Stratigraphic and Structural Development of the Aure Trough and Adjacent Shelf and Slope Areas


ABSTRACT

The Aure Trough is a partially submerged south-south-easterly trending eugeosyncline which comprises the main axial zone of sedimentation in the Cainozoic Papuan Geosyncline. It is bounded to the west by a broad stable mioeogynclinal shelf and slope, and to the east by a narrow unstable shelf.

Onshore the trough consists of 10 000 m of deep-water sediments. These extend offshore where the axis of sedimentation coincides with the axis of a present day bathymetric feature, the Moresby Trough. Sediments are folded into north-trending linear anticlines and broad synclines; anticlines are ruptured by thrust faults and offshore by diapirc intrusion of mudstone. The western slope (5000 m of fine marine sediments) and shelf (2500 m of deltaic and shallow marine sediments) are relatively undeformed. Over the eastern shelf, 5000 m of folded fluvialite, deltaic and shallow marine sediments are transitional eastwards to 2000 m of relatively undeformed sub-aerial volcanics. Variations in sedimentary lithologies can be correlated with periods of volcanic activity associated with periods of uplift.

The sediments of the Cainozoic Papuan Geosyncline unconformably overlie Mesozoic and Eocene sediments. West of the Aure Trough the Mesozoic and Eocene rocks are weakly deformed shelf sediments derived from the Australian continent; east of the trough they are strongly deformed, metamorphosed and partly volcanogenic. The nature, thickness and extent of these sediments beneath the Aure Trough is not known.

The Mesozoic to Eocene sequence accumulated around the margins of the Australian continent in an arcuate geosynclinal basin. Early Cainozoic interaction of the Australian and Pacific plates resulted in deformation of the outer margins of this geosyncline and in the partial emergence of mainland Papua New Guinea. Erosion of this landmass and volcanic activity provided the main source of sediment for the Cainozoic Papuan Geosyncline. Development of the Aure Trough may be related to opening of the Coral Sea Basin in the Eocene; geophysical evidence suggests crustal thinning.

Numerous oil and gas seepages have encouraged petroleum exploration throughout the area since 1911. No economic reserves have been located in the Tertiary section, but wells west of the Aure Trough have encountered gas and some oil of probable Mesozoic origin.

INTRODUCTION

The Aure Trough is a partly-submerged south-southeasternly-trending middle and late Cainozoic eugeosyncline. Sediments of the trough are exposed onshore in the Albert Mountains and Krait and Armit Ranges, bordered to the east by the Owen Stanley Range and to the west by the Kubor and Wabau Ranges (Fig. 1). Offshore the axis of the Aure Trough coincides with a present-day bathymetric feature, the Moresby Trough, with a broad shallow shelf to the west and a narrow partly-emergent shelf to the east. Further south the Moresby Canyon leads to the Coral Sea Basin.

Fig. 1. Locality map.

The Aure Trough is the main axial zone of sedimentation of the Cainozoic Papuan Geosyncline, an arcuate orthogosyncline which lies between the Australian continent and the mountain ranges of Papua New Guinea. The Cainozoic Papuan Geosyncline can be sub-divided into five tectono-sedimentary zones. From west to east these are platform, stable shelf, stable slope, Aure Trough and unstable shelf (Fig. 2). The unstable shelf to the east of the eugeosynclinal Aure Trough is a zone of tectonic instability which has been

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characterised by intermittent uplift, volcanic activity and coarse clastic sedimentation from late Oligocene to Holocene time. By contrast the miogeosynclinal platform and stable shelf are tectonically stable and were characterised by carbonate sedimentation in the Miocene. In the early upper Miocene however, uplift and deformation of the unstable shelf and the Aure Trough began to influence sedimentation over the platform and stable shelf.

The purpose of this paper is to describe the relationships between the Aure Trough and adjacent platform, stable shelf and slope to the west and the unstable shelf to the east. The regional, stratigraphic and structural framework controlling development of the Cainozoic Papuan Geosyncline is described, followed by summaries of stratigraphy and structure within each of the tectono-sedimentary zones. The relationships between these zones are summarized in the discussion of geological history. The area coincides with the four 1:250,000 Sheet areas: Kiokiri, Wau, Yule and Gulf, 7°-9° S, 144°-147° E.

The Geological Survey of Papua New Guinea has recently completed field work in onshore areas bordering the northern and eastern margins of the Gulf of Papua (Brown, 1974; Pieters and Robinson, in prep.), as part of a systematic programme aimed at providing complete coverage of Papua New Guinea at 1:250,000 scale. Compilation of these sheets has relied heavily on data obtained by the Australasian Petroleum Co., British Petroleum Co., Pappuan Apinaip Petroleum Co. Ltd. and Phillips Australian Oil Co. Summaries of the geology of western and central Papua have been prepared by the Australasian Petroleum Co. (1961). Thompson (1967) and Rickwood (1968): of western Papua by Jenkins (1974) and Findlay (1974); of central Papua by Stanley (1960), Pitt (1966) and Dow and others (in prep.), and of eastern Papua by Davies and Smith (1971). The regional gravity pattern was described by St. John (1967, 1970) and the aeromagnetic pattern over the eastern part of the Gulf of Papua and adjacent mainland by Compagnie Générale de Géophysique (1969). Geology, geophysics and drilling operations in the Gulf of Papua have been summarized in confidential reports by Phillips Australian Oil Co. (1970); information is available in various Bureau of Mineral Resources Petroleum Subsidy reports. The results of a marine geophysical survey, conducted by Compagnie Générale de Géophysique on behalf of the Bureau of Mineral Resources of Australia are described by Mutter (1972 a,b) and Wilcox (1973). Information on the submarine geology of the Coral Sea area and its relationship with the Gulf of Papua has been presented by Krause (1967), Winterer (1970), Gardiner (1970) and Davies and Smith (1971).

Fig. 2. Tectonic framework of sedimentation in the Cainozoic Papuan Geosyncline.

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The term Cainozoic Papuan Geosyncline is adopted to avoid confusion with the Papuan Basin which refers to the unmorphosed Mesozoic to Tertiary sequence of western and central Papua (Jenkins, 1974). Wise (in press) refers to the offshore part of this sequence as the Gulf Basin. The term Tertiary Papuan Basin as used by Phillips Australian Oil Co. (1970), Willcox (1973), and the term Papuan Basin as used by Mutter (1972), refer to the Tertiary sequence in the Gulf of Papua. The term Papuan Geosyncline as used by Australasian Petroleum Co. (1961) refers to the miogeosynclinal and eugeosynclinal Mesozoic to Tertiary sequence of western, central and parts of eastern Papua. However the northern and eastern limits of this geosyncline were not well known and Dow (1973) subsequently renamed the partially metamorphosed Mesozoic to lower Tertiary eugeosynclinal the New Guinea Geosyncline. The term Cainozoic Papuan Geosyncline (as used by Davies and Smith, 1971) is here retained to refer to the Cainozoic sequence only.

REGIONAL STRATIGRAPHIC AND STRUCTURAL FRAMEWORK

Fig. 3. Regional structural and stratigraphic framework.

The Southwest Papuan Platform consists of Palaeozoic metamorphics intruded by Carboniferous to Triassic granitic rocks (Australasian Petroleum Co., 1961) forming a basement which is continuous with continental Australia to the south, extends beneath the Papuan Fold Belt to the north and outcrops in the Kabor Anticline to the northeast; the eastern boundary may approximately coincide with the position of the concealed Pasa Ridge. In the early Mesozoic thin sequences of terrestrial and shallow-water marine sediments, derived largely from the Australian continent, were deposited over the Platform and thicker marine sediments with associated volcanics accumulated beyond the continental basement margins. A Mesozoic to Lower Tertiary geosyncline became established by late Jurassic to early Cretaceous time when thick eugeosynclinal greywacke, mudstone and volcanics were deposited in an arcuate basin peripheral to miogeosynclinal fine clastics accumulating over the margins of the continental basement (Rickwood, 1968; Dow, 1973; Jenkins, 1974). Sediment was derived from rocks of the pre-Mesozoic basement of the New Guinea highlands, the Southwest Papuan Platform and northern Queensland. In the late Cretaceous the Southwest Papuan Platform was epeirogenically uplifted, progressively tilted to the north-east and Mesozoic miogeosynclinal sediments partly eroded. Farther to the north and east sedimentation persisted in the eugeosyncline until some time in the Eocene (Dow, 1973). In the Eocene and Oligocene interaction of the Australian and Pacific plates resulted in emplacement of the Papuan Ultramafic Belt (Davies, 1971; Davies and Smith, 1971) and other thrust-sheet remnants along the northern fringes of the central ranges of Papua New Guinea. This initiated intense folding, faulting and partial metamorphism of the outer margins of the Mesozoic to lower Tertiary eugeosyncline.

Formation of the Coral Sea Basin (Krause, 1967; Winterer, 1970; Gardiner, 1970) also in the Eocene, is thought to have resulted from anticlockwise rotation of southeast Papua away from its position adjacent to the eastern margins of the Australian continental basement. Middle and possibly early upper Eocene submarine basaltts of the Southeast Papua Volcanic Province may represent oceanic crust generated at this time (Davies and Smith, 1971).

On the Southwest Papuan Platform a thin sequence of limestone was deposited in the upper Eocene. Elsewhere the sedimentary record during late upper Eocene through lower and middle Oligocene is not well known; the apparent hiatus has been variously attributed to emergence (Australasian Petroleum Co. 1961; Thompson, 1967), submergence (Davies and Smith, 1971), submarine erosion, and lack of palaeontological control.

The Cainozoic Papuan Geosyncline developed following the partial emergence of southeastern Papua and the central ranges of Papua New Guinea. Clastic sediments were derived from the new landmass and supplemented by contemporaneous volcanism; sediment was no longer derived from the Australian continental basement. It has been suggested that the northerly trending Auro Trough developed over a zone of crustal thinning (St. John, 1967, 1970; Mutter, 1972) which may have resulted from the opening of the Coral Sea. By upper Oligocene to lower Miocene time the Trough had developed as the eugeosynclinal axis of sedimentation of the Cainozoic Papuan Geosyncline (Pitt, 1966; Dow, 1973). It was bordered to the west by a miogeosynclinal carbonate shelf developed over the stable continental platform, and to the east by a narrow volcanolitic shelf peripheral to the emergent Owen Stanley Orogen. A narrow northwesterly extension of the Trough formed the Mendi Basin, which persisted until the early upper Miocene.

Rapid sedimentation, contemporaneous folding and intermittent uplift accompanied by volcanic activity has characterized the Trough and its eastern margin through to the present day. The western shelf was a zone of stable sedimentation until the late Pliocene when uplift of the Kabor "basement high" initiated detachment tectonics and resulted in the formation of the Papuan Fold Belt (Jenkins, 1974; Findlay, 1974). Southwesterly sliding and overthrusting of Miocene limestone, and of various levels within the Mesozoic sequence, continues to the present day. In places the Papuan Fold Belt is blanketed by extensive Quaternary volcanics.

SEDIMENTARY TECTONICS

The partially deformed and metamorphosed Mesozoic to Lower Tertiary geosyncline provided a framework of sedimentation for development of the Cainozoic Papuan Geosyncline. East of the Auro Trough a major regional structural and stratigraphic unconformity separates the Mesozoic to Lower Tertiary rocks from the Cainozoic sequence. To the west they are separated by a stratigraphic break and low-angle structural unconformity.
Phillips Australian Oil Company subdivided the Gulf of Papua area into five seismically-defined zones: here termed platform, stable shelf, stable slope, Aure Trough and unstable shelf (Fig. 2). These offshore zones can be correlated with onshore geological zones established by APC (Rickwood, 1968), BMR (Dow and others, in press), and GSPNG (Brown, 1974; Pieters and Robinson, in prep.). The Cainozoic tectonic framework of deposition and general rock type characteristic of each zone is shown in Fig. 2; detailed geology in Figs. 4 and 5, and interpreted cross-sections in Fig. 6.

Periods of uplift, volcanic activity, and variation in sedimentary lithology on the eastern shelf can be correlated with periods of uplift and variations in lithology on the western shelf and in the Aure Trough. Tectonic activity is clearly reflected in lithological type in the eastern shelf and less distinctly in the Aure Trough and western shelf.

STRATIGRAPHIC AND STRUCTURAL ANALYSIS

The following information is largely abstracted from the Explanatory Notes to accompany the Yule, Wau and Kikori 1:250 000 geological sheets (Brown, 1974; Dow and others, in press; Pieters and Robinson, in prep.). Further detailed information is contained in "Geological Results of Petroleum Exploration in Western Papua" (Australasian Petroleum Co., 1961) and in various unpublished reports by Phillips Australian Oil Co. Lithologies encountered in onshore and offshore wells are shown in Figure 7, and the stratigraphy and correlation of formations are summarized in Figure 8. Letter symbols in brackets are those used in Figs. 4 and 5.

Mesozoic to Lower Tertiary Geosyncline

Mesozoic sediments underly the Tertiary west of the Aure Trough are miogeosynclinal and those to the east are eugeosynclinal.

East of the Aure Trough: In the Owen Stanley Orogen and underlying the unstable eastern shelf (Fig. 2) Mesozoic metamorphic rocks consist mainly of low grade greenschist facies
Fig. 6. Geological cross-sections. (Note that the scale of Sections C-D-E is 16% reduced compared with Sections A-B and F-G).

Fig. 7. Papuan Basin well and outcrop sections.
Fig. 8. Stratigraphic correlation diagram.

slate, phyllite and schist, mostly of pelitic derivation with minor psammitic material and intercalations of green metavolcanics. To the east the metamorphics are overthrust by Cretaceous ultramafics (U) while to the west they appear to grade with decreasing metamorphism into folded Upper Cretaceous to Eocene sediments. Alternatively this contact may be unconformable (Davies and Smith, 1971). In the southeast of the map area (Fig. 4), Eocene limestone near the top of the sedimentary sequence appears to interfinger with and partially underlie a sequence of green sheared Eocene submarine volcanics (Ev.). Miocene to Pliocene granodiorite, diorite and monzonite intrude throughout the area. At least two major episodes of folding and metamorphism are indicated by microscopic and mesoscopic structures. The minor structures suggest that Mesozoic to Lower Tertiary rocks were probably folded to form large-scale recumbent isoclinal similar folds dipping steeply to the northeast. The Mesozoic to Lower Tertiary province is intensely fractured, with many north-trending high-angle faults, probably overthrust from the east. Initiation of the main metamorphic and deformational events probably coincided with the emplacement of the Papuan Ultramafic Belt in the Eocene. Evidence for a further metamorphic event in the early Miocene is presented by Dow and others (in press) and supported by geochronological work by Page (in press).

West of the Aure Trough: Mesozoic sediments (K) are exposed in the Puri Anticline and have been penetrated in several onshore and offshore exploration wells (Australasian Petroleum Co., 1961; Phillips Australian Oil Co., 1968 a,b). The little evidence so far available suggests that black, micaceous, open marine, Mesozoic shales are about 4000 m thick immediately to the west of the Aure Trough and that the Mesozoic section thins towards the west and may be entirely absent over the Pasca "basement" ridge. Marine shales with a projected thickness of about 2000 m occur in a north-trending embayment immediately to the west of the Pasca ridge and grade laterally into fluvialite, deltaic and shallow water marine facies sandstone, mudstone and siltstone developed over the Southwest Papan Platform (Australasian Petroleum Co. 1961). A thin sequence of upper Eocene argillaceous limestone and calcarenite (E) unconformably overlies the Mesozoic section. Upper Eocene reefal limestone occurs over "basement highs" and shool limestone occurs over the margins of the Southwest Papan Platform. Offshore, the Mesozoic section is only weakly deformed, broadly warped and faulted; onshore Mesozoic rocks in the Puri Anticline area are folded and disrupted by a high angle overthrust from the northeast.

Underlying the Aure Trough: Eocene sediments are exposed in the Aure Trough as fault slices and in anticlinal crests.
The sediments are detrital and micritic limestone in the northwest, and pelagic siliceous argillite, chert and micritic limestone in the southeast.

The nature, thickness and extent of Mesozoic sediments beneath the Aures Trough are not known. Any Mesozoic sediments would have been affected by crustal thinning, rifting and volcanism associated with the opening of the Coral Sea Basin in the early Eocene. Section AB (Fig. 6) illustrates possible disruption and burial by Eocene volcanics, and Section CD (Fig. 6) illustrates possible thinning of the sediments due to rifting. The concept of crustal thinning is supported by anomalously high gravity values across the Aures Trough. St. John (1967) deduced a crustal thickness of 28 km at Cape Cupola, and Mutter (1972 a) a thickness of 20 km offshore.

**Cenozoic Papuan Geosyncline**

**Unstable Eastern Shelf:** The eastern shelf is a tectonically unstable, partly emergent area characterized by rapid lateral and vertical variation in lithology. The stratigraphy of the shelf is summarized in Table 1 and is briefly discussed below. In order to simplify the discussion, the eastern shelf is considered in two parts, northern and southern, separated by the Lakekamu embayment (Fig. 4).

In the north, upper Oligocene to lower Miocene marine shelf sediments (Tm), with minor volcanics and limestone, are exposed in a north-northwest-trending belt along the western margin of the shelf. In places these rocks are unconformably overlain by basal middle Miocene volcanics (Mv), and elsewhere by a more extensive sequence of middle Miocene sediments (Ta). To the east middle Miocene sediments overlap the lower Miocene and are unconformable on the Mesozoic-Lower Tertiary sequence.

Younger sediments are not common. Near the Lakekamu embayment late upper Miocene to lower Pliocene mudstone (Tc) overlies early upper Miocene reeal mudstone and shallow-water marine sediments (Tb); in places the same mudstone unconformably overlies middle Miocene sediments. Further north, minor Pliocene fluviatile and shallow-water marine sediments unconformably overlie the middle Miocene in synclinal cores.

In the south, the Mesozoic-Lower Tertiary “basement” is unconformably overlain by small remnants of upper Oligocene to lower Miocene shallow-water marine sediments (Tm); in eastern part only and by extensive subhorizontal Miocene and Pliocene volcanics and derived sediments (Mv, Pm). The volcanics dip west beneath the coastal fluviolitic plains and are known to extend offshore (geophysical evidence from Compagnie Générale de Géophysique, 1969; drill-hole information from Phillips Australian Oil Co., 1968c). At the coast middle Miocene to Pliocene sediments form narrow northwest-trending anticlines. The sediments are mostly derived from the volcanic complex to the east and consist of middle Miocene marine shelf sediments (Ta), early upper Miocene reef limestones and shallow-water marine sediments (Tb), and late upper Miocene to lower Pliocene mudstone (Tc), which, in places, grades up into Pleistocene limestone (Tw) and elsewhere into Pleistocene fluviolitic, deltaic and shallow-water marine sediments. The onshore sediments grade laterally offshore into upper Oligocene to Holocene eugeosynclinal sediments of the Aures Trough.

The sediments of the eastern shelf are folded into a series of narrow discontinuous northwest-trending anticlines, generally asymmetric with axial planes dipping steeply to the north-east. High-angle thrust faulting may occur at depth. A major downwarp, the Lakekamu embayment, cuts across the

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**Table 1. Detailed stratigraphy of Unstable Shelf.**

<table>
<thead>
<tr>
<th>AGE</th>
<th>NORTH OF LAKEKAMU EMBAYMENT</th>
<th>SOUTH OF LAKEKAMU EMBAYMENT</th>
<th>VOLCANIC PLATEAU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pliocene to Holocene</td>
<td>Alluvium and littoral deposits</td>
<td>Gravel, sand, silt, mud, carbonaceous mud, clay, peat. Deposited over fluvial plains and associated swamps and in beach-barrier estuarine and shifting dunal environments.</td>
<td>Colluvium</td>
</tr>
<tr>
<td>Pliocene (post Tg)</td>
<td>Aplini formation (650-2000 m)</td>
<td>Immature calcareous and non-calcareous tuffaceous sandstone, pebbles and cobble conglomerate, silstone, mudstone, minor reeal limestones. Volcanic agglomerate, and breccia. Minor tuff. Tuff and breccia from lava. Minor transgressive-regressive fluctuations in relative sea level resulted in rapid facies variations from fluviolitic to deltaic to littoral to shelf environments.</td>
<td>Mount Davidson Volcanic (Pv) (650 m)</td>
</tr>
<tr>
<td>Upper Miocene lower Pliocene (Tg)</td>
<td>Baham - Conglomerate (700 m +)</td>
<td>Polymictic conglomerate, sandstone, mudstone and coralline limestone.</td>
<td>Wedge Hill (Iw) (350 m)</td>
</tr>
<tr>
<td>Upper Miocene (upper Tg)</td>
<td>Lower Miocene (Tc) (2000-4000 m)</td>
<td>Monotonous sequence of soft grey-green and grey-blue thinly bedded mudstone, shale and minor thin interbeds of silstone, mudstone, limestone and conglomerate. Contains abundant Tg Globotheca pelagica Foraminifera. A characteristic of the mudstone is presence of many surface gas seeps.</td>
<td>Yalla Formation (here included in Mv) (300 m)</td>
</tr>
<tr>
<td>Upper Miocene (upper Tg)</td>
<td>Muri Mudstone (Tb) (2000-4000 m)</td>
<td>Calcareous tuffaceous sandstone, conglomerate, lenses of bioclastic limestone with reef debris. Limestone lenses consist of coral reef with coralline sandstone, breccia, silstone and mudstone. Original reef fabric corals rarely preserved in situ; most beds consist of chaotic reef-flank sediments which grade into calcareous tuffaceous sediments typical of Tb. Deposited in shallow-water marine, limestone and reef platforms in which bioclastic reefs were flanked, and periodically engulphed, by reef talus and coarse-grained tuffaceous sediments.</td>
<td>Talama Volcanic (Mv) (1500 m)</td>
</tr>
<tr>
<td>Middle Miocene (lower Tg)</td>
<td>Langim Mudstone (Ta) (500-4000 m)</td>
<td>In the north: conglomerate and sandstone, interbedded calcareous mudstone and calcareous sandstone with basaltic and andesitic lava and pyroclastics towards base. In the south, thin silty mudstone and silstone with sandstone and conglomerate; bioclastic limestone.</td>
<td>Chilia Formation (Ta) (1700 m +)</td>
</tr>
<tr>
<td>Upper Oligocene to lower Miocene (largely Upper Tc)</td>
<td>Omsaura Greywacke (Tm)</td>
<td>Shale, volcanically-derived greywacke, and silstones; some conglomerate, reef limestone and basic volcanics.</td>
<td>Omsaura Greywacke (100 m)</td>
</tr>
</tbody>
</table>

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central part of the eastern shelf and appears to have been initiated in upper Miocene time. The vast area of alluvium and swamp sediments indicates that subsidence continues to the present day. In the southeast of the map area the south-westernerly-dipping sheets of volcanics and intercalated derived sediments responded to Pliocene deformation by broad upwarping and fracturing. The resultant near-vertical tension fractures control present-day erosional and drainage patterns. Predominant orientation of fracture planes is to the northeast and northwest. Northerly-trending sinuous faults may reflect reactivation of Mesozoic faults propagated through competent volcanic cover.

Major periods of uplift appear to have occurred in the lower Miocene, early upper Miocene and late Pliocene.

**Aure Trough:** The Aure Trough is an asymmetric downwarp with more rapid sedimentation towards the steeper eastern flank (Fig. 6, Section AB). Eastward, the trough sediments grade abruptly into shelf facies, whereas to the west they are gradually transitional into mudstone of the broad western slope.

Sediments of the Aure Trough are predominantly turbiditic and consist of immature, poorly sorted lithic greywacke with increasing mudstone and minor micritic argillaceous limestone towards the west. The sediment is largely volcanically-derived with variable amounts of metamorphic and sedimentary clasts from the Owen Stanley Orogen. Onshore, folded turbiditic sediments are upper Oligocene to early upper Miocene and form a monotonous 10 000 m thick sequence. Beds are laterally extensive and range in thickness from a few centimetres to over a metre. Graded bedding, load casts, slumping, convolute laminations and small scale cross-bedding have been observed. Good planktonic foraminiferal assemblages are restricted to the uppermost Miocene calcareous limestone of the graded beds and rare larger foraminifera are found in some bands of coarse calcareous grit.

Although no regional unconformity has been mapped within the turbiditic sequence, it is thought that early upper Miocene deposits are probably absent over much of the Trough area to the northeast: where present to the south and west, they include calcareous sediments. The onshore turbiditic Trough sediments are disconformably overlain to the south and west by a thick sequence of late upper Miocene to lower Pliocene open marine mudstones (Te) similar to those which occur over the unstable eastern shelf. The pattern of mudstone deposition appears to have been controlled by uplift and folding of Trough sediments in the late Miocene which resulted in shallow seas in the northwest, and in a depression along the axis of deposition. The mudstones are in turn conformably overlain by Pliocene to Recent shallow-water marine, deltaic and fluviatile sediments, again similar to those deposited on the eastern shelf. Offshore, accumulation of turbiditic Auro Trough sediments probably continues today.

Onshore, to the east and north, competent Miocene Trough sediments are folded to form northerly-trending narrow anticlines, up to 80 km long, separated by broad synclines. The axial planes dip steeply to east or west and thrust-faulting from the east is associated with some of the more asymmetric folds. Farther west, the Miocene greywacke turbidites are less competent, due to increasing mudstone content, and in places are overlain by a thick sequence of incompetent late upper Miocene to lower Pliocene mudstone (TC). Here, north-northwest trending, discontinuous, symmetrical anticlines and synclines are of much the same width. Thrust-faulting from the east, though present, is not obviously associated with anticlinal axes, possibly because the faults were not propagated through the incompetent mudstone. In the extreme western part of the onshore Aure Trough, the north-northwest trending folds give way to a complicated system of cross-folds formed as a result of interference with east-west-trending overthrust folds related to the uplift of the Kabor Range to the north (Findlay, 1974). Offshore, Trough sediments are folded to form a series of seismically-defined northerly trending, linear anticlines separated by broad synclines. Anticlines are disrupted by high-angle axial-plane faults overthrust from the east or by diapiric intrusion of incompetent mudstone into anticlinal cores (or by both thrusting and diapirism).

The fold style and associated thrusting suggests that detachment planes may have developed at several stratigraphic levels within the greywacke/mudstone sequence and that the uplifted Aure Trough sediments may have "glided" to the west and southwest in response to gravity. Fold structures mapped at the surface may be relatively shallow features and are possibly underlain by further thrust planes at depth.

**Stable Slope:** The stable slope is a transitional zone between deep water eugeosynclinal sediments of the Aure Trough and miogeosynclinal sediments of the stable shelf. Offshore, near the trough, the sediments are relatively undeformed, gently folded, locally faulted and have an easterly depositional dip. They are thought to consist of alternating mudstone and greywacke which, farther west, become increasingly fine-grained and thinner (Fig. 6, cross section AB). Finer-grained slope sediments were deposited over the stable shelf area in an embayment between the Pasca and Uramu areas (Fig. 2). Onshore, the slope zone is apparently narrow and slope sediments are probably concealed beneath Aure Beds overthrust from the east. Offshore and onshore exploratory wells penetrated a thick sequence of upper Miocene to lower Pliocene open marine mudstone, conformably overlain by Pliocene shallow water marine and deltaic clastic sediments. Lower Miocene to early Miocene rocks are not exposed onshore and were not penetrated in exploration wells but are thought to consist of mudstone with intermittent greywacks.

Hohoro No. 1 well (Australasian Petroleum Co., 1961) penetrated 630 m of Pliocene shallow water marine and deltaic sediments and 2600 m of upper Miocene to lower Pliocene blue-grey mudstone. Offshore, Orokolo No. 1 well (Phillips Australian Oil Co., 1968d) was still in lower Pliocene mudstone at total depth of 3650 m (Fig. 7).

**Stable Shelf:** The stable shelf is a miogeosynclinal deep-water Miocene carbonate zone developed around the margins of the Southwest Papuan Platform. Several exploration wells were drilled in the area, both onshore and offshore (Fig. 7). The shelf is overlain by relatively undeformed sediments which thicken eastward and have a depositional dip to the east. During the lower and middle Miocene reeval limestone accumulated over "basement highs" in the Pasca and Uramu areas (Phillips Australian Oil Co., 1968b, 1969; Australasian Petroleum Co., 1969d). The Miocene reefs probably served to protect the shelf and platform from further subaerial exposure and the development of clastic sediments of the Aure Trough and western slope; at this time most terrigenous sediment was derived from the east and north.

Lower Miocene deepwater argillaceous micritic limestone extends over much of the stable shelf and is bordered to the east by the shallow water reeval limestone and calcarenite developed over the Pasca and Uramu highs. Middle Miocene limestone is similar to the lower Miocene with the exception that northwest of Kikori the argillaceous limestone grades into coarse bioclastic calcarenite developed around irregular patches of reef limestone. Part of the Pasca area may have been emergent during the middle Miocene. Early upper Miocene sediments are conformable over the middle Miocene except over the Pasca and Uramu areas where they appear to be absent. In the Kikori area they consist of shallow-water argillaceous limestone and elsewhere of calcareous mudstone. The average thickness of Miocene limestone over the stable shelf is less than 1000 m, but it is considerably thicker in the Omari area where some 3300 m of limestone was penetrated (Australasian Petroleum Co., 1961). Late upper Miocene to lower Pliocene mudstones, up to 2000 m, extend over the eastern half of the stable shelf area and grades westwards into

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calcareous mudstone, less than 500 m thick, over the western half. Part of the Pásca area and an area northwest of Kikori appear to have been emergent at this time. A minor build-up of reefal limestone was encountered in the Mira well (Phillips Australian Oil Co., 1972). The lower Pliocene mudstone is conformably overlain by Pliocene fluvialite, deltaic and shallow marine, coarse clastic sediment in the northern part of the area and probably by mudstone to the south. The younger Pliocene sediments are up to 2000 m thick in the east and thin to less than 500 m to the west.

Platform: The platform is a broad stable penetralialed Mesozoic shelf blanketed by a thin sequence of Miocene to Holocene deltaic to shallow water marine sediments which dip gently to the west. Several boreholes drilled into the South-west Papuan Platform have been described by the Australasian Petroleum Co. (1961). These indicate that Miocene sediments consist of calcareous reef detritus and irregular patches of reef limestone which developed in shallow water marine conditions. Pliocene sediments consist of deltaic to shallow water marine clastic sediments with minor argillaceous limestone towards the base. Several seismically defined Miocene reef structures occur along the eastern margin of the Platform. Borabi No. 1 (Phillips Australian Oil Co., 1968a) was drilled to test one of these reefs and encountered 440 m of Quater-

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**Fig. 9.** Geological history: Upper Oligocene — Lower Miocene: 1. Emergence of Owen Stanley Range. 2. Unstable shelf: uplift and erosion of coarse clastics; minor volcanism. 3. Aure Trough: turbidite sedimentation. 4. Stable shelf/platform carbonate sedimentation. 5. Folding of Aure Trough and unstable shelf sediments.


Early Upper Miocene: 1. Continuing emergence of Owen Stanley Range. 2. Unstable shelf: emergence of northern sector; marine regression, limestone deposition, uplift, erosion; volcanism. 3. Aure Trough: emergence of northeast sector; turbidite sedimentation to South. 4. Stable shelf: emergence of reefal “heights”, introduction of fine terrigenous clastics from mountain ranges to North and East. 5. Folding, westerly thrusting of Aure Trough and unstable shelf sediments.

Late Upper Miocene — Lower Pliocene: 1. Landmass stable. 2. Unstable shelf: subsidence, marine transgression, mudstone deposition; volcanism quiescent. 3. Aure Trough: mudstone deposition to North; turbidite sedimentation to South. 4. Stable shelf: reefal limestones swamped by mudstone from North and East.

Pliocene: 1. Renewed emergence of landmasses to East and North. 2. Unstable shelf: marine regression, coarse clastic sedimentation; volcanism. 3. Aure Trough: coarse clastic deposition to North, turbidite sedimentation to South. 4. Stable shelf/platform: coarse to fine clastics from emergent ranges to North and East. 5. Folding and thrusting of Aure Trough, unstable shelf and northern sector of stable shelf zones.
nary mudstone, siltstone and sandstone overlying 750 m of Pliocene micaceous and carbonaceous mudstone, sandstone, minor lignite and limestone, unconformable over 825 m of middle Miocene calcareous reef-derived sediment and 485 m of lower Miocene bioclastic reefal limestone. The upper Miocene to lower Pliocene mudstone is apparently absent over the Borabai area.

**GEological HISTORY**

By the late Oligocene the tectonic framework of sedimentation, controlling development of the Cainozoic Papuan Geosyncline, was established and eugeosynclinal turbidite sedimentation commenced in the Auro Trough. Sedimentation was derived from the emerging ranges of central and south-east Papua New Guinea. The geological history of the area is summarised in a series of illustrations depicting palaeogeography and sedimentation at various times (Fig. 9).

In the upper Oligocene to lower Miocene, uplift and emergence of the Owen Stanley Orogen and adjacent unstable shelf were accompanied by volcanism (early lower Miocene). Coarse clastic sediments poured into the Auro Trough while fine clastics were carried across the trough to be deposited over the stable slope. To the west, shallow lagoons and basins developed over the margins of the platform and deeper water argillaceous micritic limestone accumulated over the stable shelf. Reefal limestone, which developed over “basement highs” in the Pasca and Uranum areas, shielded the stable shelf from inundation by fine clastics from the northeast. Sediments of the Auro Trough and unstable shelf were folded in the early Miocene.

In the middle Miocene there was a marine transgression over the unstable shelf and minor shallowing over parts of the stable shelf. During the early upper Miocene, folding and partial emergence of Auro Trough and unstable shelf sediments was accompanied by marine regression throughout the Cainozoic Papuan Geosyncline. Over part of the stable shelf, the introduction of terrigenous clastics derived from mountain ranges to the north and east resulted in the deposition of calcareous mudstone in place of the argillitic micritic limestone. Turbidite sedimentation continued in the southern part of the Auro Trough; farther north the axis of sedimentation shifted westward as Trough sediments were elevated and became emergent in the northeast. The Lakekamu Embayment probably developed along the southern margin of the emergent unstable shelf and Auro Trough sediments at this time.

The late upper Miocene to lower Pliocene was a period of subsidence and marine transgression accompanied by deposition of a thick sequence of open marine mudstone. To the west the Miocene reefs of the stable shelf were swamped by mudstone and to the east mudstone filled the Lakekamu Embayment. There was no volcanic activity and older sub-aerial volcanics were re-worked to form pockets of fluviatile and lacustrine sediments.

In the Pliocene, renewed emergence of the landmasses to the north and east was accompanied by further folding and volcanism. On the margin of the emerging Auro Trough, and over the unstable shelf, Pliocene coarse to fine clastic sediments were draped around rising antilines and formed thick accumulations in synclinal cores. Offshore, in the Auro Trough, anticlinal structures were disrupted by diapiric intrusion of underlying, late Miocene to early Pliocene, incompetent mudstone into anticlinal cores. In the late Pliocene, following uplift of the Kuber “basement high” (Fig. 3), the uplifted northern sector of the stable shelf was subjected to south-westerly sliding, overthrusting and folding. The southern sector of the stable shelf and the platform remained tectonically stable. In the Quaternary, continued uplift of the northern part of the unstable shelf was accompanied by sub-aerial volcanism in places.

**PETROLEUM EXPLORATION**

Since the first discovery of seepages near Uapoia in 1911, many surface indications of gas and oil have encouraged a continuing programme of exploration. Gas has been discovered in four onshore and two offshore wells (Iehi*, Barikewa, Kuru, Bwata; Pasca, Uramu) and gas with some oil in one onshore well (Puril). Largest known reserves are in the Pasca field where reserves of around 30 billion m³ (about one trillion cubic feet) of gas have been unofficially estimated. All of the discoveries are on the western stable shelf. Wells in the eastern unstable shelf and in the Auro Trough have been unsuccessful. Almost all of the onshore wells, both successful and unsuccessful, have been located on surface anticlines and almost all have encountered structural complication at depth. In most cases the structural complication is a thrust or steep reverse fault, and in some cases the fault is clearly related to gravity tectonics.

The western shelf continues to be the area of most interest, and Mesozoic sands and Miocene reefs the favoured targets. There is much less exploration activity in the Auro Trough and eastern shelf where all previous wells have been unsuccessful, structure is complex, and reservoir rocks are scarce. Upper Miocene-lower Pliocene mudstone is a known source of gas in some of the eastern seepages and is a possible target for further drilling if potential reservoirs can be located.

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* About 20 km NW of Barikewa No. 1; not shown on Figs. 2 and 4.


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