PETROLEUM GEOLOGY OF FIJI

By Howard Johnson

ABSTRACT

The Fiji Platform developed as an island arc in the Tertiary. Extensional and transpressional tectonics have deformed the fill of extensive sedimentary basins within the Platform. These basins commonly contain over 3 km of stratified deposits.

Five deep petroleum-exploration wells were drilled between 1980 and 1982, but all were dry. There remain reasonable prospects, however, because none of the wells tested their targets, and there are indications that thermogenic hydrocarbons have been generated and are locally trapped-in the subsurface.

Doubts remain with regard to the quality and quantity of source-rocks and of the hydrocarbons generated.
1. INTRODUCTION

There has been petroleum interest in Fiji since 1968 when seeps of crude oil were discovered in the geologically similar setting of Tonga. In the years 1980-1982 five deep wells were drilled, all of which were dry. There remain, however, reasonable prospects - see Section 4.

Most petroleum exploration in Fiji has been directed towards sedimentary basins offshore and extending onshore Viti Levu. Seismic profiles across these basins show thick sedimentary sections and numerous potential trapping styles. In the following account the geology and petroleum prospects of sedimentary basins in Fiji are briefly described.

Initially the evolution of the Fiji Platform is put into a regional plate-tectonic setting.

2. REGIONAL PLATE-TECTONIC SETTING

The southwest Pacific region is dominated by plate convergence between the Pacific and Indo-Australian plates and the present-day convergence vector is oriented east-west over much of the region (Fig. 1).

The Tonga-Fiji-New Hebrides section of the plate boundary has been referred to as an interarc region (Hamburger and Isacks, 1988) and is anomalous in several respects. Firstly, the convergent boundary is discontinuous, jumping from westward subduction at northern Tonga to eastward subduction at the southern New Hebrides. Secondly, the interarc region is one portion of the convergent plate boundary that is not dominated by plate subduction. Thirdly, the broad, geologically complex Fiji Platform sits within the plate boundary. Finally, two east-trending bathymetric deeps, the Vitiaz Trench and the Hunter Fracture Zone mark the sites of former subduction zones.

The seafloor morphology of this area is shown in Figure 1 and emphasises the major tectonic elements of the interarc region. The main features-immediately surrounding the Fiji-Platform-are described below.

The **Hunter Fracture Zone** is a well-defined curvilinear belt of ridge/trough topography. Bathymetric and seismic-reflection profiles show that the subduction-margin morphology is preserved well into the Fiji Platform (Brocher-and Holmes, 1985). The absence of an inclined seismic zone and shallow, thrust-type focal mechanisms favour the interpretation that the Hunter Fracture Zone is not accommodating plate convergence at present (Hamburger, 1986).
Island arcs stand out on Figure 1 as bathymetric highs landward of trenches. The Lau Ridge is a remnant arc isolated from the Tonga subduction zone by back-arc spreading in the Lau Basin (Karig, 1970). It formed part of the adive-Tonga arc through the Miocene and into the Pliocene (Whelan et al., 1985; Woodhall, 1985).

The Fiji Platform is delineated by a broad area of shallow water depths. The rocks exposed on the Fiji islands record a complex history of arc volcanism and deformation beginning in the Late Eocene and extending into the Quaternary (Rodda 1967, and in press).

Active back-arc-basin spreading has been identified in the North Fiji Basin and Lau Basin (Karig, 1970; Chase, 1971). These basins stand out as relatively uniform areas of medium water depths (c 3 km) surrounding the Fiji Platform. The South Fiji Basin is an inactive back-arc basin of Oligocene age (Watts et al., 1977) and is marked by relatively deep water.

A major transcurrent boundary in the interarc region is the Fiji Fracture Zone. Strike-slip focal mechanisms along its entire length confirm its identification as the southern transcurrent boundary of the Pacific Plate in this area (Chase, 1971; Isacks et al., 1969; Hamburger and Everingham, 1986).

A working model of regional plate evolution has been developed by several authors, notably Karig (1970), Chase (1971), Packham (1973) and Falvey (1975 and 1978). This model holds that, during the Tertiary, Fiji was part of a continuous volcanic arc extending along the New Hebrides through Fiji to the then united Lau-Tonga Ridge. This arc was the product of subduction of the Pacific Plate at the Vitiaz, Tonga and Kermadec Trenches. Subduction is thought to have taken place here until the Late Miocene when it was interrupted by a reversal of subduction in the New Hebrides leg of this volcanic arc. This reversal of arc polarity was followed by clockwise rotation of the New Hebrides arc and by creation of the North Fiji Basin in its wake. Anticlockwise rotation of the Fiji Platform is also attributed to growth of the North- Fiji-Basin-(Malahoff et-al., 1982; Brocher and Holmes, 1985).

The entire interarc region has been considered as a zone of transtension (Hamburger and Isacks, 1988) in which the dominantly transcurrent motion of the Pacific and Indo-Australian plates is accompanied by a significant component of extension.
3. BASIN TECTONICS AND SEDIMENTATION

The Eocene to Late Miocene stratigraphy of Viti Levu has been significantly revised following work by Hathway (1988). The rocks known to be Late Eocene and Early Oligocene have been separated from the Wainimala Group (Rodda and Band, 1967) as the Yavuna Group, and the Sigatoka Sedimentary Group has been abandoned. Constituent strata of the Sigatoka Sedimentary Group have been assigned to the Wainimala Group and the (new) Tuva Group.

3.1 Basins onshore Viti Levu:

The Yavuna block in southwestern Viti Levu (Fig. 2) is the only proven area of Upper Eocene to Lower Oligocene rocks in Fiji. The dominantly rudaceous volcaniclastic sedimentary sequence has been interpreted as a proximal volcaniclastic apron of the arc. Associated detrital, non-reefal, biostromal limestones indicate local shoaling to depths of around 100 m or less (Hathway, 1988). This group of rocks may form much of the basement of Fiji. The polarity and initial location of the Yavuna arc remains uncertain but it was probably originally located to the west of its present location and rifted north-eastwards as the South Fiji Basin opened in the Oligocene.

In the Late Oligocene-Middle Miocene the Fiji Platform is thought to have formed part of a volcanic arc with a southwest dipping subduction zone along the Vitiaz Trench. The Late Oligocene to Middle Miocene Sigatoka Basin in southwestern Viti Levu contains over 4 km of volcaniclastic rudites grading northward into finer grained mass flow and hemipelagic deposits (Wainimala Group). Shallow-water, locally reefal limestones within the proximal dispersal-apron of the volcanic arc indicate local or periodic shoaling. The Sigatoka Basin is floored by pillow basalts and andesites. Broadly similar sequences are exposed to the north of the Colo Plutonic Belt in northeastern Viti and these basins are interpreted as extensional forearc half-grabens that may have originated during mid-Oligocene arc rifting (Hathway, 1988).

Thick platform limestones including reefs (Qalimare and Nakorowaiwai Limestones) were deposited at the edge of the late Early to Middle Miocene forearc basin.

A regional mid-Miocene hiatus coincides with emplacement of tonalite and grabbo stocks of the Cola Plutonic Suite along the axis of the Wainimala arc, but there is no evidence for crustal shortening at this time (Hathway, 1988).
In the Late Miocene, following the Colo hiatus, boulder conglomerates up to about 2 km in thickness, and probably representing a submarine-debris apron (Tuva Group), perhaps distal to a series of fan deltas, were deposited along-the margin of the emergent, rapidly eroding Wainimala-Colo massif. A thick sequence of turbidite sandstones accumulated in the basin further north.

A complex Late Miocene (intra-CN9 nannozone) phase of folding and faulting affected Wainimala and Tuva Group rocks prior to, and during deposition of, succeeding Late Miocene strata.

In southeastern Viti Levu the tight folding is locally en echelon and consistent with sinistral movement on northeast-trending wrench faults (Hathway, 1988).

Late Miocene sequences overlying the angular unconformity are up to several hundred metres thick and dominantly composed of mass flow rudites, turbidite sandstones and terrigenous mudstones with associated shallow-marine to subaerial calcalkaline volcanics. Minor reefal limestones locally occur. The conglomerates commonly contain abundant clasts of tonalite derived from unroofed Colo stocks.

The Messinian low sea level, in the Late Miocene, produced a widespread disconformity on Viti Levu and is locally associated with shallowwater limestones. Post-Messinian sedimentation appears to be almost wholly Early Pliocene (Rodda, in press).

Early Pliocene submarine and subaerial volcanism produced volcanic edifices across the northern half of the island, but sedimentation of several hundred metres of rudites, sandy turbidites and deep-water marls continued away from the volcanic centres. Emergence of the centre of the island occurred in the Early Pliocene and/or in the Late Pliocene and brought Late Miocene shallow-water limestone to more than 1000 m elevation (Rodda, in press). Large faults affect the post-Miocene rocks, but there is little folding.

Thin Late Pliocene and Quaternary deposits locally fringe the coast of Viti Levu.

3.2 Basins offshore Viti Levu:

a. Bligh Water area
Total sediment thickness is unproven, but seismic reflection data indicate over 3 seconds two-way-time (TWT) of sediment locally occur in the Bligh Water basins. Water depth is generally less than 100 m, but locally up to 1000 m (Fig. 2).

The Bligh Water and Great Sea Reefs exploration wells (Chevron Oil Company of Fiji, 1980 and 1981) proved over 2500-m of Upper Miocene to Pleistocene mudstones and Upper Oligocene to Lower Miocene volcanioclastic rudites, mudstones and tuffs, with minor hemipelagic limestones (Fig. 4). The Upper Oligocene to Lower Miocene rocks are considered to be age and facies equivalents of Wainimala Group sequences in the Sigatoka forearc basin (Bronnimann and Zaninetti, 1979/80; Hathway, 1988). In this area Pliocene and Quaternary sequences alone are locally over 2 seconds TWT (c 2 km thick) (Fig. 3).

In the central part of the Bligh Water Basin a major unconformity resulting from the onset of faulting and tight folding (Figs 5 and 6) is tentatively correlated with the Late Miocene (intra-CN9 nannozone) angular unconformity in southeast Viti Levu. This is similarly attributed to extensive strike-slip tectonism during breakup of the Outer Melanesian Arc (Hathway, 1988; Wood, 1980). The folds are locally asymmetric with vergence and overthrusting reverse faulting to the north and northwest. Delineation of basement involvement in the structural style is limited by seismic resolution, but flower structures have been interpreted (Fig. 7) (Harding and Lowell, 1979; Johnson 1988a). The tectonism produced a major east-northeast-trending faulted anticline which divides the Bligh Water Basin, and a major south-dipping monocline at Pascoe Reefs, separating the Great Sea Reefs area, where Late Pliocene sediments are generally much thinner (Fig. 5). A similar southeast-dipping monocline crops out along the Yasawa Group of islands and local overthrusting to the northwest is recorded on the Yasawa Island in the north (Rodda, 1986 and in press). West of the Yasawa and Mamanuca Groups a rifted arc margin bounds the Fiji Platform (Falvey, 1978; Brocher, and Holmes 1985; Johnson, 1988a).

Fold trends apparently curve from east or northeast in central Bligh Water to north and northwest at the southern end of the Yasawa Group (Fig. 2), and local overthrusting or reverse faulting to the west occurs (Fig. 8) (Johnson, 1988a). Similar variation in the axial traces of folds occurs Around the resistant core of the Yavuna block and this has been attributed to the effect of a sinistral strike-slip regime upon an extremely heterogeneous crust (Hathway, 1988). Local inversion of fold-basin depocentres in Bligh Water is consistent with continued strike-slip deformation (Harding, 1985; Johnson, 1988a).
Significant erosion occurred at the loci of major Late Miocene uplift in Bligh Water, such as the central Bligh Water anticline and probably supplied coarse clastics into the basin.

An angular unconformity at about 1000 m in Bligh Water No.1 (Fig. 4), below which strata are gently folded and locally eroded, is probably an Early Pliocene feature (Fig. 3) (Maung and Eden, 1983; Chevron Overseas Petroleum Incorporated, 1979; Johnson, 1988a).

Compressive tectonism had generally ceased by about the Early Pliocene, and extensional faulting has since been dominant. A Late Pliocene phase of uplift and erosion resulted in a major angular unconformity at basin margins (Fig. 9).

Parallel-layered strata above the intra-Late Miocene unconformity suggest fairly deep-water turbiditic/hemipelagic deposits, but an easterly-prograding Pliocene sequence in Western Bligh Water indicates shallow-water shelf deposits, possibly with some reefal buildups.

b. Bau Waters area

In the Bau Waters area, east of Viti Levu, water depth is less than 1100 m landward of the reefs bordering Viti Levu and the small offshore islands, but commonly over 500 m elsewhere (Fig. 2). Seismic profiles and well data (Fig. 10) show Late Miocene and Pliocene sequences of tuffaceous mudstone, sandstone and volcanic rocks, similar to those at outcrop nearby. These sequences onlap ridges of older rocks, and the angular unconformity may correlate with the Late Miocene (intra-CN9 nann ozone) break recorded on Viti Levu.

Total sediment thickness is unproven, but over 2 seconds (TWT) of Late Miocene to Quaternary strata locally occur in the northwest trending half-graben west of Ovalau island (Fig. 11). This structure was initiated during Late Pliocene extensional tectonism (Johnson, 1988b). A similar northwest trending half-graben occurs in the deep-water area between Batiki and Nairai islands (Holmes et al., 1985). Seismic resolution in the Bau Waters area is fair, to near the base of the Pliocene, but poor below this. The offshore well Cakau Saqata No.1 (Pacific Energy and Minerals Limited 1983d) proved over 2000 m of Miocene to Quaternary tuffaceous
marine mudstones and sandstones with minor limestones and capped by Pleistocene reef (Fig. 10). The well terminated at 2272 m in a plutonic intrusion of the Colo Suite dated at 8.8 Ma. Maumi No.1 well (Pacific Energy and Minerals Limited, 1983a) near the east coast and the margin of the Late Miocene Pliocene Rewa sedimentary basin proved about 1000 m of similar sediments and terminated at 1591 m in ?Middle Miocene spilitic volcanics.

c. Nadi Bay area

Bouger anomalies and a 1.5-second relative delay in P-wave earthquake arrivals measured in the shallow-water Nadi Bay area off western Viti Levu (Fig. 3) indicate the presence of a great thickness (about 7 km) of low density material, such as sediments (Everingham in Burley, 1986). The Yakuilau Island well (Pacific Energy and Minerals Limited, 1983e) on an island just off the coast, proved about 1500 m of ?Late Miocene to Quaternary marine, tuffaceous sandstones and mudstones. Middle Miocene dates from near the bottom of the well are probably the result of sedimentary reworking (Katz, 1986). Seismic resolution in this area is fair down to an angular unconformity tentatively correlated with the Early Pliocene break at Bligh Water No.1 well. Up to 1.4 seconds (TWT) of relatively undeformed Pliocene to Quaternary strata onlap weakly layered Late Miocene to 'Earliest' Pliocene strata which have been deformed into broad northwest trending folds (Fig. 12). A local northeasterly dipping deep reflector -about 0.7 seconds (TWT) below the Early Pliocene unconformity may represent the Mid to Late Miocene stratigraphic hiatus. Wainimala rocks probably underlie this event.

d. Suva Basin

The deep-water (generally over 2000 m) Suva Basin in Kadavu Passage (Figs. 2 and 13) contains over 3 seconds (TWT) of stratified rocks. The age of the sedimentary fill is unknown, but a prominent unconformity defining the tops of tilted fault blocks possibly correlates with the intra-Late Miocene angular break of southwest Viti Levu. The tectonic style appears to be dominantly extensional. Brocher and Holmes (1985) suggested that the bulk of the sediments are volcaniclastics, although some reefal material has been interpreted to occur at the northern margin of the basin (Holmes et al., 1985).
e. **Baravi Basin**

The deep water (water depths between 1200 and 2400 m) Baravi Basin offshore southwest Viti Levu (Figs. 3 and 14) contains an undeformed sedimentary sequence of over 3 km. This is believed to consist dominantly of Late Miocene to Plio-Pleistocene volcanioclastics, although the base of the sedimentary sequence is not resolved and could extend into the Eocene (Brocher and Holmes, 1985).

f. **Vanua Levu**

Vanua Levu essentially consists of a pile of submarine volcanoes of varied composition (basalt to dacite), with intervolcanic sedimentary strata, surmounted by a large subaerial shield volcano. The rocks are of Late Miocene to Pliocene age and have undergone little deformation other than faulting. The centre of the island, however, has undergone considerable relatively recent uplift.

Several plate-tectonic reconstructions (Falvey, 1975 and 1978; Hathway, 1988) locate Vanua Levu on the forearc of the Outer Melanesian Arc, and a thick folded, sequence of Oligocene to Late Miocene strata, similar to those in the Bligh Water and Great Sea Reefs areas probably underlies the volcanic island.

g. **Lau Ridge**

The Lau Ridge formed as a result of Miocene (and probably Late Oligocene) to Early Pliocene island arc volcanism. Along with the western part of the T9nga Platform forearc, it was rifted from Tonga in the Pliocene (Woodhall, 1985; Green and Wong, 1984). The rifting resulted in widespread block faulting and the formation of sedimentary basins. The mid-slope basin on the western side of the ridge, and the Nanuku and Lakeba basins contain at least 2 seconds (TWT) of sediment.

4. **HYDROCARBON POTENTIAL**

   **Source-rocks and maturation**
   The presence of sea-floor geochemical anomalies, minor indications of thermogenic hydrocarbons in some of the wells, and a possible 'flat-spot' on reflection seismic data suggest that mature source-rocks do exist in Fiji, although further work is required to establish their extent and quality.
Source-rock tests on material from Bligh Water No.1 and Great Sea Reefs No.1 were discouraging. No significant petroleum source-beds were encountered. Total organic carbon content rarely exceeds 1% and decreases with increasing stratigraphic age. Vitrinite reflectance measurements indicate a relatively normal thermal maturation gradient and the top of the 'oil window' was estimated at about 2400 m in Bligh Water No.1.

Although source-rock tests from Bligh Water No.1 were discouraging, geochemical investigations of adsorbed hydrocarbons in Recent Bligh Water sediments indicate an area with anomalously high values (Fig. 15) (Horvitz Research Laboratories, 1979). Horvitz (1979) commented that the presence of appreciable amounts of pentane suggests that liquid hydrocarbons are present in the potential subsurface reservoirs. Results of carbon-isotope analyses of 10 samples from the anomalous area tended to confirm the view that the anomaly reflects a subsurface deposit, probably oil (Horvitz in Stahl, 1979).

Reported shows of distillate in Buabua Nos.1 and 2 wells (Pacific Energy and-Minerals Limited, 1983b and c) are now considered to have been contamination from refined oil products (Havard, 1987; W. Austin pers. comm., 1988).

Minor gas shows were recorded in Cakau Saqata No.1 (Pacific Energy “and Minerals Limited, 1983d) and geochemical investigations of interstitial and adsorbed hydrocarbon gases, and of fluorescence, in seafloor sediments -in the Bau" Waters area - (Horvitz Research Laboratories Inc.," 1981) indicate widespread anomalies. Large anomalies occur around Cakau Saqata Reef (Fig. 15) where faulting possibly provides migration pathways to the surface. A 'flat-spot' seismic amplitude anomaly to the east suggests that hydrocarbons are trapped at depth in this area (Fig. 16).

The depth to the top of the 'oil window' in Maumi No.1 is reported to be 1310 m. (Eden and Smith, 1983). This is considerably shallower than in Bligh Water and is possibly caused by a higher heat flow. This suggests that strata as young as Early Pliocene could be more mature in the Bau Waters half-graben.

Two heat-flow measurements in the Suva area to the southwest (Sclater et al., 1972) are consistent "with a thermal gradient of 80 to per kilometre. Brocher and Holmes (1985) noted that if this gradient existed since the Pliocene, then thermally mature sediments could be found only 1 to 2 km below the seafloor.
Havard (1987) noted that thin beds with good source-rock potential were encountered in Maumi No.1 and Cakau Saqata No.1, but the amount and quality of source-rock material decreases with increasing stratigraphic age. He speculated that this may indicate that the contemporary land mass was the principal source of organic matter.

The Colo uplift (c 14Ma) certainly produced land, and there is evidence of mangrove-fringed coasts in the Late Miocene (Rodda, 1976). This could be significant for source-bed development, because mangroves have a high organic productivity and tidal flushing can blanket large areas of the seabed with organic detritus. Furthermore, the organic matter produced is relatively more lipid-rich and reduced than most terrestrial debris transported to the sea and is likely to be a source for high-wax crude oils (Risk and Rhodes, 1985).

Recent source-rock and palaeontological analyses by the Bureau of Mineral Resources and University of Western Australia on behalf of the Fiji Mineral Resources Department (Co-ordinated by CCOP/SOPAC) have included samples from widespread localities in Viti Levu, borehole cores from Viti Levu and Vanua Levu and a 300 m drill-hole to evaluate the Late Miocene Veisari Sandstone in the Suva area.

Tests on Lower Miocene mudstones in Viti Levu are generally disappointing. The mudstones are commonly intensely bioturbated indicating well-oxygenated bottom conditions and poor preservation potential for enclosed organic matter. Half-graben development during the Late Oligocene to Early Miocene, however, may have led to the development of local silled basins with anoxic bottom conditions and improved source-rock potential.

It has been suggested that Early to Mid Miocene reef complexes could provide suitable source material (Eden and Smith, 1984). So far, however, source-rock tests have been discouraging. The shallow-water limestones appear to have been deposited in relatively high-energy well-oxygenated environments in which the preservation potential of organic material is low (Sassen, 1985).

Tests on the Veisari Sandstone show it to contain less than 1% TOC. The-organic matter is dominantly Type-III kerogen. In the Suva area the rocks are immature. Only minor quantities of gas could be generated at higher levels of maturity (Buchbinder and Halley, 1985; Boreham, 1989).

The Lau Ridge may include the western part of the Tonga forearc basin and crude oil seeps in Tonga indicate the presence of mature source-rock in this basin.
Reservoir Rocks

From the start of petroleum exploration in Fiji it has been recognised that limestones are likely to have better reservoir properties than sandstones. Thick units of Early to Middle Miocene limestones outcrop in Viti Levu and have been considered to be suitable targets, but these have not been tested by any of the deep wells.

The Qalimare Limestone in southwest Viti Levu consists of a series of limestone bodies at the top of the Wainimala Group along the southern margin of the Sigatoka Basin. These appear to form parts of a once continuous horizon and the largest body is the 250 m-thick mass of Qalimare. These lagoonal, and locally reefal, limestones are laterally equivalent to widespread redeposited deep-water limestones in the basin, which are up to 130 m thick. The redeposited limestones resulted from emergence and erosion of the adjacent carbonate platform, a conclusion supported by evidence of an Early/Middle Miocene hiatus accompanied by subaerial diagenesis within the limestone at Qalimare (Hathway, 1988). Enhanced reservoir characteristics may have developed during the emergent phase.

The Early to Middle Miocene Nakorowaiwai Limestone in northeast Viti Levu has been correlated with the Qalimare Limestone. This comprises up to 600 m of lagoonal limestone (Bonnimann and Zaninetti, 1979/80, Paleo. Report 27, station ZF 115) towards the top of the Wainimala Group.

Other notable lagoonal limestone bodies in the Wainimala Group include the 600 m thick Early Miocene Wailotua Limestone in northeast Viti Levu, and the 150 m thick, fine-grained early Middle to Middle Miocene limestone at Sawa-i-Lau in the Yasawa Islands, northwest of Viti Levu. Early Miocene reef limestones also occur at Tau in southwest Viti Levu.

In fact many of the limestones appear tight in hand specimen, but may well have fracture porosity. Late Oligocene to Early Miocene deepwater limestones are recorded in both Bligh Water No. 1 (42 m thick) and Great Sea Reefs No.1 (4m), but appear to be tight.

Limestones also locally occur in the Eocene to Early Oligocene Yavuna Group and in the Late Miocene to Pliocene sequences Eocene shelf limestones are locally over 100 m thick (Eden and Smith, 1984).

The Late Miocene Early Pliocene Lami Limestone which occurs in the Suva area, reaches more than 50 m in thickness. Local patch reefs occur, and 37% porosity and 1989 millidarcies permeability are recorded at outcrop (Mitchell and Pees, 1970). The Lami Limestone can be recognised in Maumi No.1 some 22 kIn northeast of Suva, where it comprises about 20 m of fossiliferous limestone. The Navosa Group in southwest Viti Levu also
includes a large, massive, reef limestone body of Late Miocene or possibly Pliocene age (Hathway, 1988). Solution brecciation and presence of vadose crystal silts indicate early subaerial exposure of this body.

Shallow-water limestones of Middle Miocene, but mainly Late Miocene to Early Pliocene age occur in Lau (Woodhall, 1985) and possibly have reservoir potential in subsurface traps.

In a volcanic island arc environment clastic sediments are generally of low porosity and permeability because of alteration of mafic minerals and plagioclase, and the filling of pore spaces with volcanic ash. In Fiji the only major source of quartz is the Colo Plutonic Suite, and although this may contain up to 40% of quartz by volume, quartz in sediments rarely exceeds 10%.

Volcaniclastics in the Yavuna Group are dominantly rudites showing greenschist metamorphic facies mineral assemblages. In the Wainimala Group sandstones are dominantly quartz-free to quartz-poor litharenites, although some are more quartz-rich.

Eden and Smith (1984) suggested that volcaniclastic and epiclastic sediments may have reservoir potential and drew a parallel with Japan, where gas reservoirs are developed in fractured tuffs (Miyazaki et al., 1980).

**Traps**

Cap-rocks are generally not perceived to be a problem in Fiji, most of the claystones, which are abundant in the five wells drilled are likely to constitute satisfactory seals; Locally, however, young faults may provide pathways for leakage of hydrocarbons.

**a. Bau Waters**

A 'flat-spot' seismic amplitude anomaly in a structurally closed high at 1.4 seconds (TWT) depth and about 650 m of water southeast of Ovalau possibly represents a subsurface trap bearing hydrocarbon gas (Fig. 16). The top of the closed structure is interpreted as the Late Miocene (intraCN9 nannozone) angular unconformity, but the nature of the strata in the trap is uncertain. Seismic data across the flat spot are limited to one profile, so its extent can only be estimated, but it is at least 2 km long and the closure is 0.1 seconds (TWT).
In moderate water depths (c 500 m) further south, a fault-bounded structural high measuring about 12 by 3 km and with about 0.3 seconds (TWT) of closed high is also be prospective (Fig. 17). The upper surface of this closed high is also interpreted as the angular Late Miocene unconformity. This surface is onlapped by Pliocene strata, although a basal layer of Lami Limestone facies could also occur. The nature of the strata under-lying the unconformity is uncertain, but a dominantly volcanic and volcaniclastic sequence occurs in the Suva area 40 km to the west. The eastern boundary fault of the structure has been active in the Late Pliocene or Quaternary, and local sea bed geochemical anomalies suggest that some leakage of hydrocarbons may have occurred.

Additional pre-unconformity structural traps may be apparent with reprocessing of seismic data or collection of new data.

b. Bligh Water, Nadi Bay and Great Sea Reefs areas

Several mound-like anomalies in western Bligh Water buried at depths of about 1-1.5km and under shallow to moderate depths of water (less than 100 m to about 500 m) may represent carbonate buildups (Fig. 18). Pliocene bodies are approximately 2.5km across and 0.2 seconds (TWT) thick. A reflection-free seismic facies is apparent, with onlap and drape of overlying sediments. Several similar anomalies occur below the prominent Early Pliocene unconformity.

Late Miocene folding and later faulting has produced a number of potentially prospective closures (Maung and Eden, 1983; Johnson, 1988a, 1988b and 1989) (Fig. 2), although seismic mapping is incomplete. Structurally-controlled stratigraphic traps due to a post-folding erosional and onlap unconformities also occur.

c. Suva and Baravi deep-water Basins

Only a limited amount of seismic reflection data are available across these basins. In the Suva Basin, tilted fault blocks below the Late Miocene unconformity, arid possible reefal strata suggest numerous potential traps(Holmes et-al., -1985). In the Baravi Basin seismic resolution is limited to ?Late Miocene and younger strata, which are virtually undeformed. Unconformities occur however and could form traps. Structural traps are possibly present at depths beyond the resolution of available seismic information.
d. Lan Ridge

Commercial and other seismic profiles indicate widespread Pliocene block faulting (Woodhall, 1985) and possible trap information. Late Pliocene strata progressively onlap the faulted Miocene and Early Pliocene rocks, and structurally-controlled unconformity traps may occur.

5. PROSPECTIVITY SUMMARY

Positive Aspects

- Thick enough sedimentary sequences and sufficient heating for maturation of potential source beds
- Indications that thermogenic hydrocarbons have been generated
- Numerous potential trapping styles
- Large areas of sedimentary basins occur on land or under relatively shallow water (less than 200 m) and are, therefore, relatively attractive for exploration in the short-term.

Negative Aspects

- Five negative wells
- Doubts regarding the availability of adequate source-rocks
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FIGURE CAPTIONS

Figure 1. Morphology and tectonic features of the Pacific and Indo-Australian plate boundary.

Figure 2. Structure contours on Late Miocene unconformity and summary of structural trends.

Figure 3. Extent of Pliocene sedimentary basins around Viti Levu and structure contours on 'Base Pliocene'.

Figure 4. Interpreted seismic section illustrating correlation of Bligh Water No.1 with seismic data.

Figure 5. Interpreted seismic section across the Bligh Water Basin showing folds and reverse faults related to Late Miocene wrench faulting.

Figure 6. Interpreted seismic section across the Bligh Water Basin illustrating folds related to Late Miocene wrench faulting.

Figure 7. Interpreted seismic section across the Bligh Water Basin illustrating a positive flower structure related to Late Miocene wrench faulting.

Figure 8. Interpreted seismic section across the margin of the Bligh Water Basin illustrating folding and reverse faulting related to wrench faulting.

Figure 9. Interpreted seismic section across the Bligh Water Basin illustrating a Late Pliocene unconformity.

Figure 10. Interpreted seismic section illustrating correlation of Cakau Saqata No.1 with seismic data.

Figure 11. Interpreted seismic section illustrating extensional faulting and sedimentary basins in Bau Waters, offshore eastern Viti Levu.

Figure 12. Interpreted seismic section illustrating sedimentary basin in Nadi Bay, offshore western Viti Levu.

Figure 13. Line drawing from an interpreted multichannel seismic section across the Suva Basin, offshore southeast Viti Levu.
Figure 14  Line drawing from an interpreted seismic section across the Baravi Basin, offshore southwest Viti Levu.

Figure 15  Geochemical anomalies offshore Viti Levu.

Figure 16  Interpreted seismic section across a 'flat-spot' anomaly in Bau Waters, offshore eastern Viti Levu.

Figure 17  Interpreted seismic section across a structural high in Bau Waters; offshore eastern Viti Levu.

Figure 18  Interpreted seismic sections across a Pliocene reef-like anomaly in Bligh Water.
7. REFERENCES

The designation (c) indicates that the item is confidential at present.


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