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CONTENTS

Petroleum potential of remaining exploration areas in the Papuan Basin

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In late 1984, the government of Papua New Guinea invited applications for Petroleum Prospecting Licences (PPL's) covering 24 open exploration areas in the Papuan Basin. By the closing date of 31 March 1985, applications for 14 of these had been received, of which 12 were successful. Most of the 12 remaining exploration areas are considered to have good petroleum potential, and will be included in a forthcoming invitation in late 1985.

The Papuan Basin is known to contain large reserves of gas and condensate, and good potential exists for the discovery of commercial accumulations of oil. The basin contains a thick marine Mesozoic clastic and Tertiary carbonate sequence (fig. 1), which today is distributed in three major tectonic provinces: the Papuan Fold Belt, the Aure Tectonic Belt, and the Fly Platform (figs. 2, 3). All but one of the available exploration areas are located on the Fly Platform, where three gas and gas-condensate discoveries have been made to date.

Basin evolution. The Papuan Basin was the site of littoral, deltaic, open-shelf, and continental-slope sedimentation on and around the margins of subsiding Australian continental crust during the Mesozoic and Cainozoic. During this period, two major tectonic events significantly affected basin evolution. First, thermal bulging along the axis of the Coral Sea during the latest Cretaceous and earliest Paleocene resulted in regional uplift and erosion of much of the Cretaceous section in the southeastern part of the basin. Extensive faulting occurred at that time on the southwestern Fly Platform, and along at least two wrench-fault zones to the north (Komewu and Fly Wrench Systems). Second, convergence between the Indo-Australian and Pacific Plates from the latest Miocene onward led to the formation of a major fold and thrust belt along the northern and eastern margins of the basin.

3

Sedimentation history. Sedimentation commenced in the Papuan Basin by the Triassic, but the main phase of widespread clastic deposition occurred from mid-Jurassic through Late Cretaceous time. During the Middle and Late Jurassic, predominantly fluviodeltaic deposition prevailed on the western Fly Platform and northwestern Papuan Fold Belt (Kuabgen Group; fig. 1). Within this regime, sandy and shaly facies of the Bol Arkose, Magobu Formation and Koi-Iange Formation accumulated in fluvial, delta plain and pro-delta environments. Meanwhile, fine clastic sediments of the Maril Shale accumulated in distal parts of the shelf and on the continental slope to the north and northeast.

Sedimentation patterns varied during this period as a result of a series of apparently eustatically controlled transgressions and regressions. Major transgressions during the Callovian and latest Oxfordian-earliest Kimmeridgian led to widespread mudstone deposition (Barikewa and Imburu mudstones; fig. 1). The latter transgression was more extensive, and prominent basement highs on the western Fly Platform were at least partially submerged. General regressions during the Kimmeridgian and Berriasian led to widespread sand deposition, and culminated in regional low sea-level stands. The resultant depositional hiatuses are recognisable in most parts of the basin (Omati and mid-Neocomian breaks; fig. 1). The second regressive phase resulted in the deposition of the upper Toro Sandstone in shore-face, barrier-bar, marine-bar and shelf environments.

Shallow marine shale and local sand deposition recommenced over wide areas by the end of the Barremian, and persisted through to the close of the Cretaceous (Ieru Formation; fig. 1). Meanwhile, fine clastic sediments of the Kondaku Tuff and Chim Formation accumulated in more distal areas.

Early Paleogene sedimentation was areally restricted, but by the Late Eocene widespread carbonate platform sedimentation had become established over the central part of the basin (Mendi Group; fig. 1). Following another period of non-deposition during most of the Oligocene, a broad carbonate platform and fringing barrier reef developed over the western and central Fly Platform and southern Papuan Fold Belt (Darai Limestone; fig. 1). At the same time, bathyal carbonates and their distal volcaniclastic equivalents (Puri Limestone and Aure beds; fig 1) accumulated to the east and northeast. Atoll reefs grew locally on structural and basement highs in this bathyal regime (Pasca and Urami Reef complexes; fig. 3).

Towards the close of the Miocene, platform carbonate sedimentation was terminated as the emerging Central Highlands supplied vast quantities of clastic sediments to the basin. The area was subsequently blanketed by fine clastics of the Orubadi beds and marginal marine to terrestrial clastics of the Era beds during the Pliocene and Pleistocene.

Reservoirs. The sedimentation history of the Papuan Basin has been conducive to the formation of a number of potential reservoir units. These include Mesozoic clastic reservoirs in the five open exploration areas on the western Fly Platform, and mainly Tertiary carbonate reservoirs in the seven open exploration areas to the east.

The Toro Sandstone is the prime Mesozoic reservoir unit in the western Fly Platform and Papuan Fold Belt. Total sand thicknesses of up to 150 m are present in areas of maximum sand development. This unit is the reservoir in three discoveries to date: Juha, Barikewa and Iehi. Local good-quality sands in the Magobu, Koi-Iange and Ieru Formations constitute secondary targets in the same general area. To the east, Jurassic near-shore and shore-face sands may have developed around the margins of the Pasca Ridge and Dibiri Spur (fig. 2).

Miocene atoll reefs form the reservoirs in the Uramu and Pasca discoveries in the central part of the basin. In adjacent parts of the Papuan Fold Belt, fractured bathyal carbonates of the Puri Limestone and shelf carbonates of the Eocene Mendi Group have good reservoir potential. The reservoir potential of the Puri Limestone has already been demonstrated by Puri 1, which had an initial flow rate of 1610 bo/d.

Potential reservoirs in the Miocene Darai Limestone include intracarbonate coral patch reefs and algal banks. Extensive reservoirs are also likely to be developed along the fringing barrier reef (Borabi Reef Trend), which borders the eastern margin of the carbonate platform. A prominent carbonate detrital wedge is developed against this feature, providing another, as yet untested, reservoir possibility.

Source potential. The most striking evidence for hydrocarbon source potential in the Papuan Basin is the documented occurrence of at least 120 oil and gas seeps. Most of these are located in the Papuan Fold Belt and Aure Tectonic Belt, and are due almost certainly to rupture of reservoir seals along these structural trends.

Source rock analyses suggest that the Maril Shale has the best oil and gas generating potential in the basin. This unit is favourably situated with respect to both Mesozoic and Tertiary reservoirs, and could have sourced either depending upon the timing of migration in any one area. The formation is fully to late-mature in the central Papuan Basin, and may be over-mature further east.

Inertinite and vitrinite derived from land plant wood tissues are the most common kerogens found in the Magobu Formation, Barikewa Mudstone and Koi-Iange Formation in the western and central Fly Platform. In areas where vitrinite-dominated kerogens are present, shales from these units are considered to have fair oil and gas generating potential. Limited available data suggest that these units are marginally to fully mature over much of the central and western Fly Platform. Data from the westernmost part of the Fly Platform are almost completely lacking, and no definite conclusions can be drawn regarding source rock quality there.

Mesozoic prospects. Mesozoic prospects are confined mainly to the five open exploration areas in the western part of the Papuan Basin. They include up-dip wedge-outs and drape-structures associated with basement highs, simple anticlines, normal fault-traps, and wrench-fault - controlled structures.

Traps associated with basement highs are common on the western Fly Platform. The largest basement high in the general area is the Oriomo High, which borders open exploration areas H and P/Q. Updip wedge-out traps and fault-traps are known to exist along its northern and eastern flanks. Seismic and aeromagnetic data indicate that additional unexplored highs of variable size are present in open exploration areas A and H (play type 1; figs. 2, 4). The highs are onlapped by the Toro Sandstone at some localities and are draped by it at others. Areal closures of up to 50 sq km have been mapped, and reservoir depths vary from 1000 to 2500 m.

Onlap/pinchout traps involving possible Jurassic sandstone reservoirs may be developed around the margins of the Pasca Ridge in open exploration areas L and Y (play type 2; figs. 2, 4). The reservoirs are expected to be clean, shore-face sandstones developed around the margins of the formerly emergent basement ridge, and would lie at depths of between 3000 and 4000 m.

Simple anticlines are present along the northern margin of the Fly Platform in open exploration area C (play type 3; figs. 2, 4). Structural closures have been mapped at the level of the surface Darai Limestone, although the configuration of the structures in the subsurface is not well understood at present. Depth to the Toro Sandstone reservoir in the area is about 1000-3000 m.

Normal faulted anticlines have been identified in the Kikori-Purari Delta region in the vicinity of open exploration area J (play type 5; figs. 2, 4). Simple anticlinal closures and up-dip closures against the faults are the main trap types. Middle to Late Jurassic sandstone reservoirs, if present, would occur at depths of about 3000 to 4000 m in the general area.

A wide variety of trapping possibilities exists along the Komewu Wrench System, which passes through open exploration areas A, C, I, and J (play type 6; figs. 2, 4). Trap types include up-dip closures against the faults and roll-overs into the faults. Associated en-echelon folds trending obliquely to the fault zone provide a further trapping possibility. The Toro Sandstone occurs at depths of about 2000 to 3000 m along this structural trend.

Normal and/or wrench-fault - controlled structures occur in the Daru Embayment, the northern margin of which borders open exploration area P/Q (play type 7; fig. 2, 4). Up-dip fault closures are the main trap type in the area. Possible sandstone reservoirs of Early Jurassic age may be present at depths on the order of 2000 to 3000 m.

Tertiary prospects. The seven open exploration areas in the central and eastern part of the Papuan Basin contain numerous plays involving reservoirs of Tertiary age. These include Eocene and Miocene reef and reef-related traps, basement-high - related traps, simple structural highs, and thrust-faulted anticlines.

Miocene atoll reefs situated east of the Borabi Reef Trend are proven reservoirs. Further exploration is warranted in the vicinity of the Uramu reef complex in open exploration area J (play type 1; figs. 3, 4). The Uramu reef tested gas and minor condensate, but the nearby Mira reef was missed by Mira 1 and remains untested. Eocene and Miocene reef and reef-associated sediments have also been identified along the faulted southeastern margin of the Uramu High.

Probably the largest and most significant Miocene reef prospect is the Borabi Reef Trend. Although much of this trend lies within areas currently under application (areas R and K; fig. 4), it extends northward into open exploration area J (play type 2; figs. 3, 4). More than 1600 m of reef complex have been built up along parts of this giant feature. Reservoir depths range from 1000 to 1500 m.

Potential Miocene intracarbonate plays occur mainly in open exploration areas P/Q and I (play type 3; figs. 3, 4). Eocene patch reefs may also be present in the eastern part of area P/Q (play type 4; figs. 3, 4). Depths to these potential, untested reservoirs range from 750 to 2000 m.

Eocene carbonate reservoirs may also be present in broad, gentle structural highs commonly associated with normal faulting in open exploration areas P/Q, Y, L, and M (play type 7; figs. 3, 4). This type of play would depend on fracturing of the normally-tight Eocene limestones, which are known to occur in other parts of the basin. Depth to the reservoir would be about 1500 to 2000 m in area P/Q, and about 2000 to 3500 m or greater in areas Y, L and M.

Tilted half-graben structures containing potential reservoirs of Eocene and Miocene age have been identified along the northwestern margin of the Pasca Ridge in open exploration area L (play type 8; figs. 3, 4). Up to 1200 m of sediments are present at depths of between 3500 and 5500 m. The reservoirs may be composed of carbonate debris derived from the Pasca reef and/or clastic sediments derived from the ridge itself.

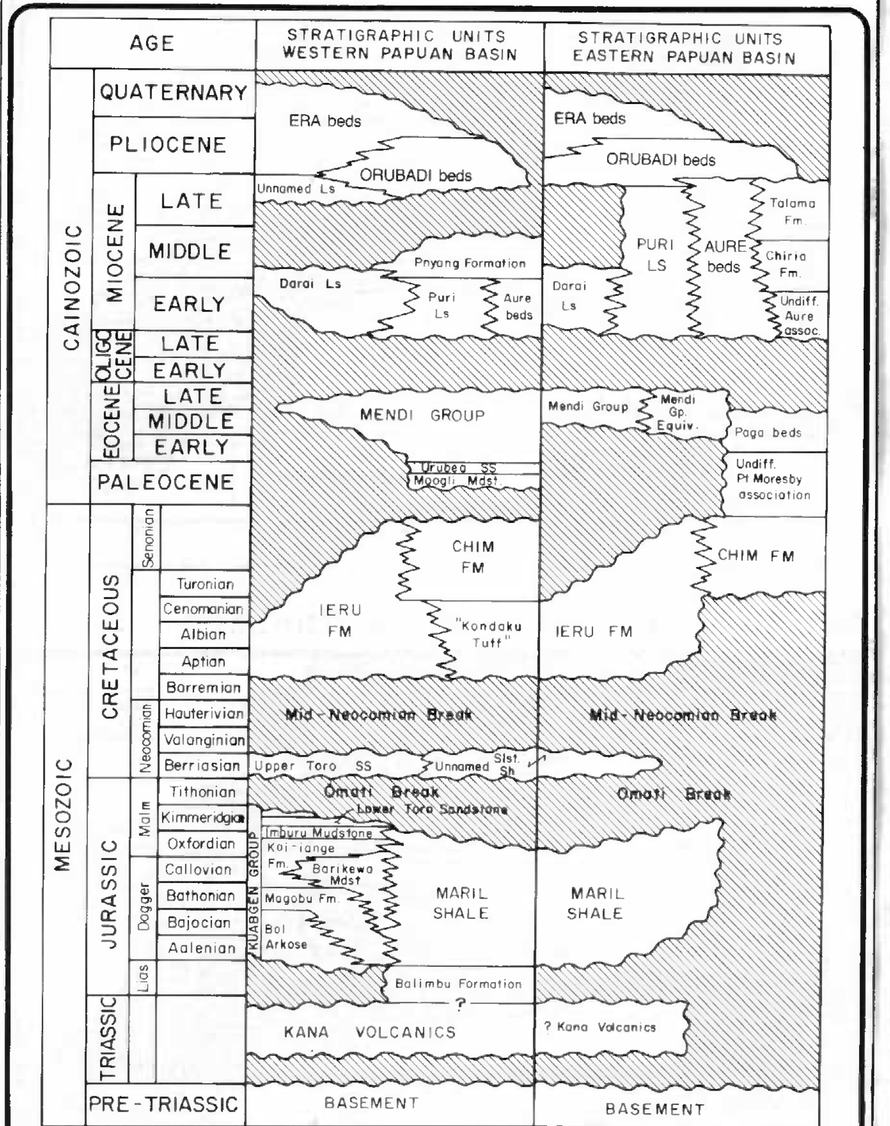
Asymmetric, thrust-faulted anticlines form important structural traps in open exploration area E and possibly in the unlicenced area north of PPL 27 (play type 9; figs. 3, 4). Fractured Puri Limestone is a proven reservoir in the general area, as demonstrated by the oil flow from Puri 1 to the southeast. Fractured Eocene limestones form a secondary target in the same area.

Reservoir depths vary between 500 and 5000 m.

Conclusions. The Papuan Basin offers a wide variety of opportunities for oil and gas exploration. Large accumulations of both gas and condensate already have been proven by past exploration in the Papuan Fold Belt and Fly Platform. Although commercial oil discoveries have eluded explorationists in the past, abundant seeps of oil in the 21 to 30 degree API range provide strong evidence that oil generation has taken place. Given the large number of play concepts that have been identified, excellent potential exists for the discovery of commercial oil accumulations in the currently unlicenced exploration areas of the Papuan Basin.

Fig. 1

Generalized stratigraphic table*



* For the western and eastern Papuan Basin

Fig. 2

Mesozoic prospects

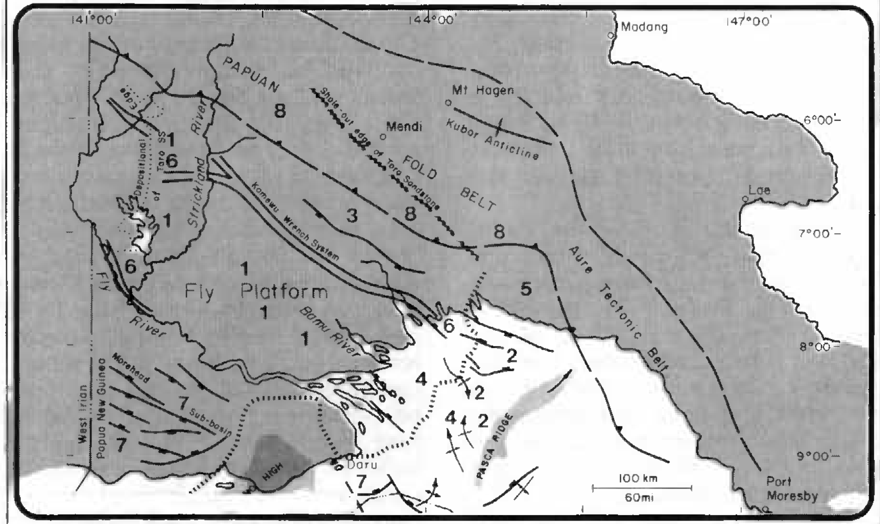
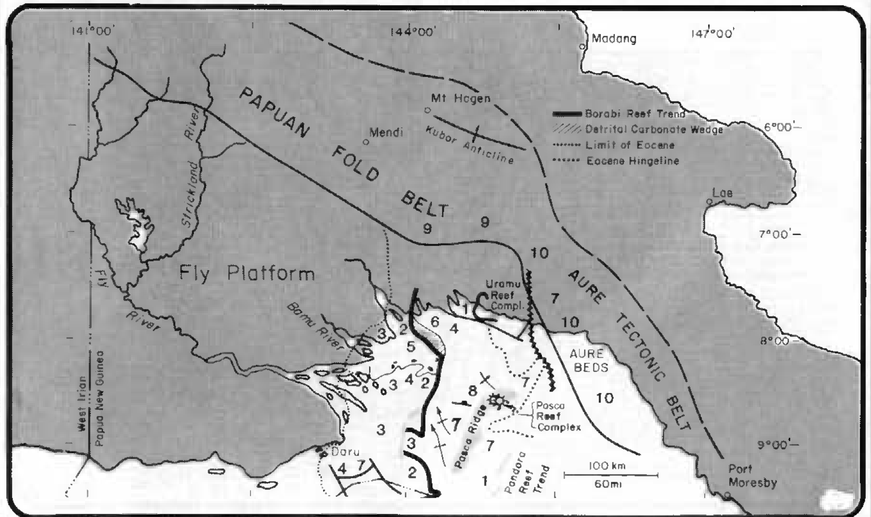


Fig. 3

Tertiary prospects



10

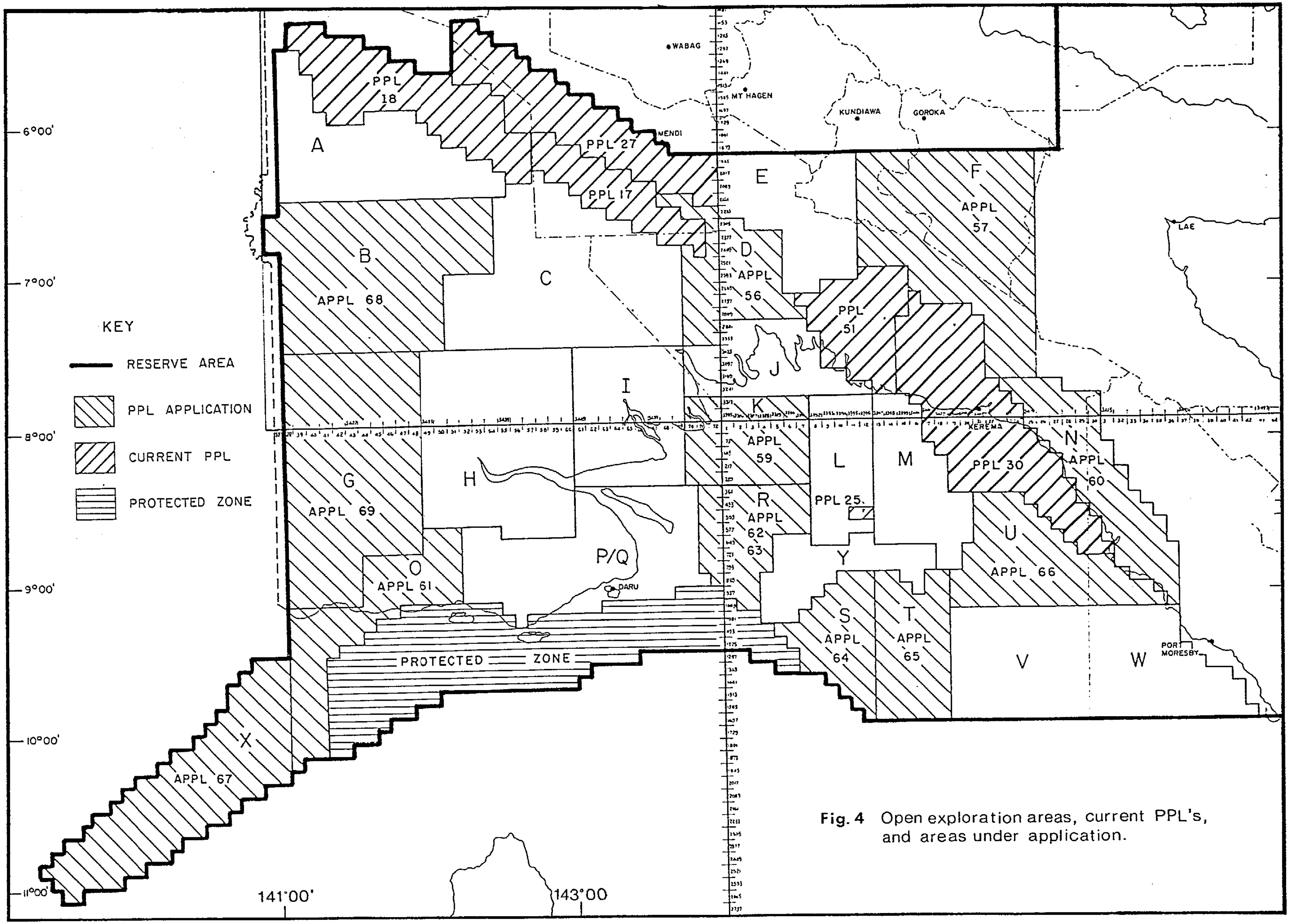


Fig. 4 Open exploration areas, current PPL's, and areas under application.

N O T E S

Basin development and regional tectonics of the
New Ireland and Manus regions

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The arcuate northwest-trending New Ireland Basin is 900 km long and about 160 km wide, and most of the basin lies offshore northeast of New Hanover and New Ireland (fig. 1). Much of the basin is a structurally simple downwarp, which formed as a fore-arc basin lying between an Eocene to Early Miocene volcanic arc in the southwest and an outer-arc high in the northeast. The basin contains up to 7 km of sedimentary rocks interpreted as generally consisting of Early Miocene and possibly Oligocene volcaniclastics, Early to Late Miocene shelf-carbonates, Late Miocene and Pliocene bathyal chalks and volcaniclastics, and Pleistocene to Recent sediment ranging from terrestrial conglomerates to hemipelagic oozes. In the eastern part of the basin, Plio-Pleistocene volcanism has formed islands and has greatly disturbed the older strata.

No petroleum exploration wells have been drilled in the basin. Possible lack of source rocks and low thermal gradients may reduce the basin's petroleum potential. However, the presence of thick shelf-limestones onshore, and the apparent presence of widespread thick and deeply-buried Miocene shelf-limestones offshore, including carbonate build-ups, suggests that the basin warrants serious exploration. The presumed shelf carbonates are up to 2000 m thick and could be both petroleum source and reservoir rocks. Volcanogenic silts could provide seals.

Multichannel seismic reflection profiles collected in 1984 by the tripartite (Australia, New Zealand, and USA) CCOP/SOPAC cruise of the R/V S.P. Lee traversed the axis of the New Ireland Basin east of New Ireland (fig. 1). Line 401, collected just southeast of Namatanai, New Ireland, revealed a flat, high-amplitude relfector or 'bright spot' within the core of an anticline some 20 km east of New Ireland (fig. 2). The bright spot is about 2 km wide along Line 401 and occurs 1.2 sec (1700 to 1800 m) beneath the sea-floor in water depths of 2500 to 2600 metres. Thus, it may well occur within the oil window of the sedimentary section in the New Ireland Basin, but in water too deep at present for commercial development. The western extent of the anticline and associated bright spot in the shallower waters off New Ireland is unknown.

The Manus Trench extends some 1500 km from New Guinea to the area east of New Ireland. The trench was active from Eocene through earliest Miocene time and now forms the northern boundary of the Bismarck Archipelago (fig. 1); (Kroenke, 1984; Exon and Tiffin, 1984). The Bismarck region in general is typical of convergent margins in the Pacific in that the region includes a volcanic island-arc (Manus, New Hanover, and New Ireland Islands), a fore-arc basin (New Ireland Basin), an outer fore-arc high (Mussau-Emirau-Feni Ridge), and a trench (Manus Trench). Although these features persist to the present, there is no active volcanism and no well-defined Benioff zone associated with active subduction along the Manus Trench. However, proponents for the existence of a Caroline Plate, north of the Manus Trench, suggest that the trench has been recently re-activated at very slow convergence rates to form the southern margin of the Caroline Plate (Weissel and Anderson, 1978).

Multichannel seismic reflection data collected in 1984 across the Manus Trench east of the Massau Trench show active convergence between the Pacific Plate and the Manus region (with the so-called North Bismarck Plate). Data across the Manus Trench west of the Mussau Trench are equivocal about convergence between the Caroline and North Bismarck Plates along this segment of the Manus Trench.

The Manus fore-arc extends north some 150 km from the Manus Island Arc (the Bismarck Archipelago) to the Manus Trench (fig. 1). Geophysical lines collected by BMR in 1970 (Willcox, 1976; Tilbury, 1975) and CCOP/SOPAC in 1981 (Exon, 1981; Tiffin, 1981) are shown in figure 1. These seismic reflection and magnetic profiles first indicated the presence of thinly-buried, highly-reflective, and magnetic layers beneath extensive areas of the 1500-2000 m deep Manus fore-arc (fig. 3). These layers are thought to be large lava flows covering much of the fore-arc.

Multichannel seismic reflection and magnetic profiles collected on the 1984 Lee cruise confirmed the existence of extensive areas of magnetic, highly-reflective and flat-lying layers thought to be outpourings of lava, which are buried by 100-400 metres of hemipelagic (?) sediment across more than 8000 sq km of the Manus fore-arc. The lava flows occupy the broad, relatively flat regions of the fore-arc, and their thickness and age are unknown. The sources of the flows are also unknown; they may be related to volcanic outpourings along the Manus volcanic arc to the south (Jaques, 1980). Alternatively, R.W. Johnson (pers. comm., 1985) suggests that the flows may be related to the formation of a back-arc basin, the Manus Basin, south of the Manus Arc, which opened about 3.5 Ma (Taylor, 1979). However, these flows extend across the Manus fore-arc, not the back-arc, and are, therefore, in the wrong position geometrically to be related to back-arc spreading.

Gravity, seismic refraction, and seismic reflection data from the *Lee* cruise suggest that the fore-arc is underlain by a thick mass of deformed sedimentary strata which apparently has been accreted to the Manus Arc by southward-dipping thrust faults. Nested, hyperbolic reflectors were recorded adjacent to and beneath the flat-lying, cap-reflections from the lava flows. The hyperbolic reflections appear to be from thrust packets within the sedimentary strata beneath the fore-arc. Earthquake studies confirm the existence of thrust events (D. Denham, pers. comm., 1985) which may be associated with southward-dipping faults in the Manus fore-arc. The style of accretionary deformation in this fore-arc is perhaps similar to that of the more extensively studied convergence zones in the Pacific and Atlantic regions, although the ages of the strata and deformational periods in the Manus fore-arc are unknown.

References

Exon, N.F., 1981 - Papua New Guinea geophysical survey : Hydrocarbons. Cruise PN-81(1). *CCOP/SOPAC Cruise Report 52* (unpub.)

Exon, N.F., & Tiffin, D.L., 1984 - Geology and petroleum prospects of offshore New Ireland Basin in northern Papua New Guinea, *in* S.T. Watson (Ed.): *Transactions of the Third Circum-Pacific Energy and Mineral Resources Conference,* 623-630.

Jaques, A.L., 1980 - Admiralty Islands, Papua New Guinea, 1:250 000 Geological Series - *Explanatory Notes*. *Geological Survey of Papua New Guinea*.

Kroenke, L.W., 1984 - Cenozoic tectonic development of the southwest Pacific : United Nations CCOP/SOPAC Technical Bulletin No. 6.

Taylor, B., 1979 - Bismarck Sea : evolution of a back-arc basin. Geology, 7, 171-4.

Tiffin, D.L., 1981 - Papua New Guinea offshore hydrocarbon and phosphate survey, Cruise PH-81(2) CCOP/SOPAC Cruise Report 53 (unpub.).

Tilbury, L.A., 1975 - Geophysical results from the Gulf of Papua and Bismarck Sea. Bureau of Mineral Resources Record 1975/115 (unpub.).

Willcox, J.B., 1976 - Structure of the Bismarck Sea. Bureau of Mineral Resources Record 1976/59 (unpub.).

Weissel, J.K., & Anderson, R.N., 1978 - Is there a Caroline plate? Earth and Planetary Science Letters, 41, 143-58.

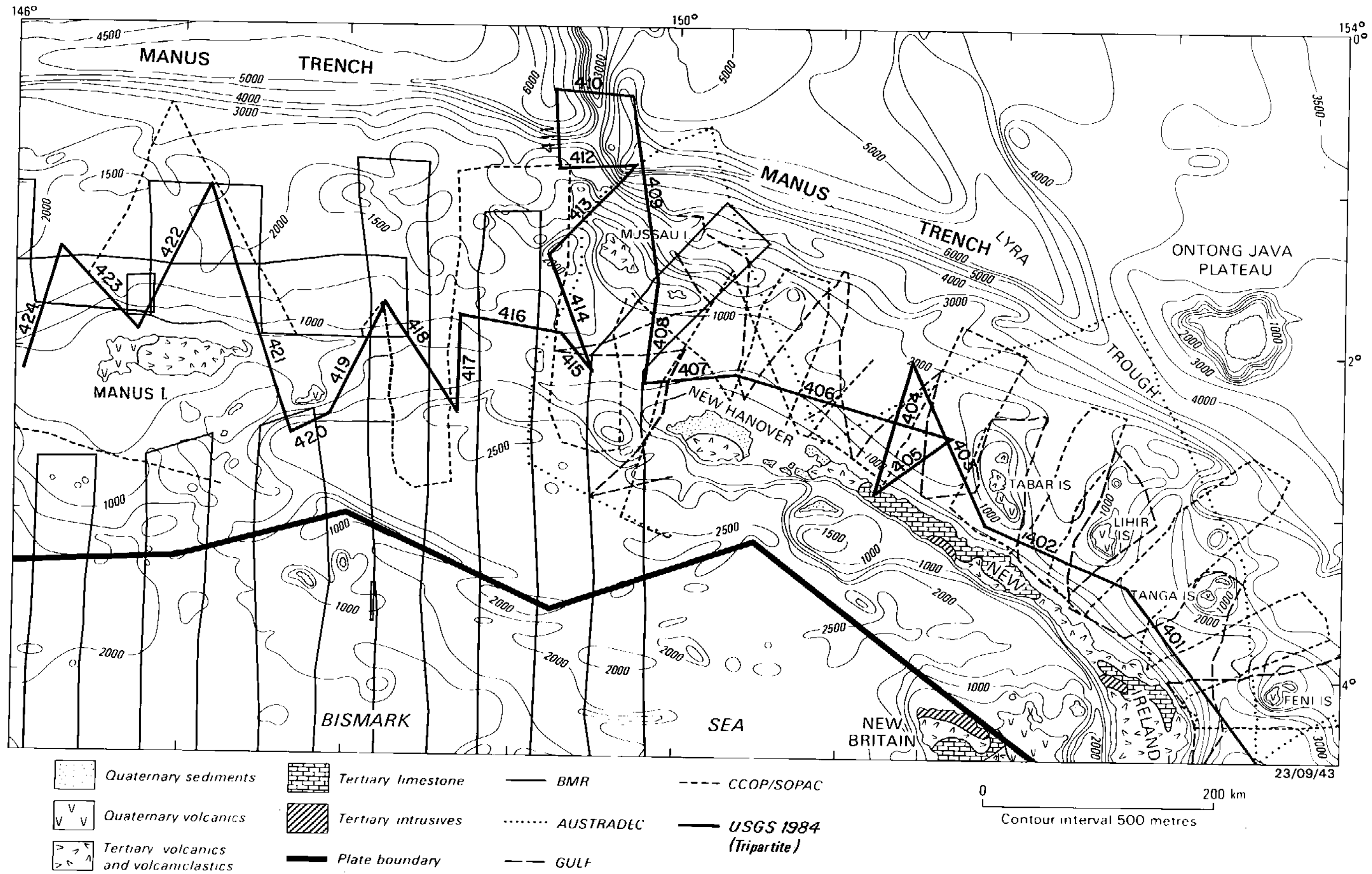

Fig 1 New Ireland Basin showing seismic tracklines.

17

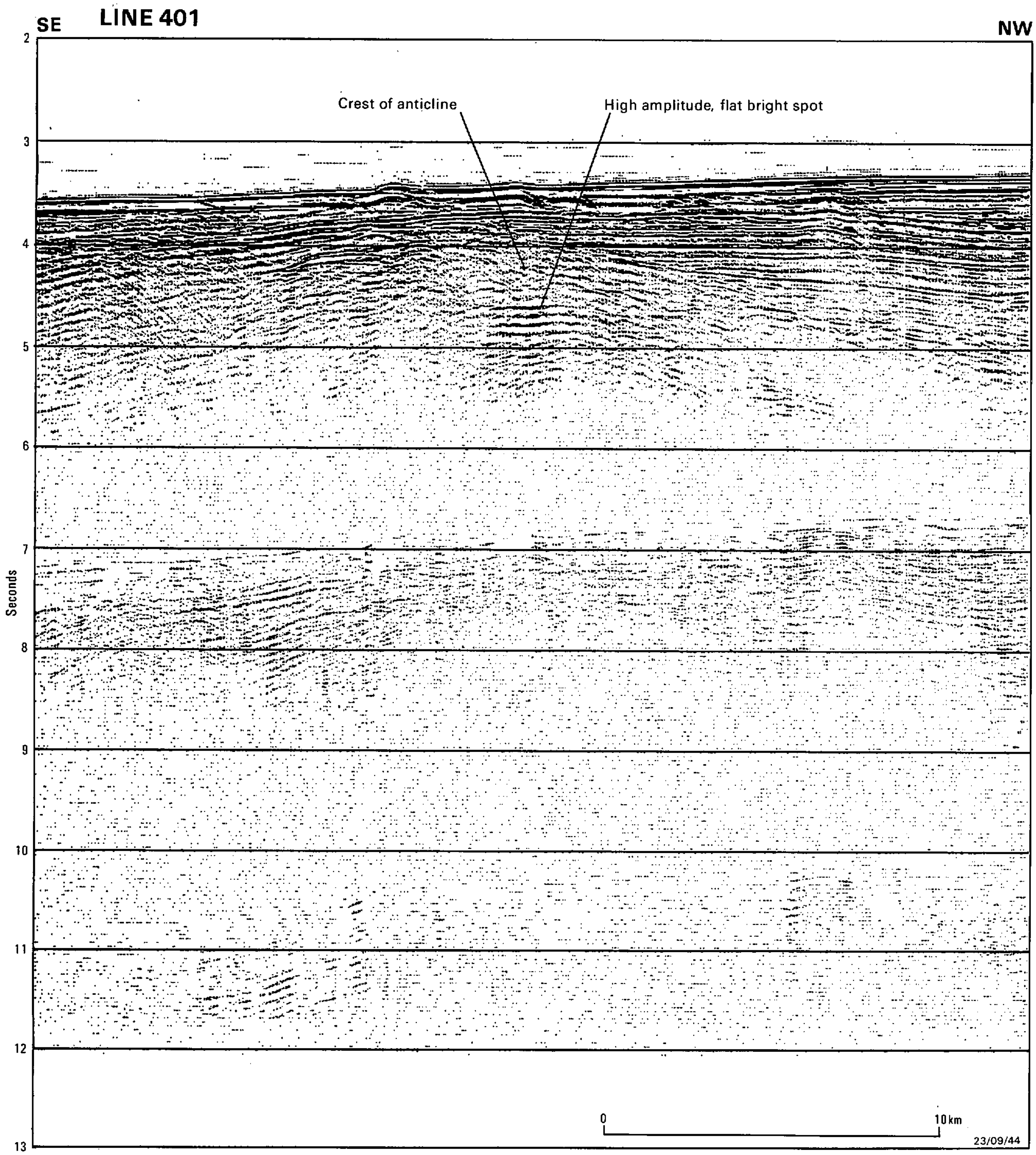

Fig 2 Flat, high-amplitude "bright spot" on R.V."Lee" multichannel seismic line 401, near Tanga Island.

18

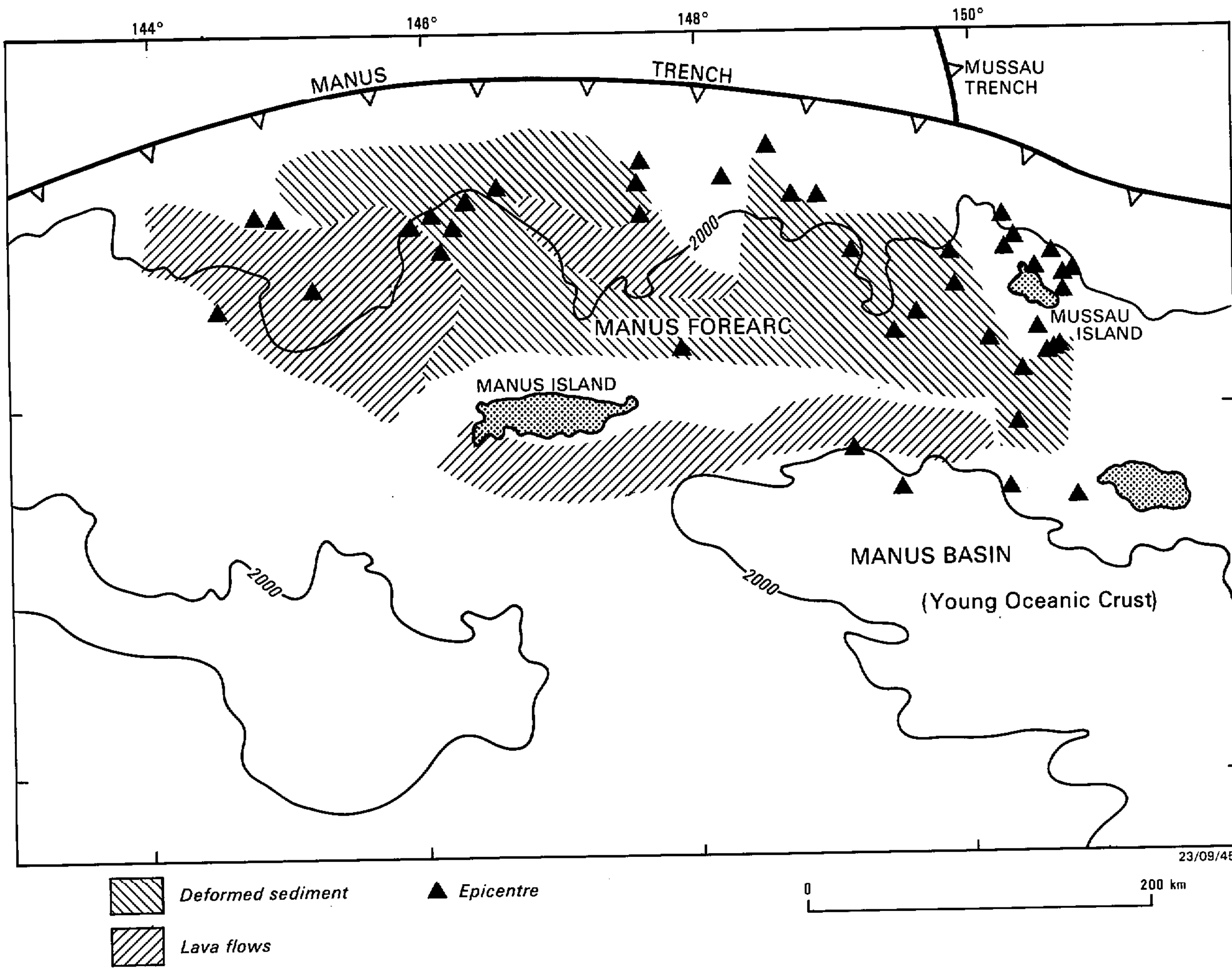

Fig 3 Lava flows, deformed sediments and earthquake epicentres in the arc and forearc region near Manus Island.

19

N O T E S

Hydrocarbon potential of the Bougainville Basin
Papua New Guinea

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Introduction

The Bougainville Basin covers an area of 12,000 km^2 and includes both onshore and offshore regions of Bougainville Island (figure 1).

The basin is virtually unexplored with one well and approximately 1800 km of seismic data recorded in the offshore area. This exploration indicated that the basin contained a thick (up to 7000 m) largely Neogene-Recent sedimentary sequence.

This paper summarises the re-interpretation of both available geophysical and geological data of the Bougainville Basin pertinent to hydrocarbon exploration. The emphasis is on the more prospective offshore area.

Exploration history

The Bougainville Basin was first indicated from onshore mapping by BMR (Blake & Miezitis, 1967). Confirmation that there existed a thick offshore extension to the basin followed in 1970 with the recording and interpretation of a number of reconnaissance seismic traverses by Shell Development (Australia) Pty Ltd and Amoco Australia Exploration Company. In 1971, Petroleum Permit No PNG/19P was granted to a consortium of Shell, Australian Gulf Oil Company, and Hematite Petroleum, across what was considered to be the most prospective part of the basin. Three marine seismic surveys, totalling 1800 km of seismic line acquisition, were conducted within PNG/19P by the consortium.

In 1975 L'Etoile-1 was drilled within the permit to test an interpreted reefal build-up. The well was plugged and abandoned at a T.D. of 1682 m after penetrating a volcanic pile. The predicted massive carbonate build-up was not encountered and no significant shows were recorded in the well.

The permit was surrendered in 1975 and no subsequent commercial oil exploration has been conducted within the basin.

Background geological information

The Bougainville Basin was initiated in Late Oligocene or Early Miocene times and was probably located in a back-arc position relative to the West Melanesian Trench. A collision between the Ontong Java Plateau and the Melanesian Trench choked the subduction zone in Late Miocene times. This collision resulted in arc reversal from which time the Bougainville Basin has occupied a fore-arc position relative to the New Britain-Bougainville Trench.

Basin structure Figure 2 shows the main structural elements recognised at the deepest seismic horizon (basement) level across the offshore area of the Bougainville Basin. Positive structural elements comprise the Kunua and Aitara Highs connected along the outer margin by a persistent structural ridge, the Tarangau Ridge. The Laruma Depocentre lies to the east of this ridge and is bordered by Bougainville Island. West of the Tarangau Ridge, basement is down-faulted into the Solomon Sea Basin. The outer down-faulted basin regions coincide with deep water.

Lying within the centre of the Laruma Depocentre is the Motupena Anticlinorium, a west-northwest trending compressional feature which developed in Late Miocene times.

Stratigraphy and history of sedimentation

Figure 3 shows the regional stratigraphic table. L'Etoile-1 penetrated only the upper portion of the sedimentary sequence which infills the offshore Bougainville Basin. Figure 4 shows the position of L'Etoile-1 relative to a generalised north-south cross section. In the virtual absence of well control the stratigraphy and interpreted depositional history draw largely on the knowledge of onshore geology and the interpretation of offshore seismic data.

Basement is represented by the Kieta Volcanics, which underlie most of the Bougainville Basin. They are a ?Oligocene to Early Miocene, sub-alkaline, andesitic sequence and probably overlie early Palaeogene oceanic crust. The Red Horizon seismic reflector is interpreted to generally coincide with the top of the Kieta volcanics.

In the Early Miocene, inner sublittoral carbonate sedimentation (Kerika Limestone) occurred throughout much of central Bougainville Island. Submarine pyroclastic volcanism probably occurred in the region of L'Etoile-1. The Green Horizon is interpreted to coincide with the top of the Keriaka Limestone. In distal and deeper water areas across the basin, lateral equivalents of the Keriaka Limestone (?Red to Green Horizon seismic sequence) were deposited. These equivalents might be similar to the Buka beds and to the Mole Formation of Choiseul. The Mole Formation contains prominent tuffaceous turbidites and other volcanoclastics, with occasional carbonates. The Orange Horizon lies near the top of the Mole Formation.

During the Late Miocene there was normal and reverse faulting, probably associated with arc reversal and the formation of the New Britain-Bougainville Trench. In the latest Miocene, volcanism increased with the development of stratovolcanoes on Bougainville and near the Fauro Islands. The lavas and proximal pyroclastics (Bougainville Group) were deposited mainly in terrestrial to inner sublittoral environments while pyroclastics and volcaniclastics (Mono Siltstone) were deposited in distal locations mainly at bathyal depths. The Mono Siltstone, a regressive sequence, prograded southwestward over the deeper parts of the basin. It unconformably overlies the Orange to Blue Horizon sequence.

Although the Mono Siltstone is generally a lower-upper bathyal clastic facies, it contains localised build-ups of inner sublittoral carbonate. These developed on structural highs, associated with syn-sedimentary tectonism.

Hydrocarbon potential

Source. No source rock geochemical studies have been undertaken on sediment samples from the Bougainville Basin. Mudstones and siltstones in the bathyal volcaniclastic (Green to Organge Horizon) sequences (lower? Mole Formation equivalents) and Keriaka Limestone equivalents are considered to have the potential to generate hydrocarbons.

Maturation. The present-day geothermal gradient calculated from bottom-hole temperatures in L'Etoile-1 is very low ($1.6^{o}C/100$ metres or $0.8^{o}F/100$ feet). If similar low gradients prevailed in the past, then the top of the oil generation zone would lie at a depth of about 4700 m. In the Laruma Depocentre, most of the Red-Green Horizon sequence (Keriaka Limestone equivalents) is overlain by more than 5000 m of sediment.

Reservoir. No quantitative data relating to porosity and permeability of reservoir rock samples from this basin are available. However, suitable reservoir rocks are likely to occur within the Early Miocene Keriaka Limestone. Reservoirs may also occur in younger carbonate build-ups, which are present within the latest Miocene to Pliocene Mono Siltstone. Water laid tuffs, similar to the Tamala Formation of the Papuan Basin which is known to have excellent reservoir properties, may also be present.

Seal. Adequate seal over reefs within the Lower Mono Siltstone is provided by the fine clastics of this unit. Intraformational seals, comprising tuffaceous fine clastics, are probably present between the Miocene Green to Orange Horizons.

Trapping mechanisms. Both structural and stratigraphic traps occur within the basin. Structural traps include both tensional fault-block and compressional features. Recognised stratigraphic traps include both unconformity traps and carbonate reef build-ups. Fault-related structures without drape are the most common type. These occur on the updip side of tilted fault blocks around the margin of the Kunua High, developing while the basin was in a predominantly tensional back-arc position. Compression, possibly associated with oblique convergence, produced the westerly-trending Motupena Anticlinorium and associated reverse faults in Late Miocene times as the basin became placed in a fore-arc position. Carbonate build-ups may have developed around the margins of the basin, as barrier reefs along the Tarangau Ridge, and as patch reefs behind this feature. Unlike the basement high L'Etoile-1 was drilled on, these complexes are generally characterised by a long history of reefal development with present day reefs forming bathymetric highs. Unconformity traps are observed around the flanks of the Laruma Depocentre, where the sub-Blue Horizon unconformity truncates underlying sequences on the margins of the highs. Truncation also occurs around the flanks of the Motupena Anticlinorium.

24

Play concepts. A consideration of source rock, reservoir and maturation history, together with structural style, as interpreted from seismic sections, has led to the indentification of four leads/prospects, which demonstrate several differing play concepts. These were not tested during the previous exploration campaign.

Motupena Anticlinorium. This is a compressional feature with fault-independent closure mapped at all key horizons below the sub-Blue Horizon unconformity level. Reservoir targets would be expected within the Green to Orange Horizon interval, in an interbedded sandstone, conglomerate and siltstone sequence of Middle Miocene age. Additional clastic reservoirs may also be present within the lower portion of the Orange to Blue Horizon interval equivalent to the upper Mole Formation. There is also potential for carbonate reservoirs within the Red to Green interval providing that Keriaka Limestone equivalents extend this far into the basin. The Motupena Anticlinorium is well located relative to a possible kitchen area. The structure is relatively well detailed by existing seismic potential of the main kitchen area, but also enables an evaluation of the overall prospectivity of the Miocene section, which was not penetrated by L'Etoile-1. The Motupena Anticlinorium provides the best opportunity for simultaneously testing a potentially large closure and obtaining much needed control on the offshore Bougainville Basin sequences.

The Tugu Fault Block Lead. The Tugu lead is an antithetic fault-block closure located on the faulted margin of the Laruma Depocentre. Structuring of the Tugu Fault Block occurred largely during the Pliocene, although there is evidence for Late Miocene movements along some of its bounding faults, and onlap indicates that it was a positive structural feature in the Middle Miocene. The Tugu Fault Block lead is well located with respect to the proposed kitchen area. It occurs in 90 m of water and would require a relatively deep well to test the entire section (2700-3000 m).

Carbonate plays. Carbonate build-ups representing Neogene barrier reefs appear to be present along the Tarangau Ridge, adjacent to the Laruma Depocentre (Tarangau Leads). Most build-ups occur in the Middle Pliocene to Pleistocene sequence and probably formed during the regressive phase noted in L'Etoile-1. The Tarangau Ridge was a persistent, structurally positive feature in the Pliocene and the site of littoral or sub-littoral carbonate development. The Bubulung Lead is interpreted to be a barrier reef complex across the outer flanks of the Aitara High in water depths of 100 m. The lead has a length of 23 km and has a vertical relief of up to 1400 m. The Bubulung Lead is well located, lying updip of the adjacent kitchen areas. The thick Mono Siltstone would provide regional seal and the absence of Pliocene faulting further enhances sealing properties.

Conclusions

The Bougainville Basin remains a relatively unexplored basin. Notwithstanding the lack of data, the results to date demonstrate the presence of a variety of play types involving both clastic and carbonate reservoirs. The variety of play types reflects both fore-arc and back-arc settings. The L'Etoile-1, the only well drilled in the basin to date, having encountered pyroclastics failed to test a valid play.

Of the identified prospects/leads the Motupua Anticlinorium provides the best opportunity for simultaneously testing a potentially large closure and obtaining much needed control on the Bougainville Basin sedimentary sequences.

References

BLAKE, D.H., & MIEZITIS, Y., 1967 - Geology of Bougainville and Buka Islands, New Guinea. Bureau of Mineral Resources, Australia, Bulletin 93 (PNG 1).

BLOW, W.H., 1969 - Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In Proceedings of the First International Conference on Planktonic Microfossils, Geneva, 1967. Leiden: Brill.

HUGHES, G.W., 1981 - Micropalaeontology of the Shortland Islands and Choiseul. British Technical Cooperative Western Solomons Mapping Project Report No. 17.

OCEANIC EXPLORATION, 1975 - L'Etoile-1, Well Completion Report (unpubl.).

SRINIVASAN, M.S., & KENNETT, J.P., 1981 - A review of Neogene planktonic foraminiferal biostratigraphy: applications in the equatorial and South Pacific STP. In Warme, J.E., Douglas, R.G., & Winterer, E.L. (eds.). The Deep Sea Drilling Project: A Decade of Progress. Special Publication of the Society of Economic Paleontologists & Mineralogists 32: 395-432.

TURNER, C.C., 1978 - Shortland Islands Geological Map sheet SH 1A, 1:100 000 Geological Survey Division, Ministry of Natural Resources, Solomon Islands.

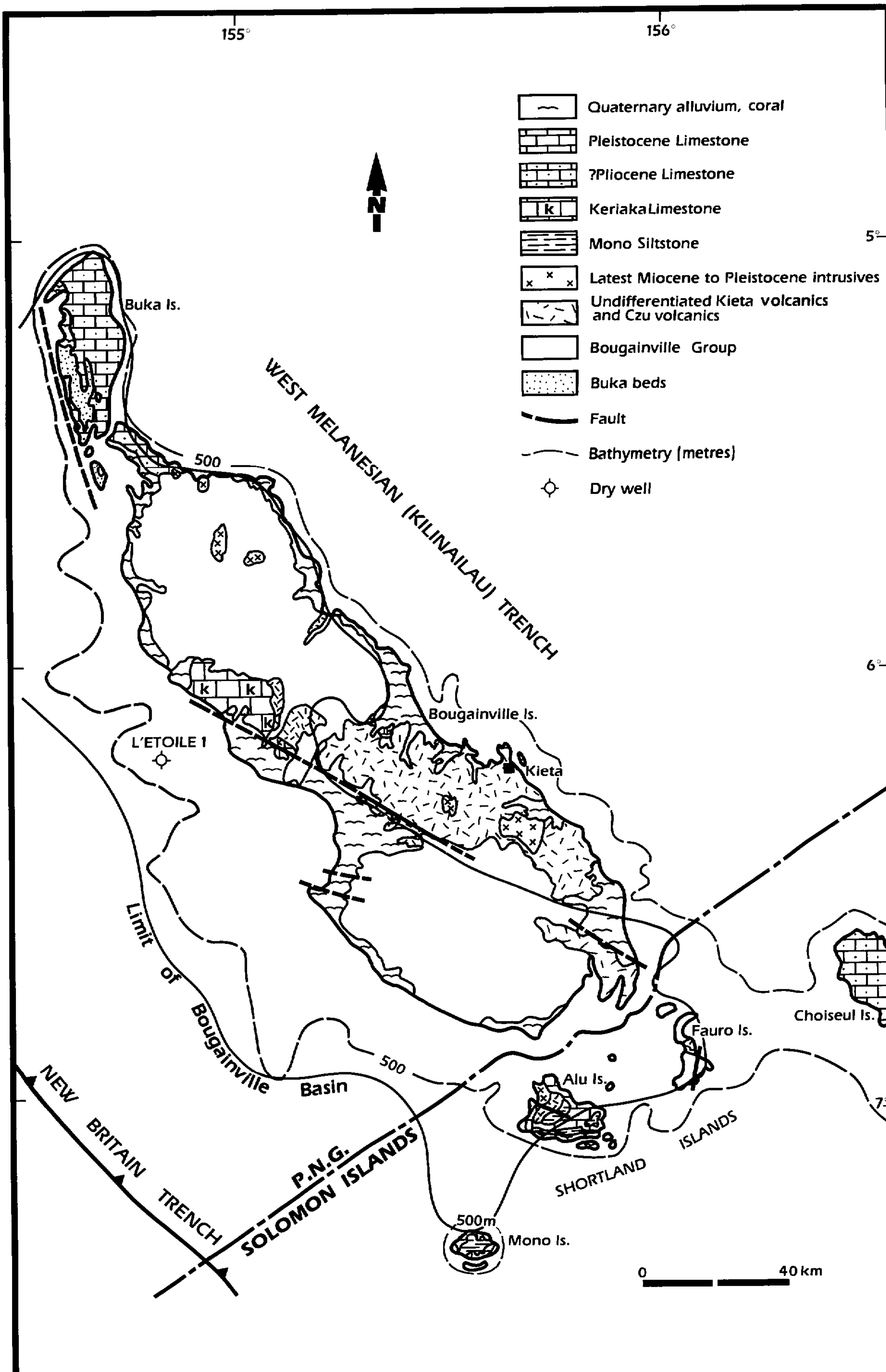


Figure 1. **GENERALISED ONSHORE GEOLOGY OF THE BOUGAINVILLE BASIN**

28

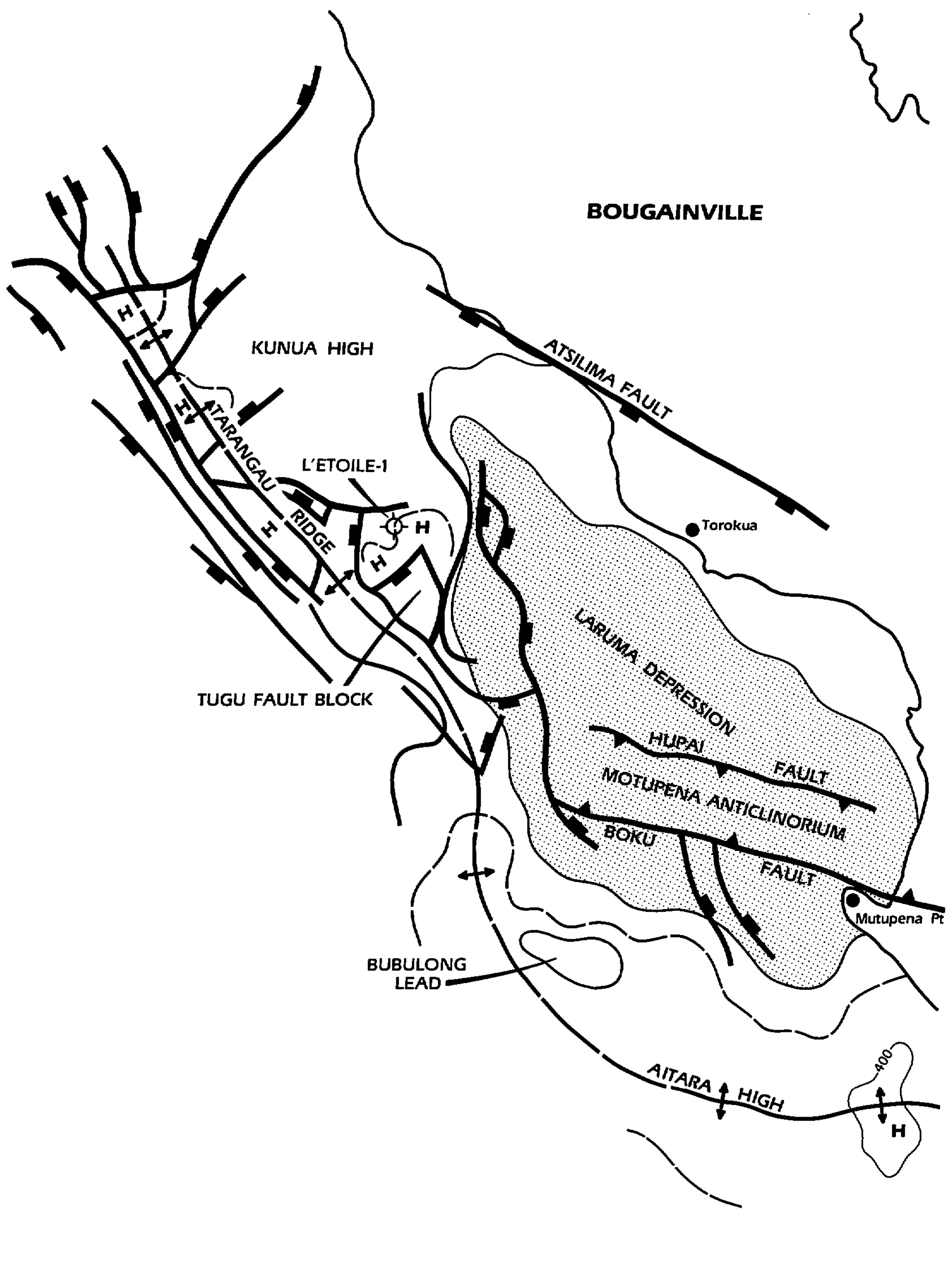


Figure 2. **BOUGAINVILLE BASIN, Main Structural Elements on Red Horizon**

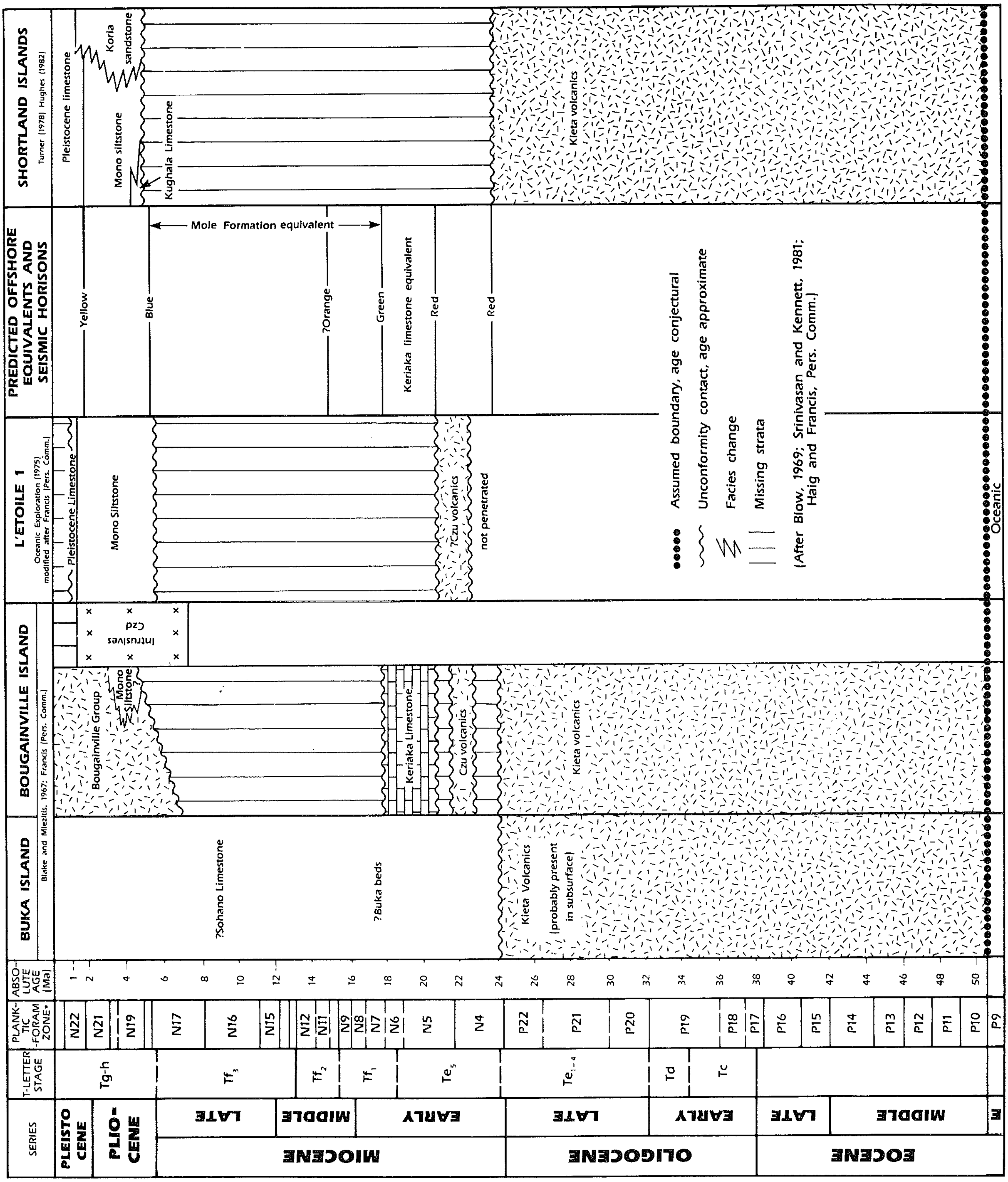


Figure 3. **BOUGAINVILLE BASIN, Stratigraphic Table**

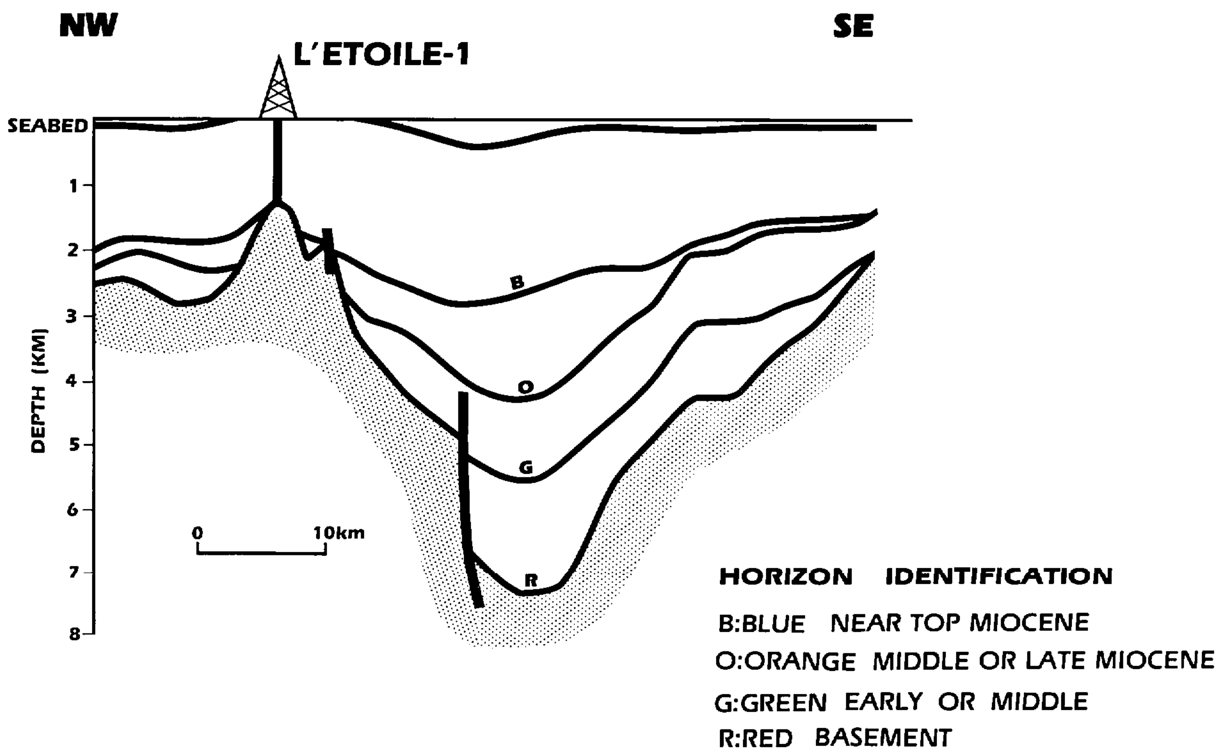


Figure 4. **GENERALISED CROSS-SECTION OF OFFSHORE BOUGAINVILLE BASIN**

N O T E S

Cape Vogel Basin, PNG - tectonics and petroleum potential

J. Pinchin (Flower Doery Buchan Pty Ltd),
& C. Bembrick (Robertson Research (Australia) Pty Ltd)

The Cape Vogel Basin is a narrow, elongate basin of Early Miocene to Late Pleistocene age situated on the north side of the Papuan Peninsula and north of the D'Entrecasteaux Islands. The basin is mostly offshore in water depths of 50 to 500 m; it is approximately 350 km long (east-west) and 100 km wide.

The basin lies on the northern margin of the Indo-Australian Plate, adjacent to the boundary with the Solomon Sea Plate and west of the actively spreading Woodlark Basin (fig. 1). It is bounded to the south and west by obducted oceanic crust adjacent to the Owen Stanley Fault Zone. The northern boundary is formed by the Woodlark Rise which extends as a basement ridge westward from the Trobriand Islands and which separates the basin from the Trobriand Trough to the north. The eastern margin of the Cape Vogel Basin is poorly defined due to a lack of seismic data. It extends southeast of the Trobriand Islands and probably terminates against a possible transform fault at the margin of the Woodlark Basin.

Existing geological and geophysical data from the Cape Vogel Basin were recently re-interpreted by Robertson Research (Australia) Pty Ltd and Flower Doery Buchan Pty Ltd, on behalf of the Geological Survey of Papua New Guinea, to provide new concepts to stimulate petroleum exploration in the area. The study included the re-interpretation of 3500 km of marine seismic reflection data and re-interpretation of the bio-stratigraphy and geochemistry by means of re-sampling the two exploration wells drilled in the basin. These wells, Goodenough-1 and Numbiam-1, were drilled in 1973 with interpreted Miocene reefs as the targets. The seismic anomalies proved to be diffractions from shallow, faulted basement blocks rather than buried reefs, and the wells were dry.

The basement of the Cape Vogel Basin consists of obducted Cretaceous oceanic crustal rocks - the Goropu association. These are overlain in places by Late Oligocene to Early Miocene Iauga volcanics. There are a few small outcrops of Paleocene limestones on Cape Vogel Peninsula, but large-scale sedimentation did not begin within the basin until the Early Miocene.

Seismic sections show normal, tensional faulting to have occurred during the Early Miocene when basin subsidence was initiated. This was probably a response to crustal tension above the Trobriand subduction zone, as the Cape Vogel Basin occupies a fore-arc position in relation to the Trobriand Trench.

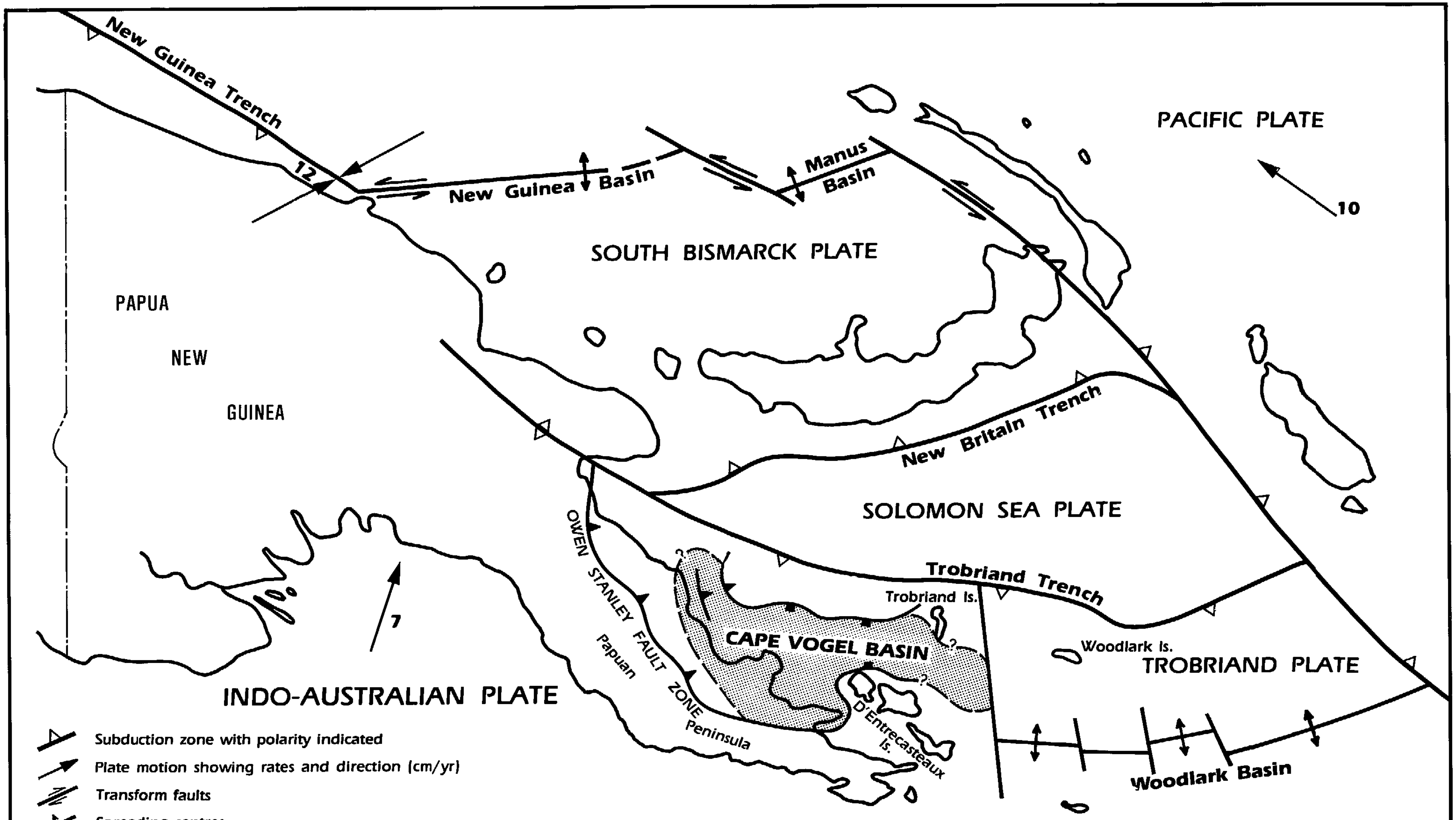
The postulated earliest Miocene sediments are not exposed onshore nor have they been drilled, hence their composition is unknown, but they are likely to contain volcaniclastics and carbonates. The sequence above this includes the marine shales of the Woruka unit (Early-Middle Miocene) deposited in a bathyal environment. During the Middle Miocene the basin at first subsided further, sedimentation became more widespread, and the marly Castle Hill unit was deposited. Following this, sedimentation rates exceeded subsidence, and the mid-Late Miocene Nubiam Shale was deposited in a gradually shallowing environment.

At the end of the Miocene, the northern margin of the basin was uplifted, accompanied by east-west compression. These movements produced high-angle thrust faults in the northwest and a steep reverse, possibly oblique-slip, fault system along the northwest margin. The tectonism also produced a major angular unconformity between the Miocene and overlying Plio-Pleistocene sediments. Plio-Pleistocene sedimentation was mostly carbonates with the exception of the conglomerate Kwinimage Formation, encountered in Goodenough-1, (and its distal equivalent, the Awaitapu Formation), north of the D'Entrecasteaux Block.

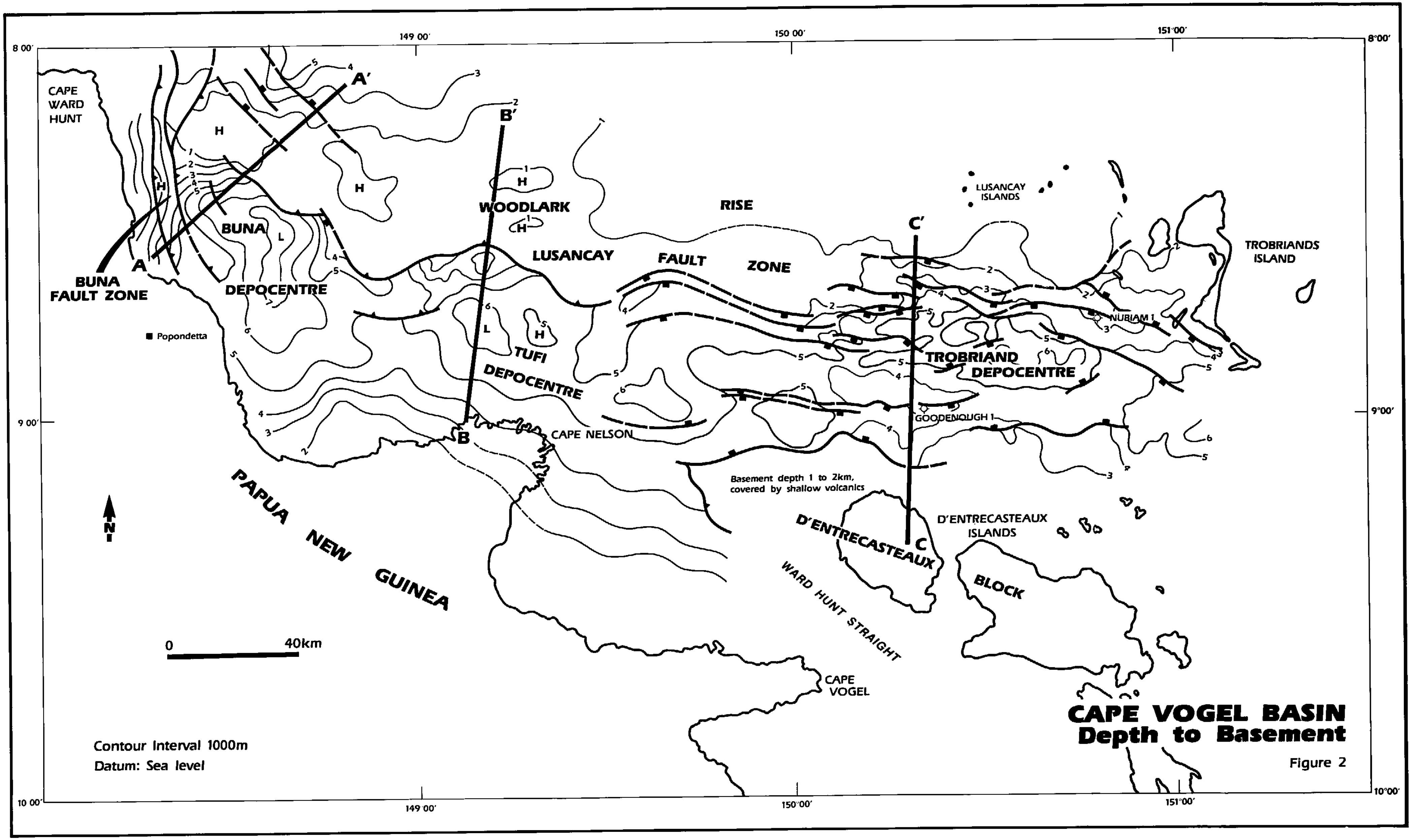
With over 7000 m of sediment in the deepest part of the basin, the Buna Depocentre in the west (fig. 2), prospectivity must be considered to be fair. Extrapolations from vitrinite reflectance measurements of well cuttings indicate that sediments below 4200 m would be mature. Carbonates and clastics within the Early and mid-Miocene could contain good reservoir rocks. There are several kinds of possible petroleum traps including Late Miocene thrust-faulted anticlines (fig. 3 Section A-A') and mid-Late

Miocene anticlines, as shown in figure 3 (sections B-B' and C-C'). In addition, there are possible onlap-pinchout traps around the basin margins, Early Miocene fault-plays, and possible stratigraphic traps as indicated by lateral amplitude changes on some of the seismic sections.

The conclusion is that the Cape Vogel Basin could be a highly prospective basin below relatively shallow water depths and with virtually untested petroleum potential.

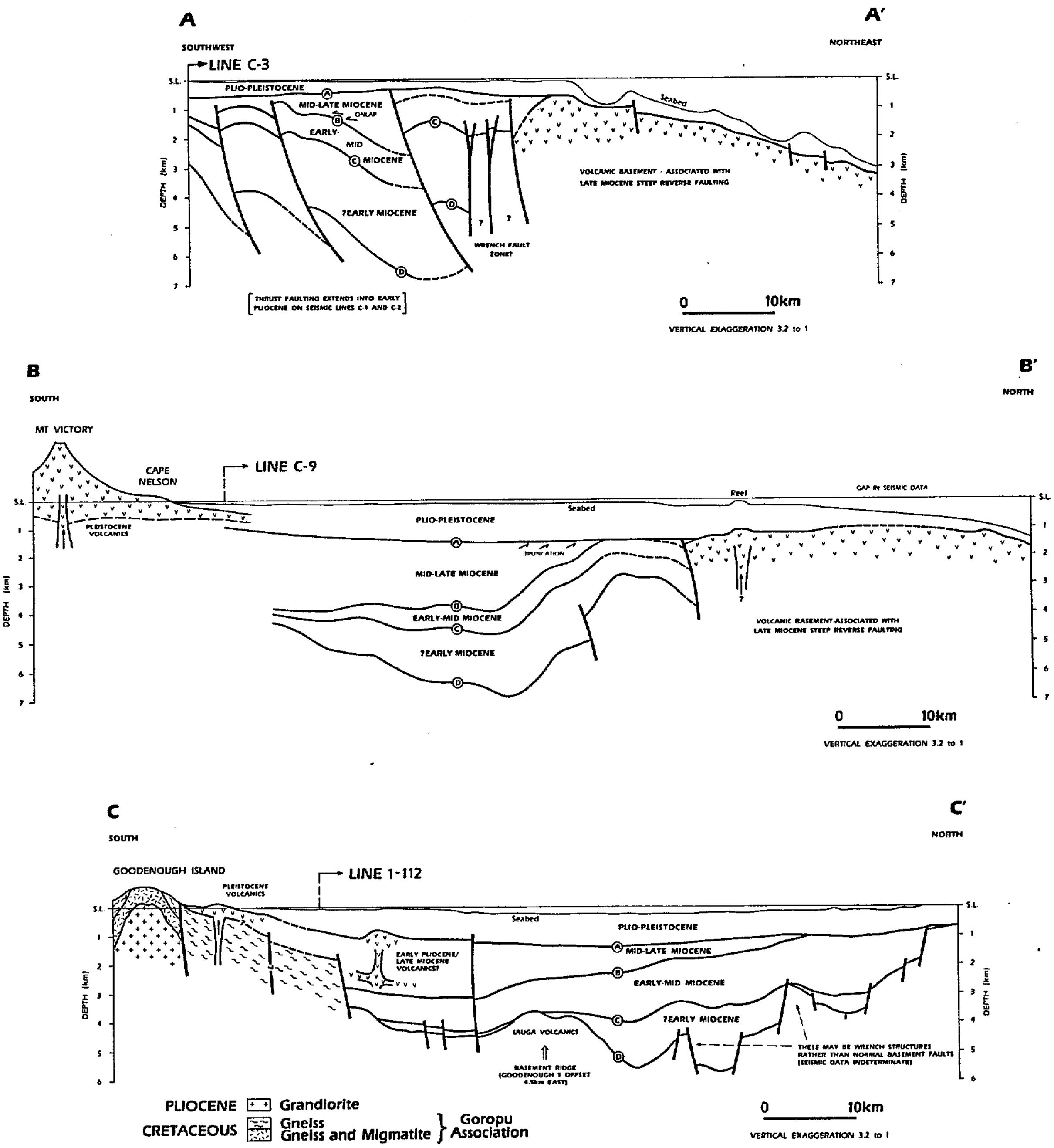


CAPE VOGEL BASIN
Regional Plate Tectonic Setting
Figure 1



CAPE VOGEL BASIN
Depth to Basement

Figure 2



Structural Cross-Sections across Cape Vogel Basin (based on seismic data)

Figure 3

New findings in offshore areas of western Solomon Islands and Buka-Bougainville, Papua New Guinea

J.G. Vedder (U.S. Geological Survey), J.B. Colwell (BMR),
& T.R. Bruns (U.S. Geological Survey)

In June 1985 the U.S. Geological survey research vessel S.P. LEE acquired reconnaissance geological and geophysical data in the western Solomon Islands and eastern Papua New Guinea as part of the CCOP/SOPAC Tripartite (Australia, New Zealand and USA)-2 series of cruises. Preliminary interpretations of 1800 km of multichannel seismic reflection profiles have revealed hitherto obscure stratigraphic and structural features in the vicinity of the Shortland Islands, Kilinailau Trench, Buka-Green Island ridge, and Buka Basin-Bougainville salient (fig. 1).

Because the Solomon Islands region straddles the convergent boundary between the Pacific and Australia-India Plates, it has had a complex history of nearly continuous tectonism and episodic magmatism since Eocene time. Three episodes of Cainozoic tectonism are perceived by most workers in the area. The first was the Late Eocene(?) and Early Oligocene southwest-directed subduction of the Pacific Plate that resulted in island-arc magmatism and substantial geeenschist-to-amphibolite-grade metamorphism. The second episode was characterised by dwindling volcanism, uplift, and rapid sedimentation during Late Oligocene and Early Miocene time. Large amounts of volcaniclastic detritus and subordinate carbonates were deposited throughout the Miocene on upwarped shelves and basin slopes around Choiseul, the Shortland Islands, and, possibly, in the Buka Basin. The third episode, which began near the end of the Miocene time, combined arc-polarity reversal with renewed magmatism that later was complicated by development of the Woodlark spreading system and subduction of nascent oceanic crust. Emergence of New Georgia, uplift of Vella ridge, and construction of Bougainville and the Buka-Green Island ridge were direct effects of this third episode, during which volcanism was most active in the Pliocene and Quaternary. Aprons of volcaniclastic sediment were deposited in the newly-formed Shortland Basin segment of the intra-arc basin, and detritus from uplifted Buka-Green Island ridge was shed southwestward into Buka Basin.

Multichannel profiles from the 1982 and 1984 cruises across Shortland Basin, Vella ridge, and the Mono Island area show conclusively that the basin is part of the central Solomons Trough intra-arc basin and that it contains as much as 5.5 km of sedimentary rocks. Pliocene and older basin strata may extend northwestward beneath the Quaternary stratovolcanoes of southeast Bougainville. Five Late Oligocene and younger seismic-stratigraphic sequences are present above the acoustic basement, and their depositional history is attributable to tectonic events that affected both the northern and southern basin margins. Unconformities and abrupt changes in seismic velocity typify the bounding surfaces of these wedge-like seismic-stratigraphic units (fig. 2A). Acoustic basement (unit A) is correlated with the Paleogene(?) Choiseul Schists and Voza Lavas on Choiseul and possibly with the Oligocene and Early Miocene Kieta Volcanics on Bougainville. Directly overlying the acoustic basement is a layered sequence (unit B) that is correlated with Late Oligocene and Miocene volcaniclastic beds of the Mole Formation on Choiseul. Next in upward succession is an unconformable, southward-thickening sequence (unit C) that is correlated with Pliocene calcarenite and calcisiltite beds of the Pemba Formation on Choiseul. Other possible correlatives are the Koria, Alu, Mono, and Kulitani Siltstones on the Shortland Islands. At the top of the seismic sequences are Quaternary basin-fill hemipelagic sediments and turbidites (unit D) that probably correlate with volcaniclastic strata on Vella ridge and the Togha Pyroclastics on Fauro. Truncation and overlap of the seismic-stratigraphic units indicate at least three episodes of differential uplift along the basin margins since 10-8 Ma. Late Miocene and younger folds and faults deform the basin strata, chiefly along the northern and southern flanks.

Eight multichannel lines across the inner wall of the Kilinailau Trench between the northwest end of Choiseul and Green Island clearly indicate that the trench is a partly filled former subduction zone. Southwestward-dipping reflectors (unit B) concordant with the acoustic-basement surface of the Ontong Java Plateau (unit A) probably represent Cretaceous and Paleogene pelagites (fig. 2B). These beds are unconformably overlain by slightly deformed Cainozoic trench-fill strata (unit C) that thicken northwestward from less than 2.0 km near Choiseul to more than 4.0 km near

Buka. Folded, upfaulted, and rotated blocks of these trench-fill strata apparently form most of the inner trench wall along the northeastern slope of Bougainville and indicate continuing compressive stress between the Ontong Java Plateau and the island arc. Acoustic basement close to the island probably consists largely of late Cainozoic volcanogenic rocks of the Bougainville Group.

Seven multichannel lines transect Buka Basin and the Bougainville salient area southwest of the Buka-Green Island ridge. A sequence of Cainozoic strata as much as 7.0 km thick overlies the acoustic basement in the central part of Buka Basin. Basement on the northeastern flank of the basin (unit A, figure 2C) presumably consists of late Cainozoic volcanic rocks of the Bougainville Group, whereas basement rocks that form the Bougainville salient (unit A-v) probably correlate with the Oligocene and Early Miocene Kieta volcanics and, possibly, older rocks. Westward-dipping reflectors in the lower part of the seismic-stratigraphic sequence adjacent to Buka (unit B) probably include volcaniclastic strata of the Oligocene(?) Buka Formation, which may have been derived from the Bougainville salient as fore-arc-basin turbidites. Thin ($<$ 0.5 km) Miocene(?) and younger reef remnants (unit A-c) seem to be present along the subsided crest of the Bougainville salient. This subsided ridge extends farther northwest than indicated on pre-existing bathymetric maps and may continue as a basin sill into southeastern New Ireland where the basement is composed of the Oligocene Jaulu volcanics. Buka Basin, therefore, represents the subsided southeastern end of the New Ireland fore-arc basin; the Bougainville salient represents part of the early Cainozoic arc; and Buka-Green Island ridge represents a segment of the late Cainozoic arc that has cut across the older arc beneath Bougainville.

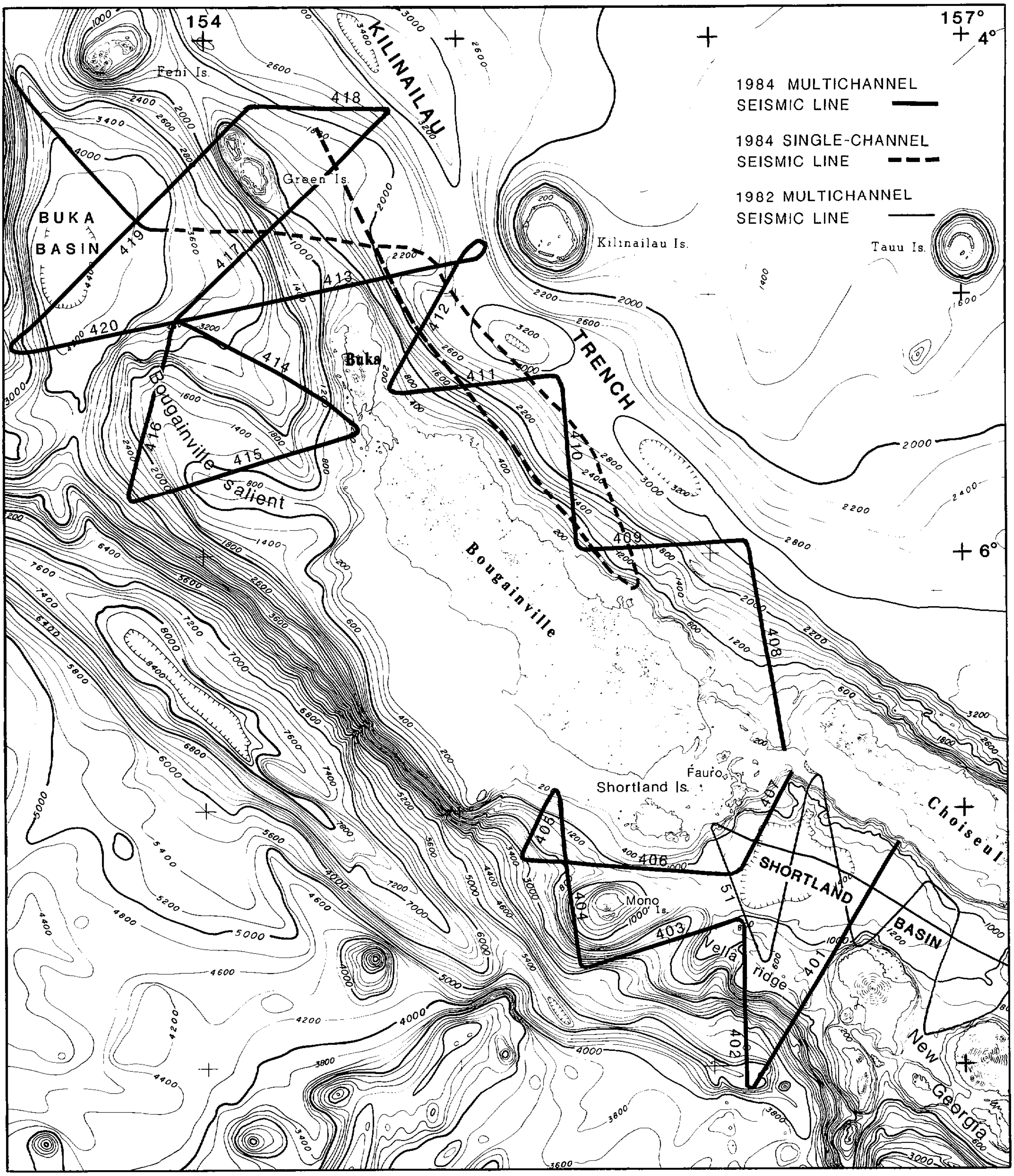


Figure 1. Map of western Solomon Islands and Bougainville, PNG, showing place names, tracklines, and undersea features.

42

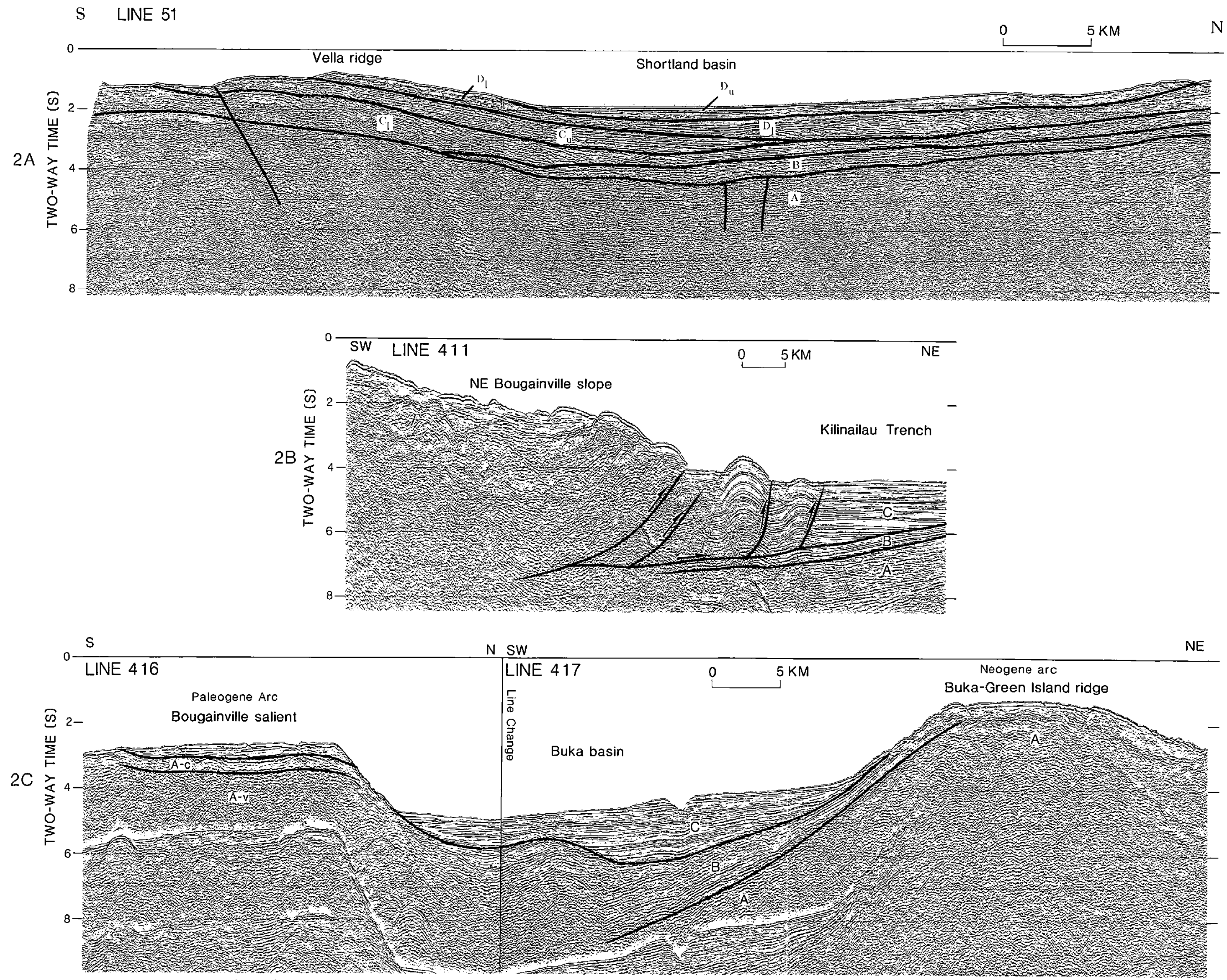


Figure 2. Selected seismic lines across tectonic features, western Solomon Islands and eastern PNG. Line locations shown on Figure 1. Seismic stratigraphic units described in text; subscripts designate lower and upper parts.

N O T E S

Offshore sampling in the Solomon Islands and Bougainville-Buka Areas

J.B. Colwell (BMR), J.G. Vedder (U.S. Geological Survey),
K.A.W. Crook (Australian National University), & S. Shafik (BMR)

As an adjunct to the geophysical surveying undertaken by the research vessel S.P. LEE in the Solomon Islands and Bougainville-Buka areas (Vedder et al., this volume), geological sampling was attempted at 39 sites (figs. 1, 2). This work was to provide a correlation between the seismic stratigraphy and sea-floor outcrops, samples for gas analysis, and information on the modern sediments.

Sampling was undertaken using chain-bag dredges, a gravity corer, and dart corers. Because of a lack of bedrock exposures, most of the dredging was concentrated along the eastern margin of the Guadalcanal-Santa Isabel platform, around the Russell Island salient, west of Vella Lavella and north of Buka. Twenty-eight dredge stations were occupied, 20 successfully. Six main types of rock were recovered: (i) reef limestones and coral (Stations 1/2, 1/4, 1/6, 1/7, 1/9, 14, 22 and 25), (ii) sedimentary rocks of mixed biogenic and volcanic origin at Stations 1/2, 1/3, 1/9, 1/10, 1/11, 1, 2, 6, 7, 11, 14, 19, 21, 23, 24 and 25, (iii) a porphyritic hornblende tuff similar to that occurring on Vella Lavella, at Station 1/10, (iv) a volcanic and metavolcanic cobble conglomerate (possibly an offshore continuation of the Vatumbulu Beds of eastern Guadalcanal) at Station 1, (v) a sheared foram- and pteropod-rich calcilutite at Station 29, and (vi) a biomicrite at Station 1/11. All of the rocks are of Quaternary age except the calcilutite at Station 29, which is Pliocene. Several of the rocks contain reworked Tertiary fossils.

The rocks dredged at Stations 1/2, 1/10, 1/11, 21, 22 and 23 indicate that the Solomon Islands fore-arc region has undergone complex tectonism in the Quaternary. For example, rocks dredged at Stations 1/10, 1/11 and 23 on the Vella Ridge have been uplifted at least 600 m over a period of about 0.5 million years. This is probably partly in response to the subduction of the Woodlark Basin spreading-ridge.

The cores taken by the LEE (fig. 2) indicate that hemipelagic sedimentation has been widespread in the Russell Basin for most of the Quaternary. The cores are typically composed of volcanic-rich slightly sandy nanno-rich clays and muds interbedded with occasional sandy turbidite layers (fig. 3). Total-organic-carbon and gas contents are low reflecting the high input of volcanic material.

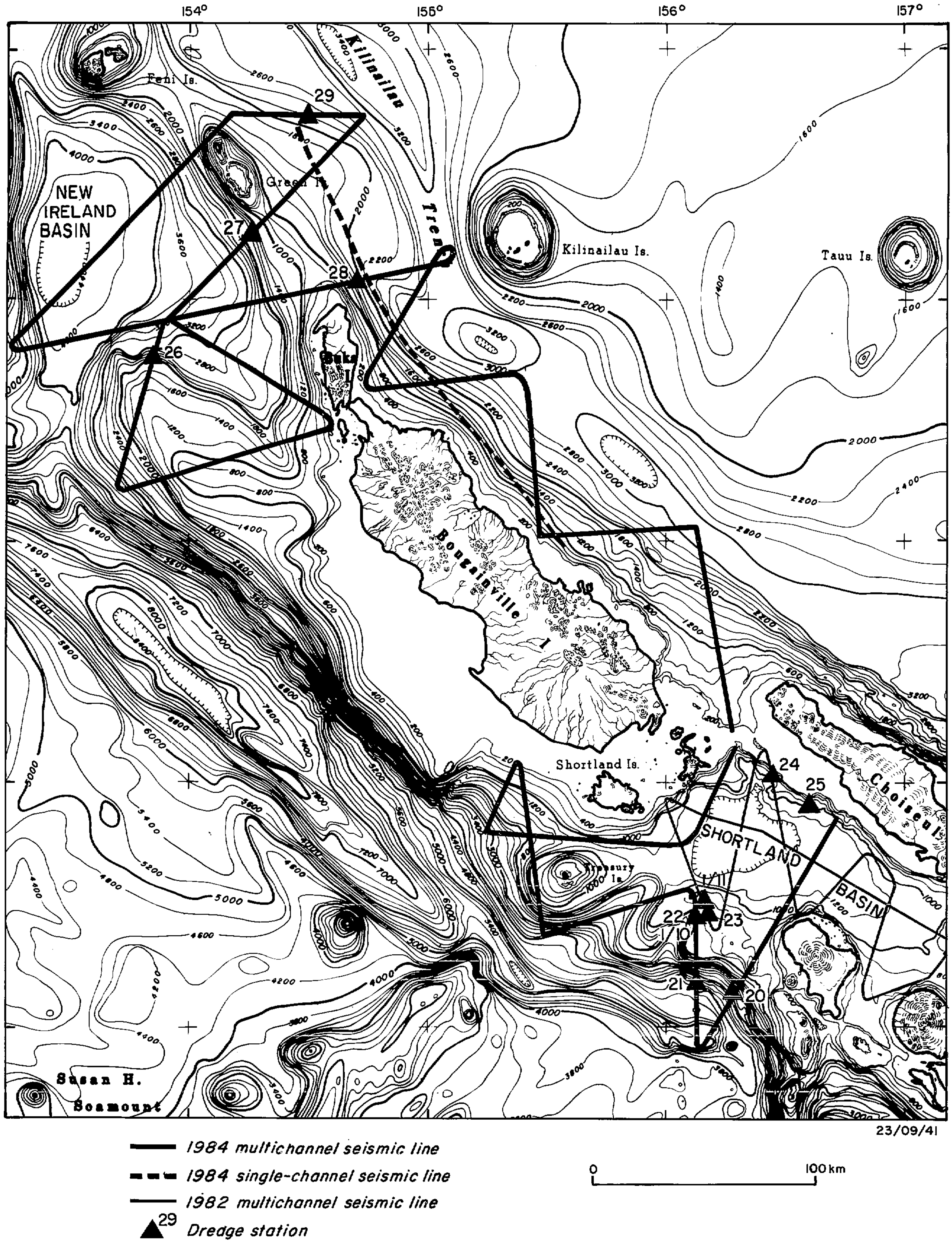


Figure 1 Location of sam pling stations in the western Solomon Islands and Bougainville-Buka areas.

47

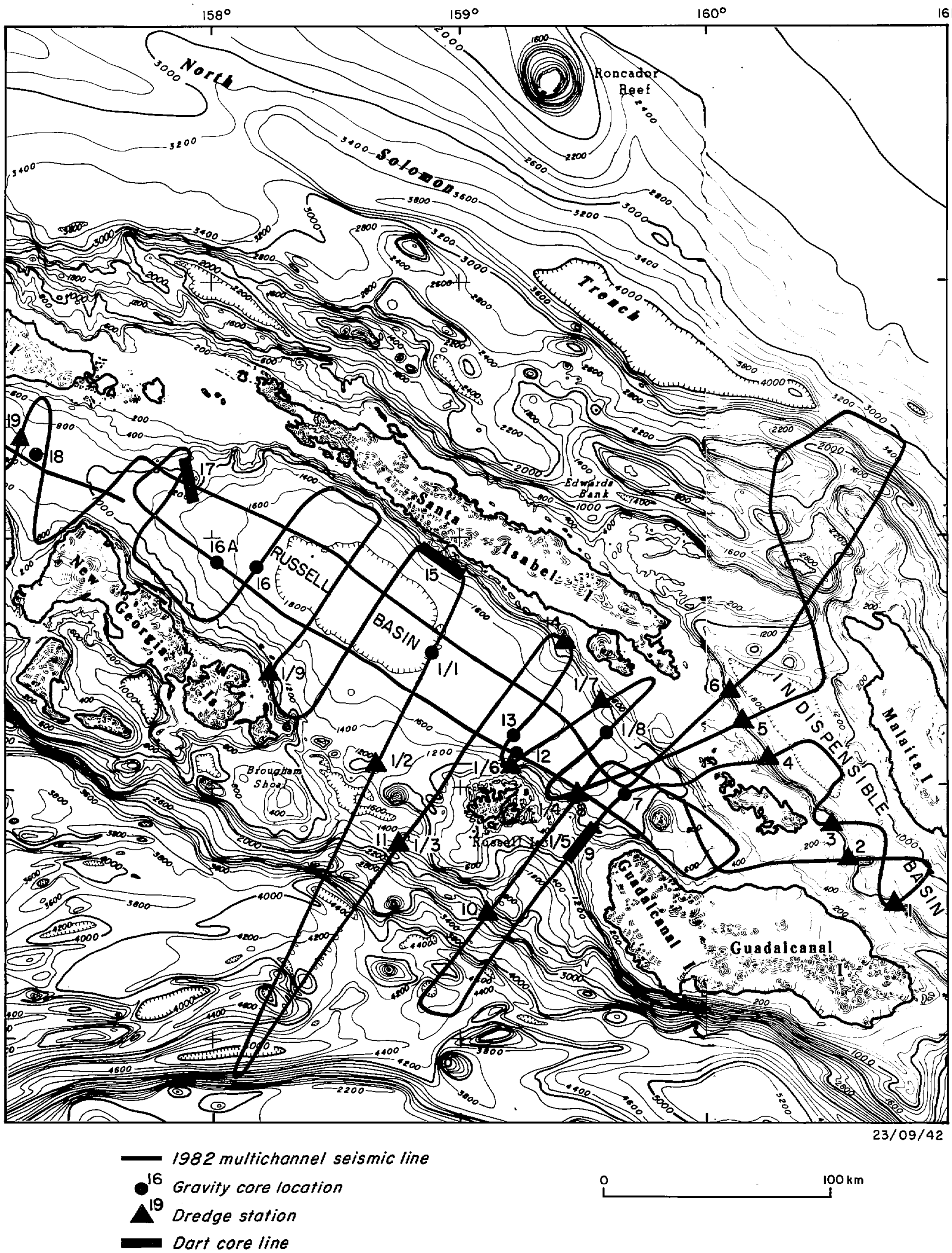


Figure 2 Location of sampling stations in the eastern Solomon Islands.

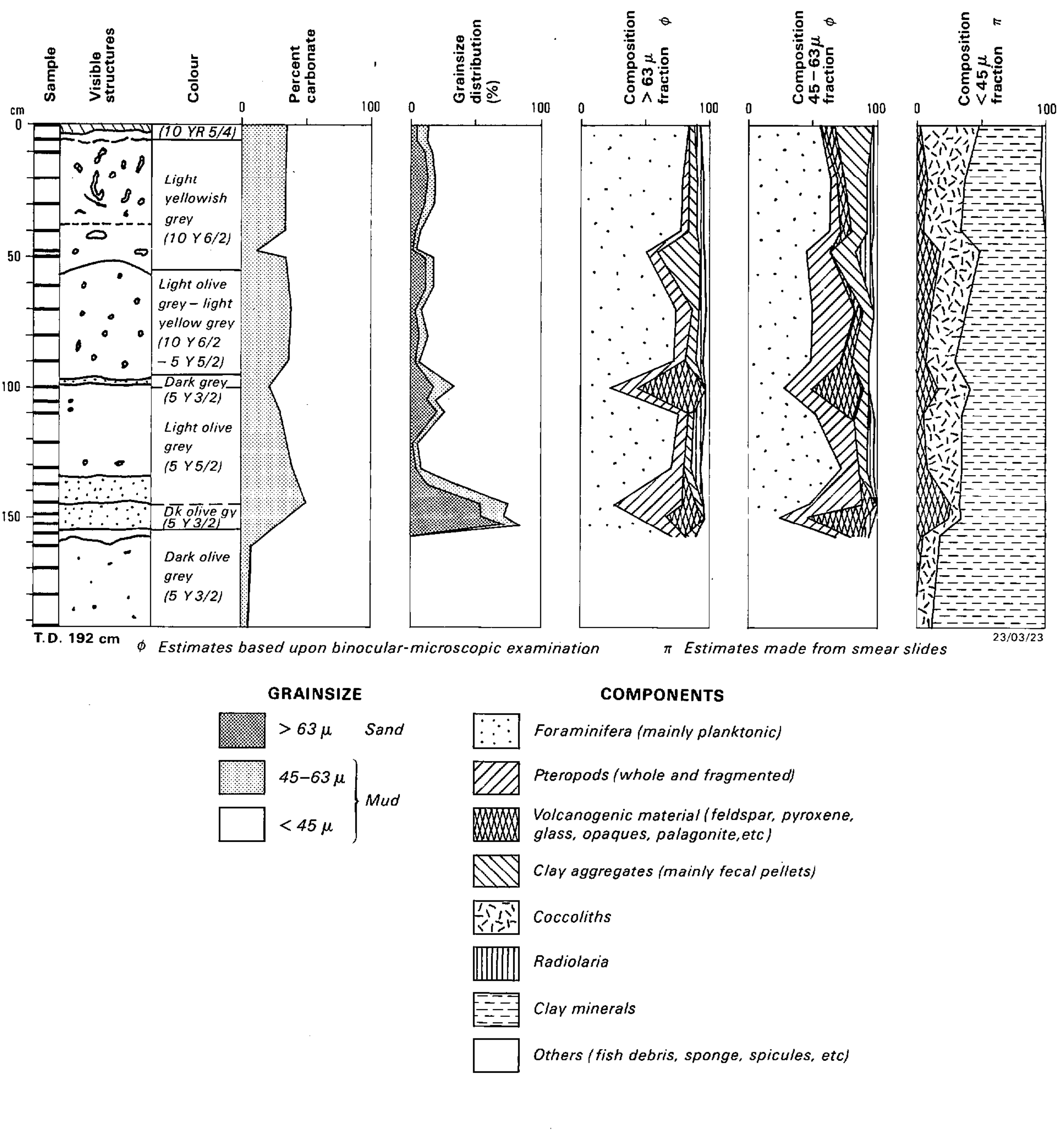


Figure 3 Typical core from the Russell Basin (station 1/1).

N O T E S

Tectonic development and petroleum potential of intra-arc basins of the New Hebrides island arc

D.A. Falvey (BMR), H.G. Greene (U.S. Geological Survey),
A. Macfarlane (British Geological Survey,
formerly Vanuatu Geological Survey), & N. Exon (BMR)

The New Hebrides island arc forms part of the active volcanic chain marking what is broadly the India-Pacific Plate boundary. Six sedimentary basins occur within the arc in both Vanuatu and the eastern Solomon Islands. These intra-arc basins are broadly described as follows:

1. Malakula Basin

   The platform basin just east of Malakula Island is called the Malakula Basin. It contains a maximum of about 2 km of fill and is bounded on the west by this island and on the east by a large anticline or basement high that lies at the edge of the platform. The locations and tectonic characteristics of this basin's northern and southern boundaries are unknown. An unconformity forms the bottom of Malakula Basin; velocity data from seismic refraction and seismic reflection measurements show that the rocks under the basin have an acoustic velocity greater than 4 km/s, whereas the lowermost basin fill has velocities less than 3 km/s. Furthermore, generally faint reflections from rocks below this basin show that sub-basin rocks terminate at the bottom of the basin and dip more steeply east than does the basin fill. The lower unit in the Malakula Basin ranges in thickness from 0 to 1.4 km. Rocks of this unit thin eastward from the island of Malakula toward the anticline along the platform edge and northward along the basin axis. The direction of thinning and downlap of these rocks suggests that sediment for this unit was supplied from the area of Malakula Island and transported eastward. The unit is probably Middle Miocene in age. The upper part of the basin fill is about 1 km thick and is probably post-Miocene in age.

2. South Aoba Basin

   The South Aoba Basin lies under 2000 m of water and is ringed by the volcanoes on Ambrym and Aoba Islands, by Pentecost Island, and by the anticline at the edge of the platform near Malakula Island. Seismic refraction data indicate that this basin contains at least 5 km of rocks with acoustic velocities less than 5 km/s. The deepest reflective rocks in this basin form two acoustic units. The rocks in the lower unit return east-dipping, strong, low-frequency reflections that are evident beneath the western basin flank on all seismic lines that cross this flank. Data show that this unit is at least 2.5 km thick. The reflections from the upper unit terminate updip along a nearly vertical line that may be a fault-plane. This relationship is especially clear on one seismic line where the vertical line of termination actually joins with a fault in the shallow section. The eastward dip of the lower unit and the vertical line of termination of the reflections may signify that rocks in this unit were deposited in a submarine fan along a major fault.

The rocks of the upper unit range from 1.0 to nearly 2.5 km thick; they dip east, and conformably overlie the lower unit. The age of these lower units is thought to be Early Miocene or older. Thus, the basin is probably as old as the island arc itself.

3. East Santo Basin

The platform basin just east of Espiritu Santo Island is the East Santo Basin. It is bordered on the west by this island and on the east and northeast by a structure that separates the platform from the slope that leads into deep water over the North Aoba Basin. The platform edge is not underlain by an anticline or high similar in size to the one that bounds the east side of the Malakula Basin. Data suggest that about 1.5 to 2 km of rocks lie within the platform basin. Reflections from rocks in this basin are generally discontinuous and difficult to follow, so that little can be said about the basin's stratigraphy.

The nature of the feature that bounds East Santo Basin on the east is not well defined. Some reflections from within this feature suggest that it is made up of layered sediments, similar to the basin fill. The basin may have formed by infilling of a slowly-subsiding, reef-bounded block.

4. North Aoba Basin

North of the East Santo Basin a dissected carbonate platform appears to lie on another subsiding block. This block is separated from the East Santo Basin by a generally east-west-trending fault and appears to have subsided much more rapidly than its counterpart to the south. There are similarities with the South Aoba Basin.

A northeast-southwest-trending transect was made across the basin, over the eastern volcanic belt and into the back-arc basin region east of the islands of Santa Maria and Mere Lava. This line ended at the south end of the Torres-Santa Cruz Basin.

5. Torres-Santa Cruz Basin

North of the Banks Islands lies a poorly-surveyed sedimentary basin called the Torres-Santa Cruz Basin. The data indicate that the basin has a general north-northwest-trending axis and is up to 70 km wide and 200 km long, covering an area of over 14000 km^2. A maximum sedimentary thickness of nearly 6 km was found in the centre of the basin in an area roughly 80 km northeast of the Torres Islands.

The morphology and structure of the basin is complex and can only be roughly sketched from the preliminary interpretations. The basin is bounded both on the east and west by basement ridges. To the east lie the exposed volcanic rocks of an eastern volcanic belt that underlies the Banks Islands group. To the west the boundary is an upbowed arch with a folded and faulted sedimentary and carbonate cover. The carbonate-capped volcanic islands of Utupua and Vanikolo bound the basin to the north and the volcanic islands of the Torres-Banks group bound the basin to the south. Only a few small intrusions pierce the sedimentary fill of the basin, and these are located principally near either the eastern or the western boundary.

The basin has no morphological expression and is primarily a sedimentary basin located beneath the relatively flat summit platform of the northern New Hebrides Arc. The surface of this platform is upbowed in the east-central region; elsewhere it is either flat or gently dipping.

The active volcanic province in this region appears to be restricted to the eastern boundary of the basin. In this area two new submarine volcanoes were found and are located approximately 25 km southeast of Vanikolo. One of these may be presently active.

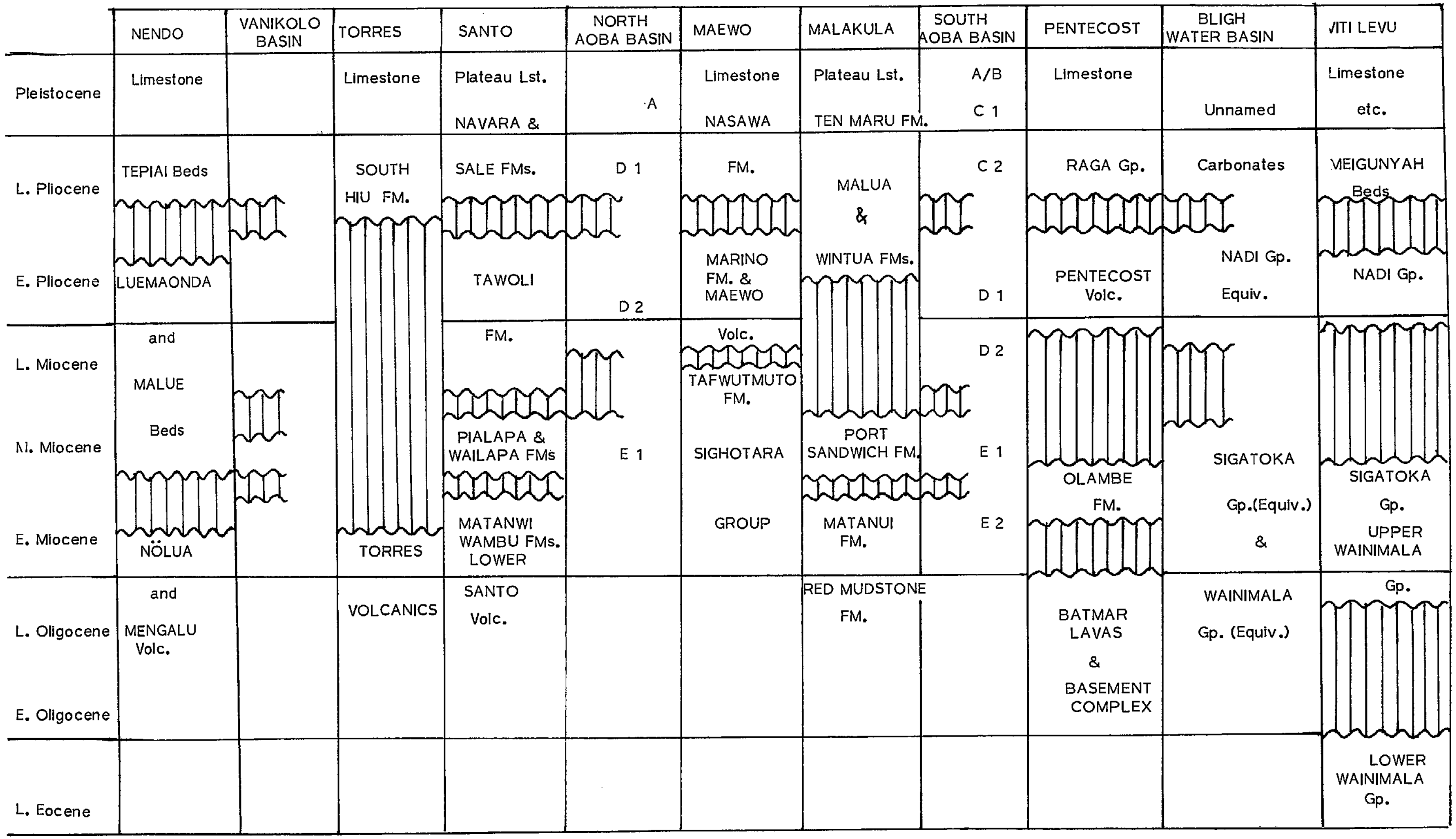
6. Nendo Basin

The region north of Nendo Island is relatively unmapped and little is known about the topography. The bathymetric maps show that the New Hebrides Arc ends abruptly north of the Reef Islands where it appears as a squared-off, possibly fault-bounded rectangular platform lying beneath 1200 m of water. Beneath this platform lies a newly discovered sedimentary basin called Nendo Basin. Bacause only two multichannel seismic reflection lines were run in this area it is not possible to define the basin in any detail. The southern end of this basin is separated from the northern end of the Torres-Santa Cruz Basin by the volcanic ridge which supports Nendo, Utupua, and Vanikolo Island. The great thickness of sediments found in the Torres-Santa Cruz Basin to the south pinches out against the volcanic ridge and disappears. Not even a thin layer of surficial sediments is observed suggesting that the area is either sediment "starved" or that strong currents transport sediment away from the area. If sediments were deposited here they have subsequently been removed by erosion. About 100 km north of Nendo Island, sedimentary deposits reappear, indicating that a basin exists in this area. The sediments are relatively thin (about 2 km) here, but appear to thicken northward. Based on the sparse data collected in this area, the southern and southeastern limits of the Nendo Basin can be inferred, but the northern and western limits are completely unknown.

The preliminary indicated petroleum potential of the region is shown in Figure 2 (after Katz).

In general the intra-arc basins of the New Hebrides are thought to be earlier fore-arc basins, now bounded front and back by ridges of arc/basement rocks as a result of arc reversal. Palaeomagnetic data show that this occurred with the formation of the North Fiji Basin 6-8 m.y. b.p. This event also delineated Bligh Water Basin in Fiji. Regional stratigraphic correlations are shown in Figure 1.

Fig 1 GENERALISED STRATIGRAPHIC CORRELATION - NEW HEBRIDES/FIJI ARCS



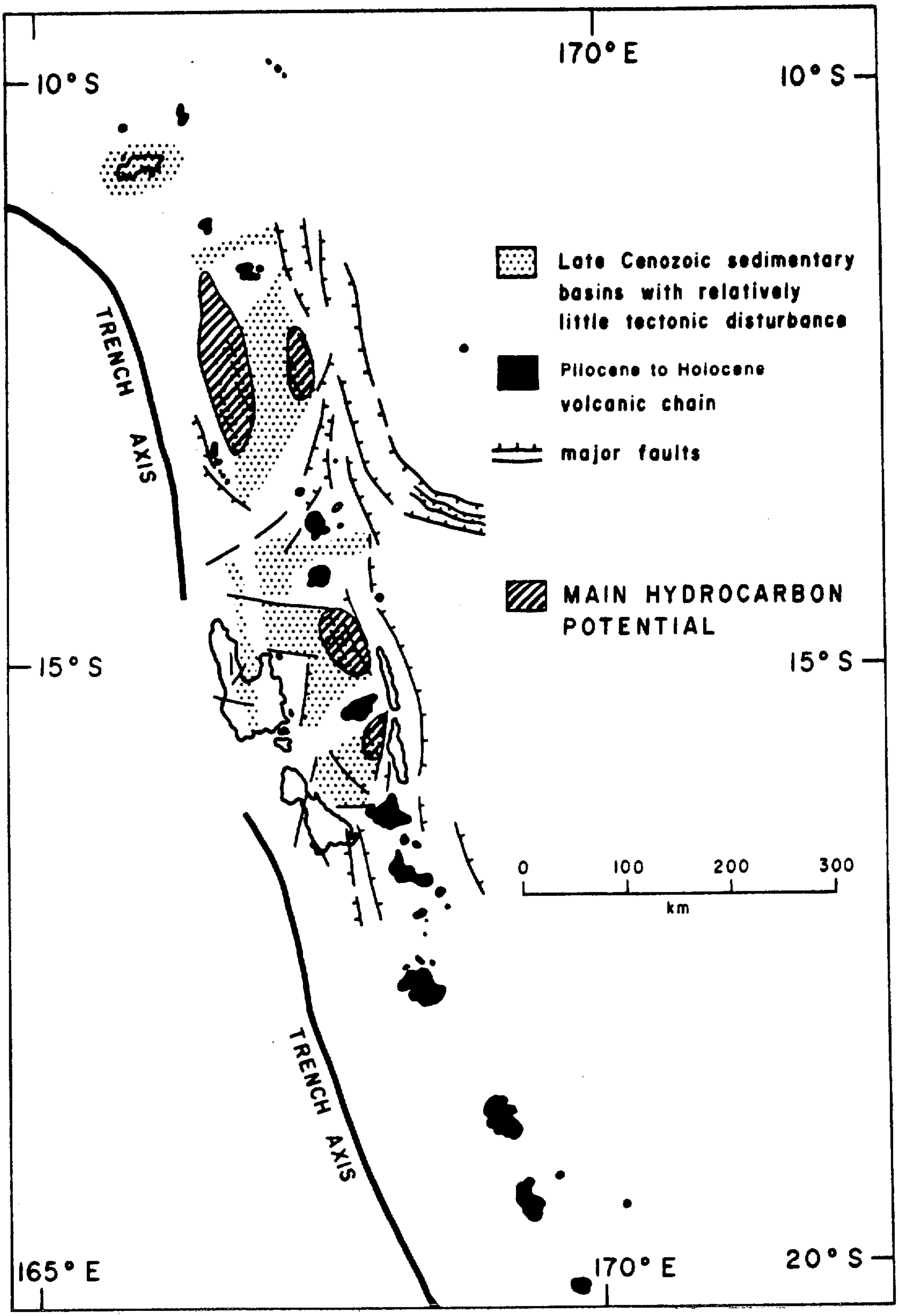


Fig 2 Areas of main hydrocarbon potential in the New Hebrides Arc (after Katz).

New geophysical and geological data on the mineral and petroleum resource potential of the Tonga region

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In 1982 and 1984, the R/V S.P. Lee operated by the Branch of Pacific Marine Geology, U.S. Geological Survey, supported geological exploration of the Tonga Ridge and parts of Lau Basin and Lau Ridge (figure 1). These investigations, chiefly carried out to assess geologically the potential for petroleum resources on the Tonga Ridge, were part of a Tripartite Agreement to support the general program of CCOP/SOPAC for marine geoscientific research and mineral resource studies in the south Pacific region. During these cruises approximately 5000 km of multichannel (24-fold) seismic reflection data were recorded. Gravity, magnetic, single-channel seismic, and bathymetric information was gathered along all track-lines (roughly 8000 km). Rock samples were dredged from submerged outcrops at 38 stations, and sonobuoy refraction lines were shot at 113 stations. In the Lau Basin, principally over Valu Fa Ridge, bottom-camera and TV stations were occupied and water samples collected from the immediately-overlying water.

The principal scientific and resource-related results supported by the 1982 investigations will be published in 1985 by the American Association of Petroleum Geologists, for the Circum-Pacific Council for Energy and Mineral Resources. This report also includes invited or commissioned papers that discuss new or largely unpublished information important to understanding the regional framework geology and tectonic evolution of the Tonga Ridge and adjacent regions.

The Tonga Ridge is a massive northeast-southwest-trending and mostly submerged mountain range (figure 1). It rises above the Tonga Trench (as deep as 10500 m) to the east and the much shallower (2000–3000 m) marginal oceanic sea of the Lau Basin to the west. The ridge's summit area is geomorphically broad; it is commonly described as the Tonga platform (figure 2). The principal nonvolcanic Tongan islands (Vava'u, Ha'apai, Nomuka, and Tongatapu-'Eua groups), which are elevated masses of Tertiary limestone and volanic rock capped by Quaternary reef limestone, rise above the central platform area.

The 1982 and 1984 Tonga cruises were conducted principally over the southern Tonga platform lying immediately south of these islands (figure 1). Water depth over the southern platform area ranges from about 200 to 1000 m. Ata Island, a deeply-eroded, extinct volcano of the active Tofua Volcanic Arc, rises above the platform's western flank, which descends steeply and step-wise toward the floor of the adjacent Lau Basin (figure 2).

Tectonically, the Tonga Ridge lies along the zone of convergence of the Pacific and Australia-India Plates (figure 1). Although geographical migration of the Tonga Ridge has occurred, its general tectonic setting in relation to the Pacific Plate may not have greatly changed since at least Middle Eocene time. Prior to this time the Ridge's framework rocks accumulated in response to constructional magmatism as part of an island arc, the so-called Inner Melanesian Arc, that closely bordered the Pacific continental edge of the Australia-India Plate. During its post-Eocene evolution, the ancestral Tonga-Lau Ridge migrated relatively eastward, leaving in its wake the south Fiji Basin, which formed in Oligocene time, and later the Lau Basin, possibly beginning as recently as about 2.5 m.y. ago.

A 3-4 km-thick sequence of chiefly sedimentary rocks, the platform section, underlies the southern Tonga platform (figures 3A and 3B). The regional dip of the platform section is west, roughly parallel to the descending bathymetric slope of the platform. The section also generally thickens in this direction (toward the Lau Basin) from a wedge-out contact with a basement of Middle Eocene and possibly older rocks that crop out along or immediately west of the platform's Pacific edge. This basement high, which is subaerially exposed at 'Eua Island, is informally referred to as the 'Eua ridge or the Pacific-rim structural high (figures 2, 3A and 3B). Regional information implies that the platform section is chiefly constructed of volcaniclastic and limestone beds of Late Eocene though Middle Pleistocene age. Oligocene strata are thin or absent.

Summarised below are the more important findings and conclusions bearing on the resource potential of the southern Tonga platform and immediately adjacent areas of the Lau Basin.

1. The platform section has been sufficiently buried, perhaps locally to 5 km, to have generated mature petroleum hydrocarbons from its basal layers. Thermally mature, although biodegraded, oil is presently seeping into upper Cainozoic reefal bodies at Tongatapu and reportedly offshore of 'Eua.

2. Opening of the adjacent part of the Lau Basin may have been associated with thermal heating and uplift of the platform area that began as early as 4-5 Ma. This heating event could have significantly enhanced the thermal gradient within the platform section, thus increasing the opportunities for the generation of petroleum fluids, possibly the oil presently seeping at Tongatapu and offshore near 'Eua, at shallower subsurface levels.

3. An older, post-Eocene thermal event could also have elevated subsurface temperatures and promoted petroleum production. Heating took place in Late Oligocene through most of Miocene time after the cessation of spreading in the South Fiji Basin and the resumption of arc volcanism along the ancestral Tonga-Lau Ridge. The early Neogene magmatic axis or front lay along the crestal area of the present Lau Ridge. Except, perhaps, for adventitious dykes and sills, there is little evidence that arc volcanism extended eastward as far as the Tonga platform area.

4. Large, subsurface domes occur within the platform section (figure 4A). These masses are thought to be reefal bodies of probable Early or Middle Miocene age that reflect subsidence of the platform. Geopotential modelling cautions that some of these structures may be buried igneous bodies or possibly a reef-capped igneous mass. Other potential reservoir carbonates are older, relatively thick platform limestone of Middle and Late Eocene age. Beneath the platform they probably exist on the upthrown sides of half-grabens filled with coeval and somewhat older deposits. However, the depositional position of the Palaeogene limestone relative to older and coeval rocks is poorly understood.

5. No direct information was gathered concerning the likelihood that organic-rich source rocks exist within the platform section. Speculatively, the best opportunity for the preservation of organic matter may have existed in Eocene and earliest Oligocene time when productive

surface waters and platform areas could have contributed organic detritus to oxygen-poor depressions of early-formed summit basins (figure 4B). These grabens formed in response to the rifting event that separated the Tonga-Lau sector of the ancient Melanesian Arc from the Australia-India Plate just prior to the opening of the South Fiji Basin, (figures 3A and 3B).

6. Ferromanganese crusts have formed over much of the platform section. They are not particularly enriched in economically important matals. However, trace metals may be more concentrated in crusts that have formed more slowly in deeper water along the landward slope of the trench.

7. Hydrothermal sulphides may be forming above a magma chamber discovered beneath Valu Fa Ridge - a spreading center along the eastern side of Lau Basin a few tens of kilometres west of the dormant Ata segment of the Tofua Volcanic Arc (figures 2 and 4C). Circulating hydrothermal fluids are presently depositing metal oxides in and on the vesicular andesitic lava being extruded along the spreading ridge. The inflated Valu Fa Ridge lacks a summit rift valley; potential massive sulphides may be located at venting-sites associated with transform offsets.

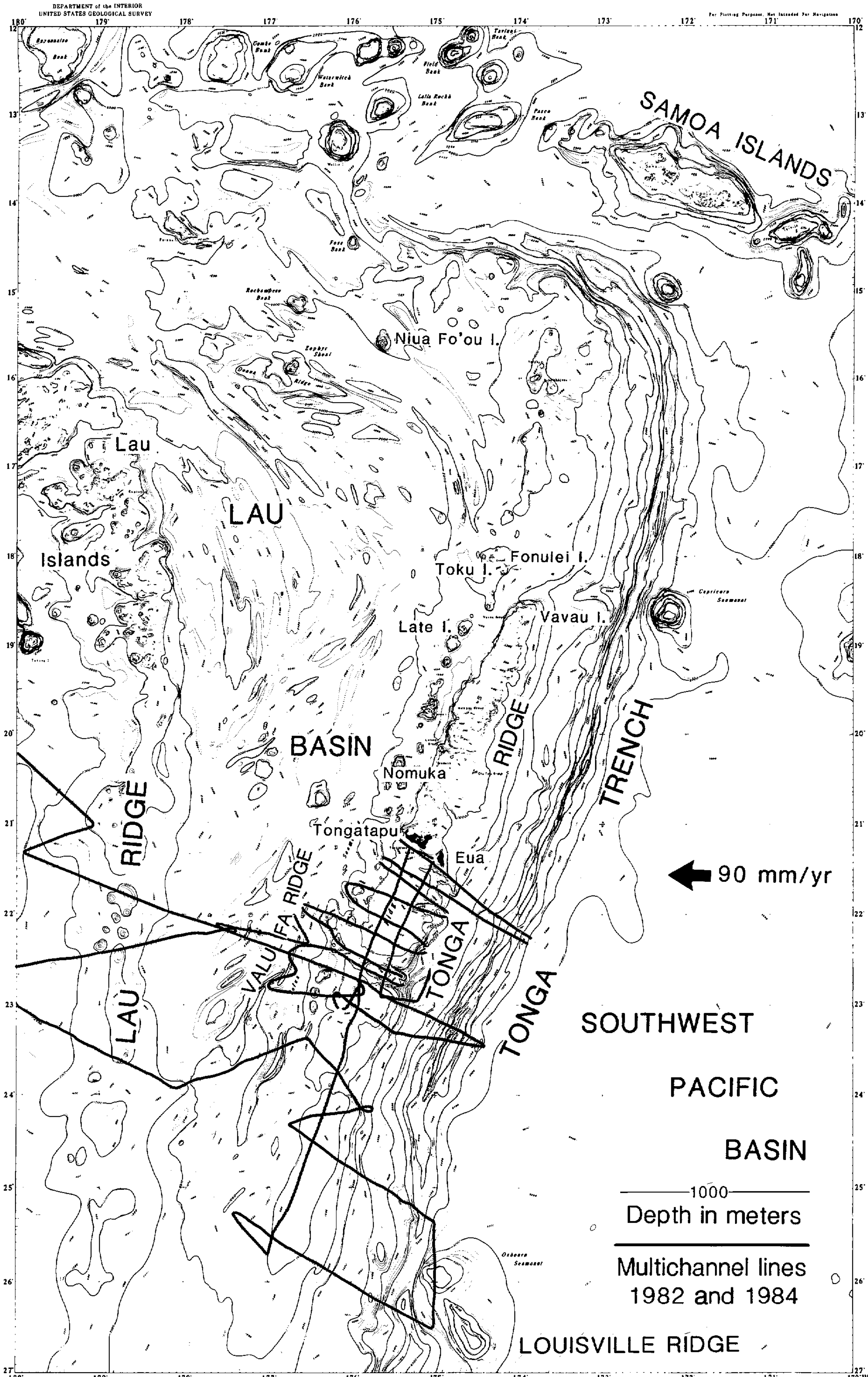

Figure 1. Bathymetric chart, in meters, of the Tonga-Lau region showing tracklines of multichannel (24-fold) seismic reflection data collected from the R/V S. P. LEE in 1982 and 1984. Arrow is direction of relative motion, Pacific vs Australia-India plates.

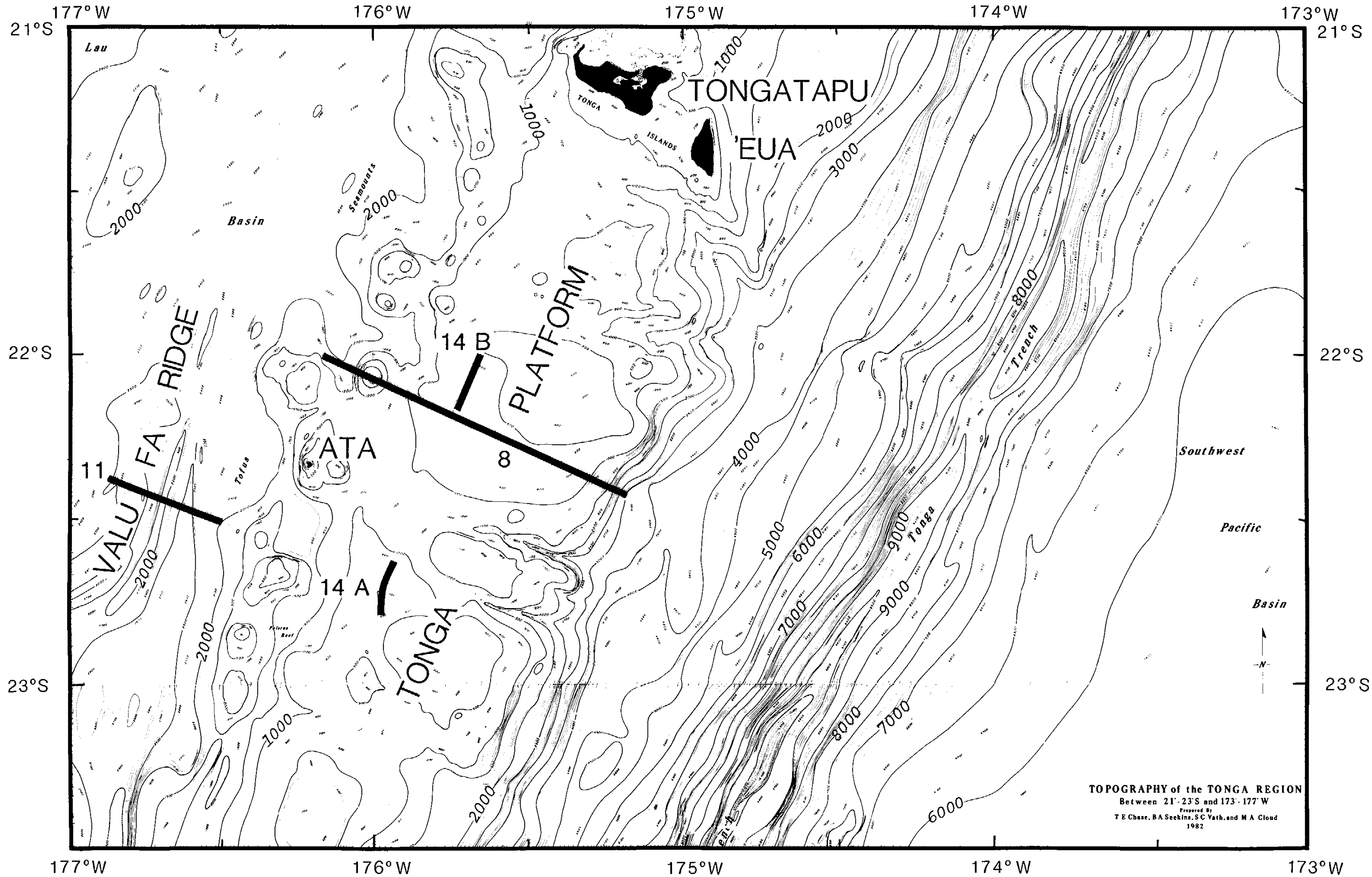

Figure 2. Bathymetry of the Tonga Ridge and adjacent sea floor, in meters, in vicinity of the southern Tonga platform. Heavy lines locate reflection profiles shown on Figures 3 and 4.

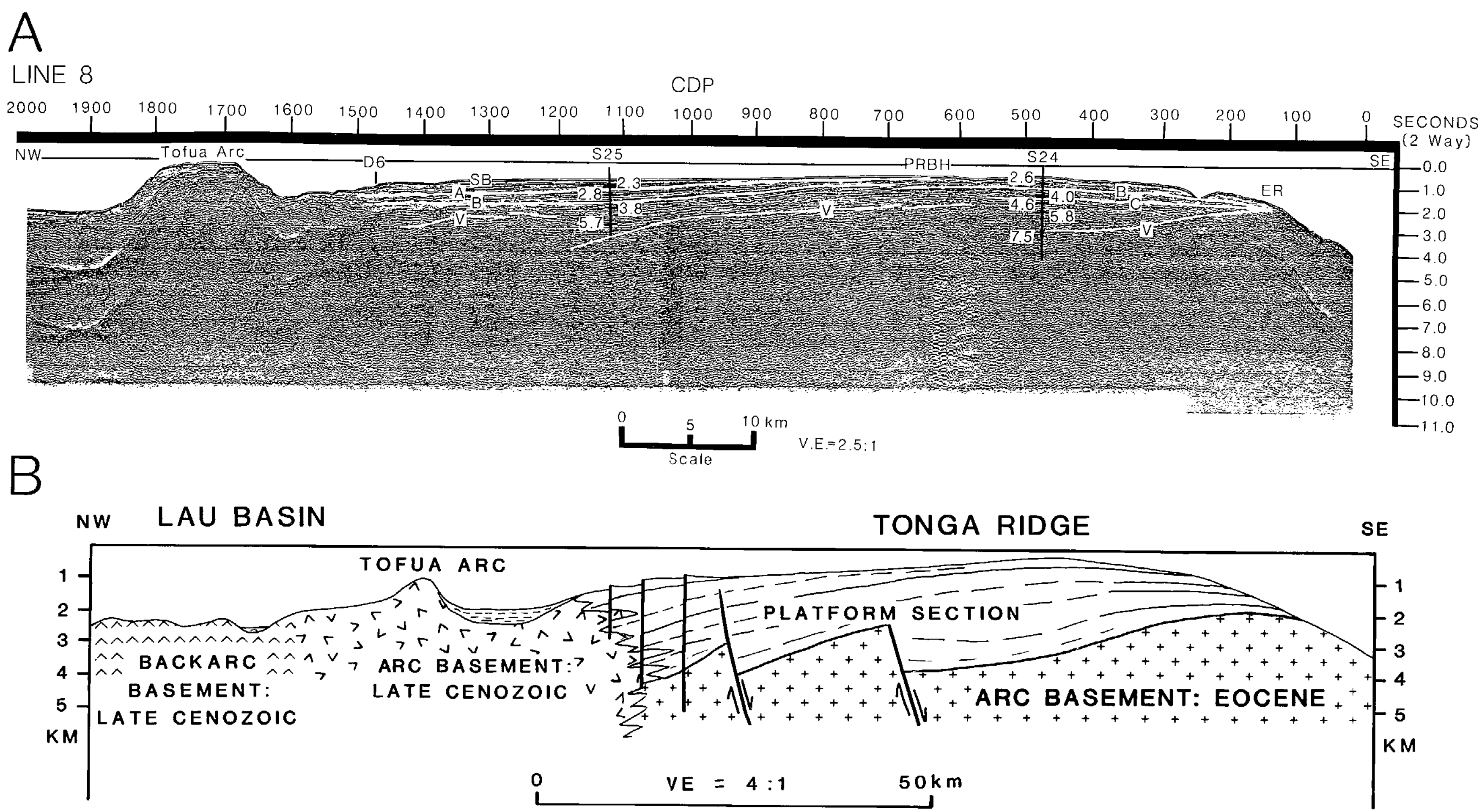

Figure 3. A: Seismic reflection profile 8 (see Figure 2); D6, dredge station at which upper Pliocene rocks were recovered; S25 and S24, sonobuoy refraction stations showing subsurface velocities in km/sec; PRBH, Pacific-rim basement high; ER, 'Eua Ridge; V, volcanic basement of middle Eocene rocks; B and A, prominent subsurface reflection horizons in Neogene deposits; SB, seabed. Lower drawing (B) is a schematic structural section of southern Tonga platform showing its relation to the crust of the Tofua Arc and the adjacent Lau Basin. Tofua crust may rest on backarc crust, but intrudes arc crust underlying platform section.

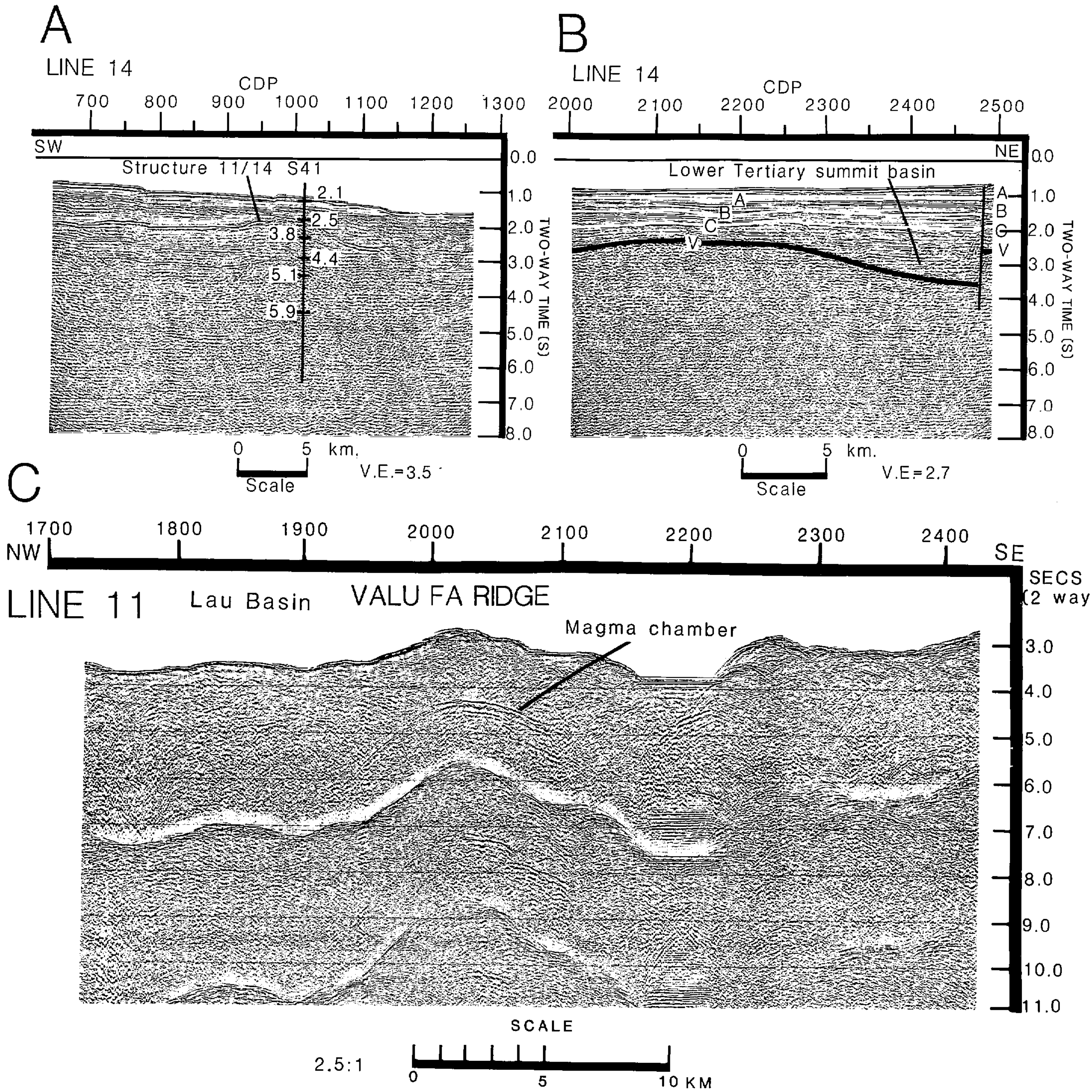

Figure 4. A: segment of reflection profile 14 (see Figure 2) showing subsurface domical structure 11/14, possibly a reefal mass of early Neogene age. Section B obliquely crosses an early Tertiary summit basin filled mostly with upper Oligocene (?) and lower Neogene deposits. C: is a sector of line 11 that crosses Valu Fa spreading center and Ridge and an underlying magma chamber at roughly 3.5 km subbottom. Vesicular andesite erupts along the ridge, which is being affected by hydrothermal circulation.