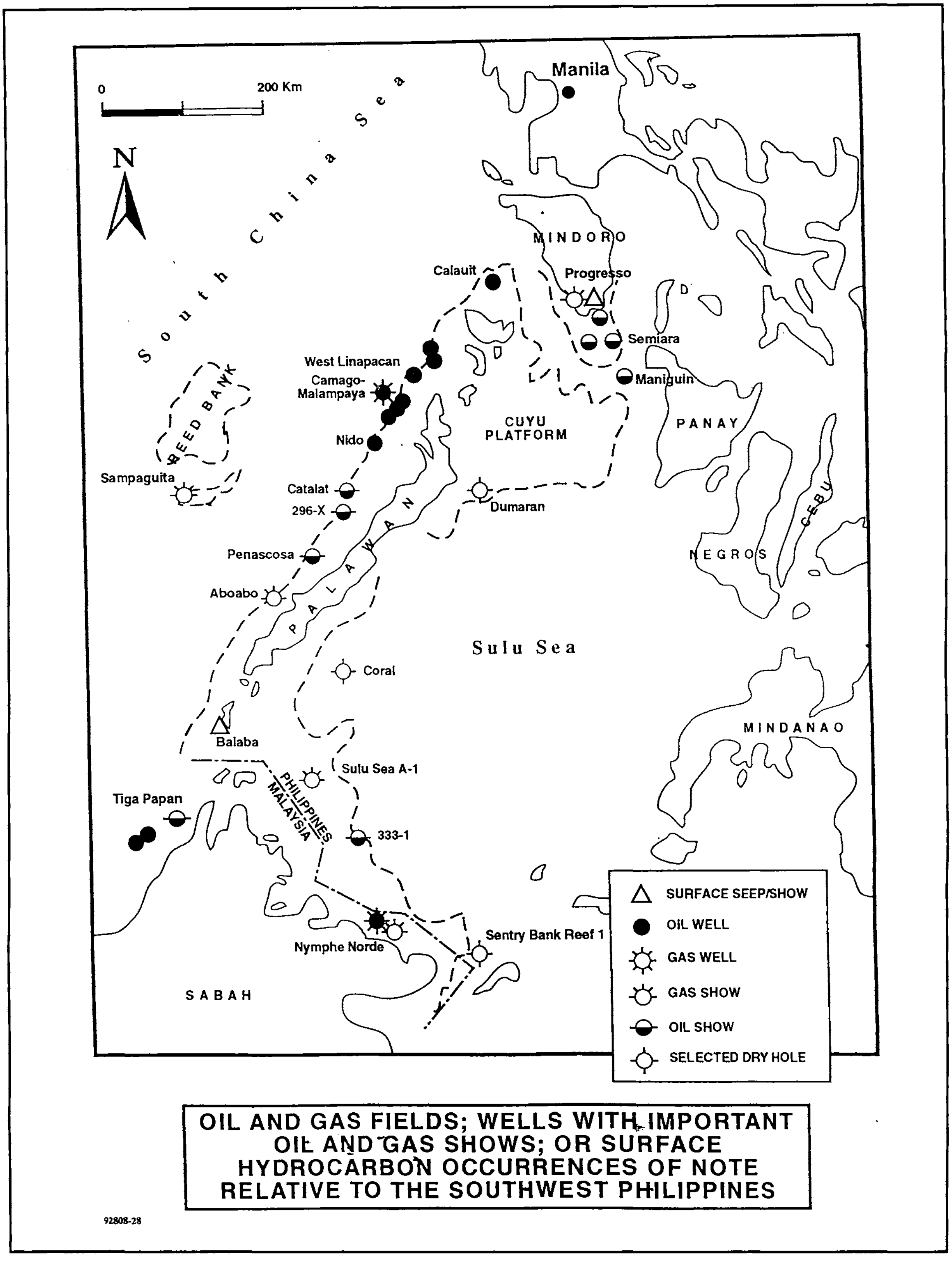


Figure 22. Oil and gas fields; wells with important oil and gas shows; or surface hydrocarbon occurrences of note relative to the Southwest Philippines.

and Schuler (1983), Lee and McCabe, 1986; and Letouzey and Sage (1988).

Two schools of thought exist. Either Palawan is the result of subduction along the south margin of the South China Sea at the Palawan Trough and or as others later proport, it is a thrust pile involving northward movement of a crust unit along the northwest Sulu Sea region.

With the concept generally accepted that the South China Sea continental plate was rifted off the main continental mass and that it subsequently split and spread as well, a vehicle was put in place to raft fragments of the continental plate, or micro-plates south to the Palawan area (Taylor and Hayes, 1980).

As this area moved south, either the Palawan shelf was pulled down by subduction at the Palawan Trough or else the area of Palawan was thrust to the north over the edge of the micro-plate(s). Based on thousands of line kms of seismic data acquired by the BGR, the concept of northwest thrusting is perhaps the dominant school today. The ophiolites of Palawan are perhaps a reflection of mélange deposits and tectonic happenings (Raschka, 1985; Faure, 1979; and Hinz *et al.*, 1989), rather than a reflection of a failed subduction zone (Figs. 8–11).

In the course of evolving tectonic schemes one of the features that crept into the usage and vocabulary of many authors is the so-called Ulugan Bay "fault" (UBF). A major transform fault it probably is not? It is the goal of this writer to erase that fault concept from as many maps as possible. Its strongest support has always been topographic alignment of certain features such as the topographically low Bahile isthmus, Ulugan Bay, and an east-facing submarine topographic slope off the southeast coast, south of Puerto Princessa.

Those authors that have rejected the term are generally the ones that have gone to look at the rocks themselves in the subject area (Hashimoto and Sato, 1973), the BGR, and more recently a detail field examination by the Philippine Office of Energy Affairs geological staff (Pineda, 1990).

Evidence refuting the presence of such a fault are:

1. Ophiolitic rocks to not stop at the Bahile Isthmus. They are present further to the northeast.
2. Gravity and magnetic data provide no indication of a major transform fault intersecting the Island of Palawan in a north south direction as many workers have shown on their maps.
3. Seismic data across the projections of a line passing north-south through Ulugan Bay provide no evidence of a major fault, as discussed below.
4. Geological field work does not support the presence of a north-south fault cutting through the Bahile isthmus of Palawan (Pineda and this writer).

A detailed study of seismic data demonstrates there is not a major fault passing north-south across Palawan in the immediate vicinity of Ulugan Bay. Gallagher's "fault" as shown on Figure 23 of this paper appears to be the maximum published length it has reached to date.

Evidence for a major north-south transform fault passing through Ulugan Bay is untenable. Even so, the suggested presence has been enough to impart negative thoughts by some explorationists and managements about exploring along the coast of Palawan to the southwest of Ulugan Bay. The Ulugan-Bahile area perhaps marks the general northeast limit of the tectonic terrains that were thrust or emplaced from a southwesterly direction. This would not have any bearing on the presence or absence of hydrocarbons in Tertiary rocks further to the north and west offshore along the central and southern Palawan coast.

SUMMARY OF NEW AND CHANGING CONCEPTS

New or changing concepts with respect to the geology and search for oil in the Southwest Philippines are:

1. The area contains world class oil fields with reserve sizes of 100 to 400 MMBO (million barrels of oil) or larger with major gas condensate reserves of 1.0 to 3.0 TCF.
2. A northwest Palawan subduction zone does not exist. Ramping, overthrusting, and duplex emplacement are more likely responsible for the Island of Palawan, at least the southwest two thirds of the Island (Hinz *et al.*, 1989, p. 728).
3. There is not a major north-south transform fault at Ulugan Bay (Faure *et al.*, 1989, p. 942; field observations, this writer) separating two types of tectonic plates. This general area might represent the northeast edge of ramping of Sulu Sea - Sabah terrains northward onto the edge of the southward drifting East Asia microplates.
4. Pre-Tertiary oil sources of Cretaceous age are perhaps likely for some of the oil to be found along parts of the Palawan shelf.
5. Reefs, especially deep water features offshore Palawan, probably need to have been associated with pre-Tertiary source rocks and or deeply depressed Tertiary strata to have obtained a hydrocarbon charge.
6. Much reduced lateral movement of segments of the South China Sea plate in Paleogene time versus that which has been published by some

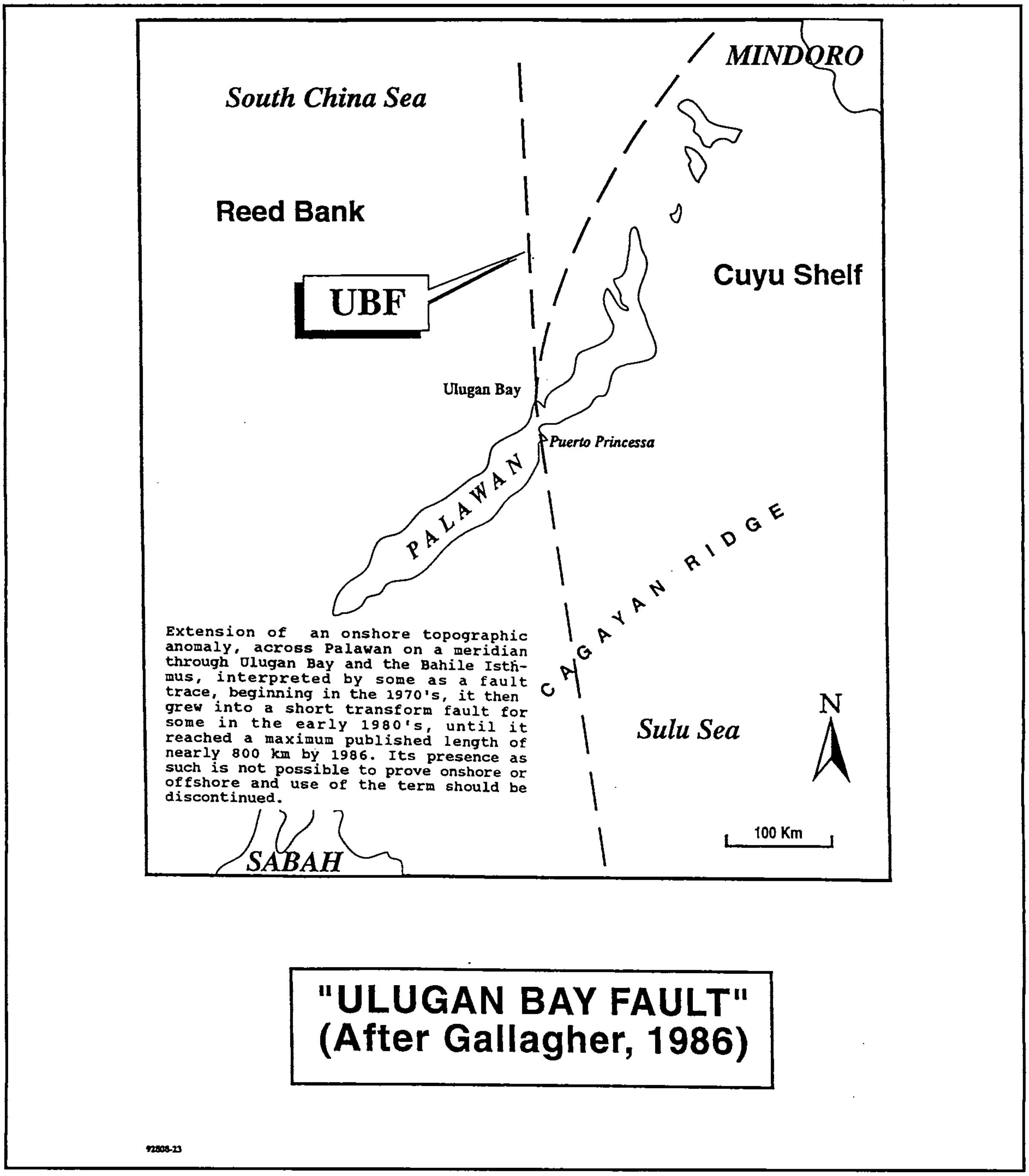


Figure 23. "Ulugan Bay Fault" (After Gallagher, 1986).

authors in the past is more acceptable. Models which show that Palawan and Mindoro have moved from a position immediately adjacent to and southwest of Taiwan are believed in error.

7. Major thrust belt, gas condensate traps might exist along the southwest end of the Palawan South China Sea coast.
8. The Sulu Sea basins have been poorly explored. Better structural positions than have been tested in the past are available to test. Big prospects remain to be tested. Deeper sedimentary section should be explored.

CONCLUSIONS

The Southwest Philippines has all the geological prerequisites to become a major oil producing area. This is demonstrated by the discovery and establishment of production from the West Linapacan field with estimated recoverable reserves of 100 to 200 MMBO.

More recently even the West Linapacan field appears to have a chance of being eclipsed by a still larger potential find at Camago-Malampaya. Press reports suggest a recoverable resource in the range of 200 to 400 MMBO at the latter.

Other world class-sized prospects remain to be tested offshore Palawan, in the Sulu Sea basins and in other parts of the Southwest Philippines including the Mindoro, Reed Bank, and Cuyo platform areas.

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Manuscript received 18th September 1992