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GEOLOGICAL RECONNAISSANCE IN IRIAN JAYA, 1976 AND 1977

by

P.E. Pieters, R.J. Ryburn, & D.S. Trail

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ABSTRACT

Geologists from the Geological Survey of Indonesia and the Bureau of Mineral Resources made reconnaissance observations in Kepala Burung in 1976 and in the Schouten Islands and the Cycloops Mountains in 1977.

In the Mar 1:250 000 Sheet area, an acid to intermediate batholith, possibly of Permo-Triassic age, intrudes low to high-grade metamorphics. Late Oligocene to Pliocene andesitic volcanics crop out along the north coast; and upper Cretaceous to Miocene limestone crops out on the coast, and in the Kebar valley where it is overlain by clastic sediment. Basalt, andesite, dacite, limestone, Pliocene sandstone, young conglomerate, and, near Sorong, fault breccia crop out on the coast west of the Mar Sheet area. In the Arfak Mountains, the north-trending Ransiki Fault separates Permo-Triassic granite intruding low to medium-grade metamorphic rocks to the west from Tertiary basaltic and andesitic volcanics, volcanogenic sediments, and limestone. In the Bomberai Peninsula, coastal exposures of early to late Miocene karstic limestone on the flanks of large gentle anticlines are overlain by Pliocene marine sandstone and siltstone. A suite of metamorphic rocks, probably metamorphosed in the Tertiary, occupies the Wandamen Peninsula in the north and southwest; in the southeast, a possible north-trending fault appears to have juxtaposed unmetamorphosed ?Mesozoic sandstone and overlying Late Tertiary sediments to the east against Eocene limestone interfolded with low-grade metamorphics.

The Schouten Islands are formed by late Oligocene to Pleistocene marl and limestone draped over a basement ridge made up of metamorphic, basic, and ultramafic rocks. Gag Island is composed of massive serpentinised harzburgite (on which a lateritic nickel deposit is being developed for mining) faulted against a sheeted dyke complex of dolerite with some plagiogranite. These rocks represent oceanic upper mantle and crust, possibly of Late Jurassic age. The Cycloops Mountains comprise a core of schist and gneiss bounded by serpentinite with some gabbro, dolerite and basalt, overlain in places by Miocene or younger limestone.

Observations having possible economic implications include pebbles of perhydrous, sub-bituminous coal with high ash and sulphur near Kebar; a quartz band with 0.87% copper in metamorphics on Supiori Island; and a site with potential for hydroelectric power 10 km from Jayapura, the provincial capital. The petroleum potential of the calcareous sequence in the Schouten Islands is poor, but a gas province may exist 100 km east of Biak on the continental shelf and in the Mamberamo delta.

INTRODUCTION

Geological and geochemical investigations in 1976 and 1977 were carried out by the Bureau of Mineral Resources (BMR), Australia and the Geological Survey of Indonesia (GSI) in Kepala Burung peninsula, Schouten Islands, Batanta Island, Salawati Island, and Gag Island, at the northwestern end of the Indonesian province of Irian Jaya (Figs. 1 and 2); scattered observations were also made in the Cycloops Mountains west of Jayapura (Fig. 1). The purpose of these investigations was to familiarise the geologists with the logistic and operational problems of working in Irian Jaya, and, in 1976, to observe the geology of Kepala Burung before preparing a detailed submission for the Australian Development Assistance Bureau (ADAB) outlining the budgetary, equipment, and manpower requirements for a 10-12 year Australian aid project of regional mapping and mineral exploration in Irian Jaya.

The 1976 BMR field party in Irian Jaya consisted of D.S. Trail (party leader), D.S. Hutchison, P.E. Pieters, G.P. Robinson, and R.J. Ryburn; the counterparts from the Geological Survey of Indonesia (GSI) were Harli Sumadirdja (Indonesian party leader), Kastowo, Memed Masria, and Nana Ratman. In 1977 the only Australian representatives in the field were Trail and Pieters, and GSI was represented by the same team as in 1976, together with three assistant geologists.

In 1976 logistic support for the geological investigations was provided by units of the Australian Army and the Royal Australian Air Force under the command of Major D. Swiney at Biak. Further assistance was provided by these units in 1977 with transportation and storage of field equipment.

This report is a compilation of reconnaissance geological investigations carried out in Irian Jaya in 1976 and 1977 by BMR geologists, and of the results of subsequent laboratory work. The geology of the Manokwari 1:250 000 Sheet area, which was mapped systematically in 1976, is described separately by Robinson & Ratman (1977, 1978), and the results of an orientation geochemical survey undertaken in 1976 have also been presented separately by Hutchison (1977). Compilation of a special 1:250 000 geological sheet of the Schouten Islands, mapped by GSI in 1977, is currently being undertaken in Indonesia by Memed Masria.

ACCESS

Kepala Burung and Batanta, Salawati, and Gag Islands comprise three administrative districts (Kabupaten), each under the direction of a Bupati, with headquarters at Sorong, Manokwari, and Fakfak, the three largest

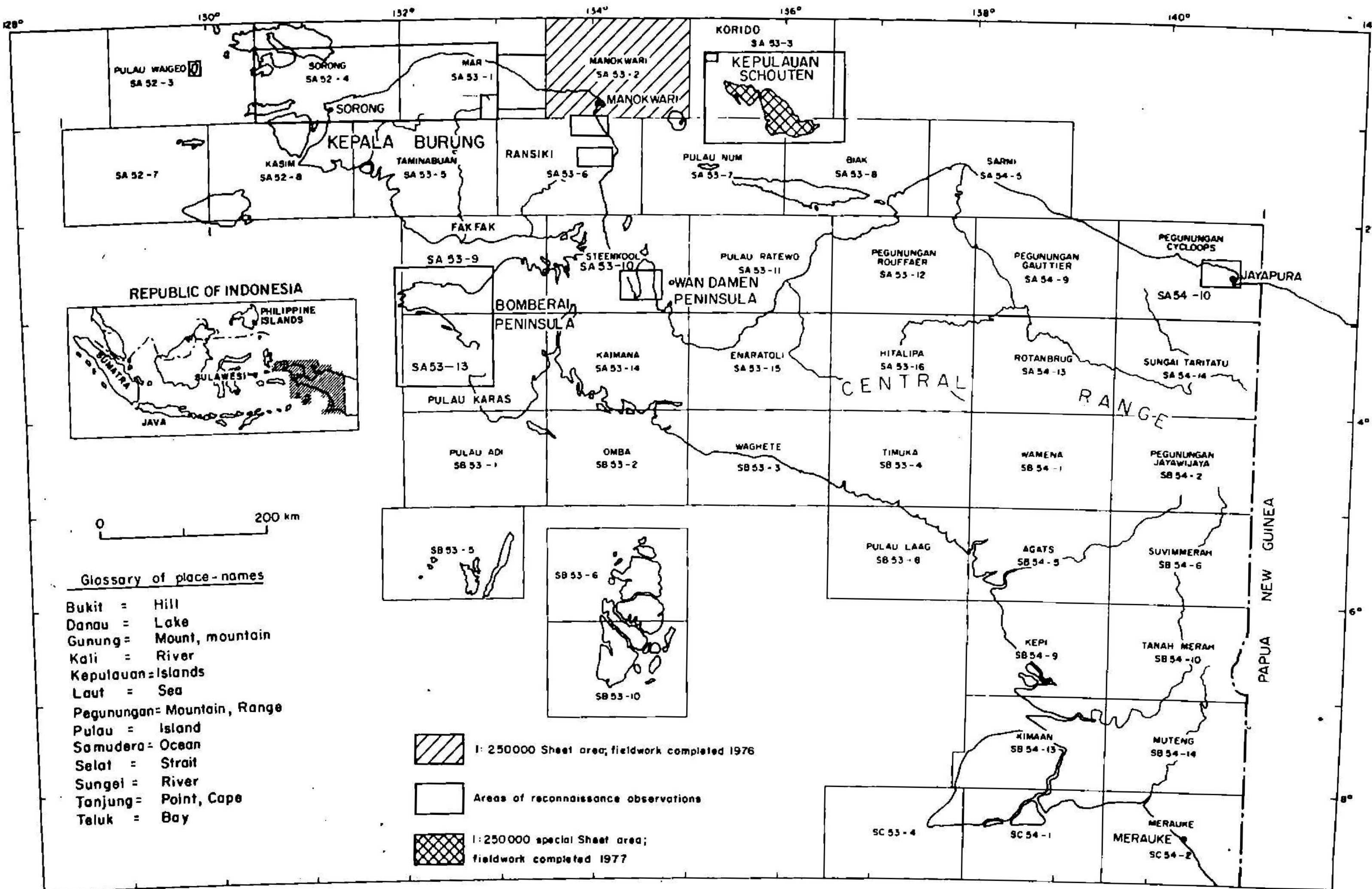

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Figure 1. 1:250 000 scale geological mapping and reconnaissance observations in 1976 and 1977

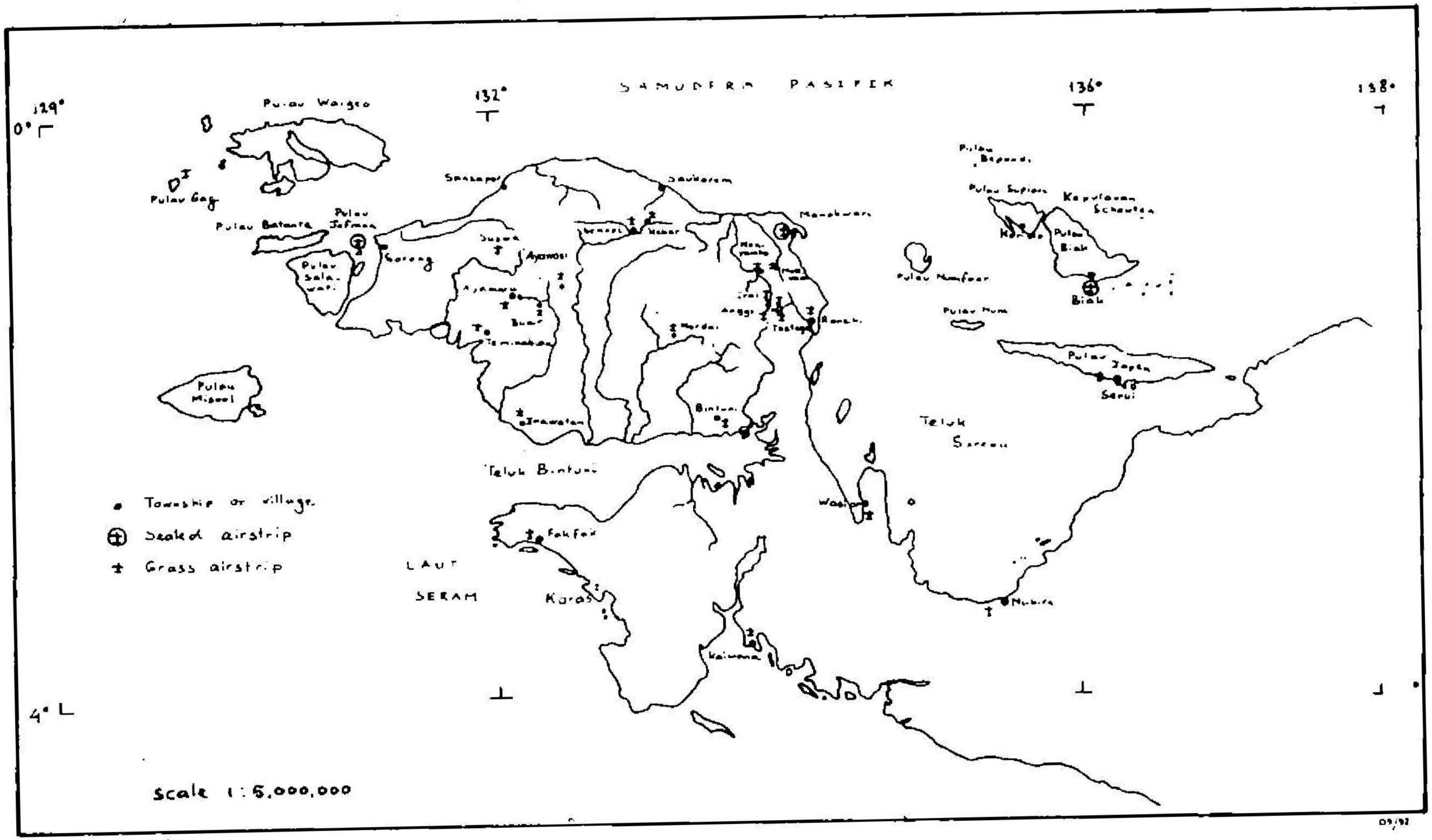

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Fig. 2 **KEPALA BURUNG and ENVIRONS**

towns in the region. The Schouten Islands and the area of the Cycloops Mountains are governed from respectively Biak and Jayapura. The Kabupaten form part of the province of Irian Jaya administered by a Governor from the provincial capital of Jayapura.

Garuda Indonesian Airways and Merpati Nusantara Airways both have frequent regular flights from Jakarta to the large sealed airstrips at Sorong, Biak, and Jayapura. Merpati operates within Irian Jaya, mainly using Twin Otter aircraft, connecting Biak and Sorong with the small sealed airstrip at Manokwari and with grass airstrips at Ransiki, Kebar, Fakfak, Bintuni, and Kaimana, in Kepala Burung. Small grass airstrips of various standards and lengths, mostly operated by missions, are located at several places in Kepala Burung, including Ayawasi, Buair, Ayamaru, Taminabuan, Suswa, Menyambo, Anggi, Irai, Testega, Mokuam, Senopi, and Merdai (Fig. 2). These are served irregularly by light aircraft operated by American Protestant (MAF) or Dutch Catholic (AMA) mission organisations.

Good port facilities are located at Manokwari, and at Sorong, which is being upgraded to take major shipping. Fakfak has a harbour and wharf capable of handling small ships. Roads and four-wheel-drive tracks are restricted locally to the main population centres. Away from these centres overland travel is possible only on foot along the numerous tracks which criss-cross the region.

The north and east coasts of Kepala Burung may be traversed by small boat or canoe, but few of the rivers debouching on these coasts are navigable for any appreciable distance. Natural helicopter landing sites in the form of gravel banks, beaches, grassy areas, man-made clearings, and landslips are numerous throughout the region.

POPULATION

Apart from the main population centres of Sorong, Manokwari, Fakfak, Bintuni, and Ransiki, Kepala Burung is sparsely inhabited by a scattered population concentrated along the coast, in the Kebar valley, and in the Anggi-Menyambo region of the Arfak Mountains. Inland, the indigenous population is mainly semi-nomadic, living in small villages. Their diet is based on subsistence agriculture, supplemented by occasional hunting and fishing. The coastal people also live mainly by subsistence agriculture supplemented by fishing in some larger centres only. Some cash crops includ-ing peanuts, copra, and rice are grown in places. Additional income is derived from casual employment in the larger towns. Several thousand Javanese people have been resettled in the region under a government transmigration scheme.

CLIMATE AND VEGETATION

The region has a wet tropical climate and is subject to the seasonal influence of the northwest monsoon from November to March, and the southeast trade winds from June to September. Limited meteorological observations (d'Audretsch, Kluiving, & Oudemans, 1966; Brookfield & Hart, 1966) indicate that the southeast is the wetter of the two seasons, and that mean annual rainfall ranges from less than 1500 mm per year at Ransiki in the east to more than 3500 mm per year in the central and western parts of Kepala Burung. There is usually a short, dry season in August, September, or October in northern and northeastern Kepala Burung.

Temperatures are uniformly high in the lowlands, where they range from about 23°C to 30°C, decreasing with elevation to a mean daily temperature of about 16°C at 2000 m. Relative humidity is also uniformly high, ranging from 80 to 100 percent in the northeast of Kepala Burung. Morning cloud and/or ground fog may hamper aircraft and helicopter operations in inland lowland areas (e.g., Ayawasi, Kebar) during the dry season. During the northwest monsoon season, strong winds (the 'mataan') cause a high dangerous surf along the exposed north coast of Kepala Burung.

Most of the region is covered by dense primary tropical rainforest of various types. Narrow belts of natural grassland occur along the braided lower reaches of some major rivers and large areas of man-induced grassland and secondary forest occur in the Kebar plain, around Ransiki, as scattered patches south of Kebar, in the Anggi Lakes area, and near the main population centres. Extensive areas of swamp vegetation occur in the flat, low-lying area to the south. Small areas of alpine-type grassland occur locally on peaks and ridge crests above 1800 m. Man-made clearings for gardens and village sites are scattered throughout the region.

GEOLOGY

PREVIOUS INVESTIGATIONS

By far the most comprehensive account of the geology of Kepala Burung and of the whole of Irian Jaya is given by Visser & Hermes (1962) in their compilation of the geological results of oil exploration carried out between 1935 and 1960 by the Nederlandsche Nieuw Guinea Petroleum Maatschappij (NNGPM).

Early geological reconnaissance in Kepala Burung was described between 1908 and 1917 by Verbeek (1908), Hirschi (1908), Wichman (1917), and Brouwer (1919). Loth (1925) produced a geological map of the area based on data collected by officers of the Netherlands Indies Mines Department including H.H. Horneman and E. Hartman. Zwierzycki (1932) used further information from the Mines Department, military expeditions, and local administration to compile a 1:1 000 000 geological map.

Van Bemmelen (1949) summarised information on stratigraphy gathered before 1942, and distinguished four geotectonic and physiographic units in Kepala Burung.

Expeditions of the Delft Technological University (Bemelmans, 1955, 1956, 1957a,b; Botman, 1953; Druif, 1954; Reynst, 1953), the Mines Department (Molengraaff, 1957a, b, 1958; Schippers & de Valk, 1954; Schippers, 1957), and the Foundation Geological Investigation Netherlands New Guinea (d'Audretsch & others, 1966) carried out investigations for metalliferous deposits until transfer of sovereignty from The Netherlands to Indonesia in 1962.

Subsequently several oil companies (including Pertamina) resumed onshore and offshore oil exploration in the southern and western parts of Kepala Burung, and the technical staff of Trend Exploration (Vincelette & Trend Exploration staff, 1973; Vincelette & Soeparjadi, 1976) have described a successful search for Tertiary pinnacle reefs. Rahardjo (1975) has reported on a large part of southeast Kepala Burung for Pertamina.

Reynolds, Havryluk, Bastaman, & Atmowidjojo (1973) reported the results of exploration for nickel laterite deposits on islands around the western tip of Kepala Burung, between 1969 and 1971.

In summary, the previous workers have recognised that the geology of the area north of the Sorong Fault and the area east of the Ransiki Fault differs considerably from the major part of Kepala Burung. Andesitic and basaltic volcanics appear to be present only in these two smaller areas, and

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though slate, phyllite and quartzite occur both north and south of the Sorong Fault, the metamorphics north of the fault were thought to be Mesozoic rocks, and those south of the fault at least partly Palaeozoic. Intrusive rocks in the centre of Kepala Burung were generally ascribed to the Devonian or Carboniferous periods, and other intrusives associated with the Sorong or Ransiki Faults were recognised at Tertiary.

The following summary of the stratigraphy of Kepala Burung is mostly compiled from Visser & Hermes (1962). The slate, phyllite and quartzite of the Kemum Formation, forming the basement over much of Kepala Burung, were dated as Silurian (from graptolites) in the west near Ayawasi and as Devonian (from ostracods) in the east near Muturi (Rahardjo, 1975), and were interpreted as geosynclinal deposits. The granitic rocks intruding the Kemum Formation were believed to be Devonian and the regional metamorphism of the Kemum Formation was thought to antedate their emplacement.

Marine and paralic clastic sediment of the Aifam Formation overlies at least one eroded granite body and was regarded as Permo-Carboniferous. This formation in turn is overlain by marine and terrestrial sediments of the Triassic Tipoema Formation in a well drilled in the southern part of Kepala Burung.

The succeeding Kembelangan Formation ranges in age from mid-Jurassic to Paleocene; it is 1000 m thick in the southeast part of Kepala Burung, but thins westwards to cut out in the centre of the area and reappear in the west. The formation comprises a basal limestone and shale, overlain by sandstone, again overlain by shale, thin sandstone, and limestone, and capped by a considerable thickness of sandstone. The progressive disappearance of the older parts of the formation westwards across Kepala Burung suggests a transgression. At least some of the slates north of the Sorong Fault are metamorphosed Kembelangan Formation, with Upper Jurassic fossils.

Except for the andesitic and basaltic volcanics of the Auwewa Formation north and east of the Sorong and Ransiki Faults, the Tertiary rocks of Kepala Burung are mainly shallow-water limestones, included in the broad New Guinea Limestone Group. The clastic sediments of the Sirga Formation, intercalated between limestone of the Faumai Formation and the Kais Formation across Kepala Burung, are considered to mark a regressive phase in Oligocene-Miocene times. The extensive deposition of fine-grained clastic sediments in Plio-Pleistocene times overlying the limestone in the Salawati and Bintuni Basins (Klasaman and Steenkool Formations) and in the Manokwari area (Befoor Formation) indicates strong subsidence.

Economic investigations in Kepala Burung since 1962 have located several large oil reservoirs in Tertiary pinnacle reefs 50 km south of Sorong (Vincelette & Trend Exploration staff, 1973; Vincelette & Soeparjadi, 1976), and a promising deposit of nickeliferous laterite overlying ultrabasics on Gag Island 150 km west of Sorong (Reynolds & others, 1973).

Earlier investigations by the Department of Mines (e.g., Molengraaf 1957 a, b) found lead (1.33-3.9%), zinc (3.7-7.6%) and copper (0.35-2.9%) in stream boulders between 20 and 30 km west of Saukorem, as well as about 10 km^2 of nickel-cobalt-bearing laterite on a serpentine body 30 km east of Kebar.

Valk (1962) stated that during follow-up investigations on the base-metal sulphides 'numerous soil samples ....failed to indicate even a single concentration of lead, zinc or copper'. He recorded pebbles with grades of 0.4 g/tonne of gold and between 0.8 and 39.2 g/tonne of silver from the same area.

Supported by helicopters based on Manokwari, D'Audretsch & others (1966) carried out a search for metalliferous deposits in the northeast corner of Kepala Burung between 1959 and 1962, using geochemical and radiometric methods in addition to photo-interpretation and systematic field examination. Their most important discoveries were:

- a primary uranium occurrence in the Anggi granite (in the upper Sivhoe River),
- a small epithermal antimony sulphide deposit in a fault in the Kemum Formation (in the upper Derah River), and
- an epithermal to mesothermal copper-lead-zinc sulphide deposit in the drainage area of the Wasirami River.

BMR/GSI INVESTIGATIONS

The results of the reconnaissance investigations carried out by BMR/GSI parties in 1976 and 1977 are described in the following pages under nine headings covering the areas in which the investigations were carried out. With the exception of the Cycloops Mountains, in the northeastern corner of Irian Jaya, all these areas are located west of longitude 136°30'E, on or near the Kepala Burung peninsula (Fig. 1).

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EASTERN PART OF THE MAR SHEET AREA

In 1976, in the eastern part of the Mar 1:250 000 Sheet area, Hutchison, Pieters, & Ryburn undertook a traverse from Saukorem on the coast to Kebar via Mount Netotti and back to the coast at Mubrani (Pl. 1). They also traversed the coast between Mubrani and Saukris (Pl. 2) by boat, making several landings. Kastowo and Pieters later flew to Kebar from Manokwari and carried out several short traverses around Kebar and Senopi (Pl. 1; Fig. 3).

Geomorphology

The Tamrau Mountains constitute the dominant topographic feature in the area covered by Plate 1. The northern foothills of this mountain range rise steeply from the coast or from narrow coastal plains. In the south the mountains rise abruptly from the Kebar valley floor (600 m above sea level) to a height of 2000 m over a distance of 6 or 7 km (Fig. 4.).

The mountains are deeply incised and relief is extreme (greater than 300 m). Mount Netotti rises to about 2000 m above m.s.l. but at least two nearby peaks are slightly higher. The dendritic drainage is coarse to medium-dense; the ridges have steep slopes and sharp crests, and are separated by V-shaped valleys with steep gradients. Most larger streams are ungraded and in many places sections of their courses are controlled or displaced by fractures or joints. Numerous waterfalls and cataracts occur in the upper reaches of the streams.

Relict altiplanation surfaces on the main east-trending watershed contrast with the strongly dissected topography lower down; one large surface occurs immediately east of Mount Netotti at an average height of about 1800 m above m.s.l. The surfaces have a finely dissected, hummocky relief with strongly meandering, low-gradient rivers. The edges of the surfaces are marked by sharp changes of river gradient, and in places form waterfalls.

Karst landforms are developed on a limestone plateau which bounds the Kebar valley to the south near Senopi (Fig. 3). The plateau is studded with sinkholes separated by pyramidal hills. In the Kebar valley, in the hilly and low mountainous country east of the Kebar valley, and from Bariambekiri on the coast to the middle reaches of the Wekareng River, the limestone outcrops have smooth massive landforms, or smooth hilly landforms with widely scattered small sinkholes.

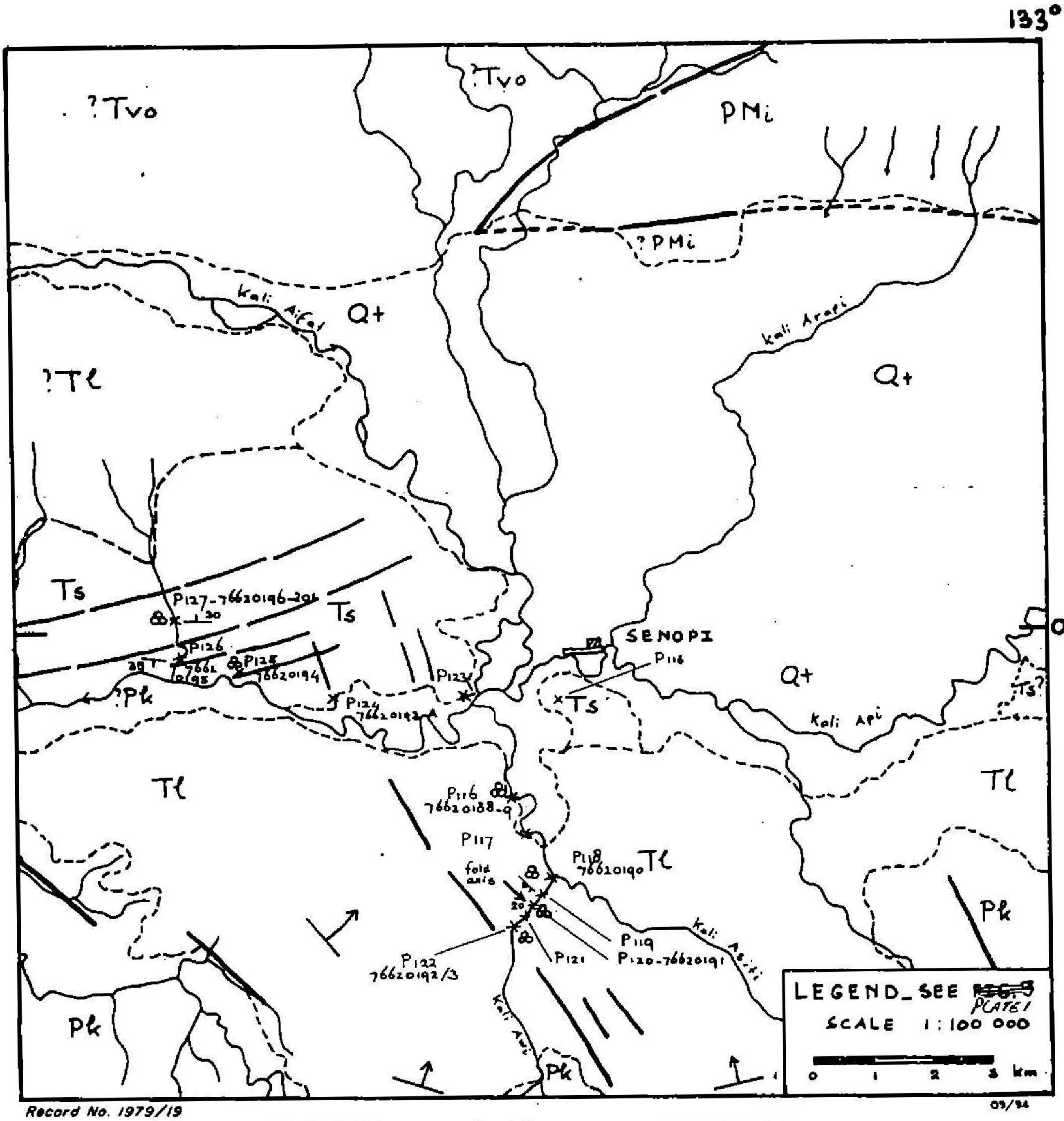

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Fig. 3 GEOLOGY around SENOPI, KEBAR VALLEY

(adjoins Plate 1)

The Kebar valley is a linear fault-controlled depression 37 km long and up to 4 km wide (Fig. 4). To the west as well as the east the flat valley floor gradually passes into hilly country. Long fault-bounded ridges ~~developed on Miocene sediments occupying the valley (Fig. 5). Swamps are~~ developed on Miocene sediments occupy the valley (Fig. 5). Swamps are common on the valley floor, and as a result tracks between the villages follow the sides of the valley. Terraces up to 30 m high are common at the eastern end of the valley but are absent elsewhere. The valley floor slopes about 2^{o} to the south around and west of Kebar; east of Inam (Pl. 1) the slope is to the north.

The lower reaches of the north-flowing rivers of the Tamrau Mountains are bounded by alluvial flats which commonly pass into narrow coastal plains. Fluvial terraces are rare, and restricted to areas where rivers debouch from the mountains. Low marine terraces (up to 3-5 m above m.s.l.) are common on the coast; they consist of weakly consolidated carbonate- cemented beach conglomerate at Mubrani and of coral west of Saukorem. The widespread occurrence of marine terraces indicates Holocene emergence of the coastal area.

The vegetation is mainly tropical rainforest. Large areas of secondary grassland occur in the Kebar valley, but are locally replaced by woodland, bamboo scrub, or herbaceous swamp vegetation. Woodland and scrub are also common on hills and plains near the coast. Stunted moss forest covers parts of the main watershed area down to 1700-1800 m above m.s.l.

Low-grade metasediments - Kemum Formation (Pk)

These metasediments extend across Kepala Burung south of the Kebar valley where they were described and defined as the Kemum Formation by Visser & Hermes (1962). Outcrop observations are restricted to the Asiti River where they unconformably underlie Miocene limestone; float samples were collected from the Aremi and Kasi Rivers (Pl. 1).

The rocks comprise dark to medium grey slate, phyllite, argillite, metasiltstone, quartzite, and minor coarse metasandstone and fine metaconglomerate. The slate and phyllite are micaceous in places. The metasandstone and metaconglomerate contain detritus of milky and grey quartz, minor feldspar, and fragments of slate and siltstone. The metaconglomerate has a quartzitic or rarely a slaty matrix. The quartzite may be recrystallised bedded chert.

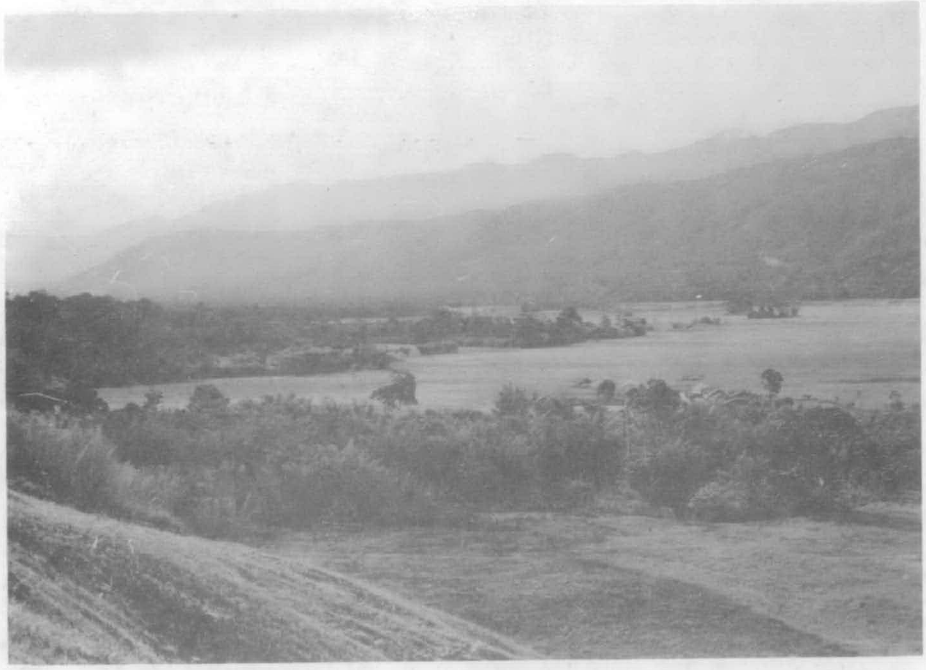

Fig. 4. East end of Kebar valley graben. View looking NW from locality 76623025 across Janderaro village.

Fig. 5. Fault-controlled cuesta of Tertiary sediments southeast of Kebar. View looking west.

Fine bedding or lamination is defined by alternating slate or phyllite and metasiltstone; metasandstone and metaconglomerate generally form thicker beds. Sedimentary structures include small-scale cross-bedding and load and flute casts. The bedding is usually steep and tight folding is widespread. Milky quartz veins are also common.

No fossils were found in the Kemum Formation in 1976, but graptolites from the Roef River, a tributary of the Aifat River, indicate a Silurian age for the formation (Visser & Hermes, 1962). In the Bintuni Basin, in the Ransiki Sheet area, the age of the Kemum Formation has been determined as Devonian from ostracods (Rahardjo, 1975).

Low to high-grade metamorphics - Kemum Formation (Pk)

A wide variety of metamorphic rocks was observed north of the Kebar valley between the Atori and Prori Rivers. They are mostly metasediments with some metavolcanics and metaplutonics. The metavolcanics and metaplutonics are mainly float; no contacts between the metamorphic units have been located.

The metamorphism is of low to medium P/T facies and ranges from low to high-grade; the metamorphic grade appears to increase progressively from north to south.

Contact relations with other rock units are uncertain. To the south the metamorphics are in contact with an acidic to intermediate batholith, and to the north and east they may be faulted against, or unconformably overlain by Tertiary volcanics and limestone. The metamorphics are intruded by Tertiary diorite and granodiorite dykes and small intrusive bodies.

The main rock types are slate, phyllite, schist, and gneiss of pelitic and psammitic derivation. The rocks are grey or greenish grey and generally micaceous. Mineral assemblages and textures in the psammo-pelitic metamorphics indicate a progressive increase of metamorphic grade towards intrusive bodies; the zones of contact metamorphism may be as wide as 1 km. The common mineral assemblage in slate and phyllite is quartz-(sericite or muscovite)-albite-chlorite, usually with accessory tourmaline, zircon, apatite and sphene. Carbonaceous matter and iron oxide are widespread; one sample of carbonaceous slate (76620172) contains post-tectonic porphyroblasts of andalusite.

The schist commonly shows incipient metamorphic differentiation as lenticles or discontinuous laminae of quartz, feldspar, and mica. The general assemblage is quartz-(albite, oligoclase)-muscovite-biotite. Some rocks also contain garnet, andalusite, staurolite, or hornblende; iron oxide, graphite, zircon, tourmaline, apatite, and sphene are accessories. Minor chlorite is formed after biotite and garnet, and sericite after plagioclase and andalusite as the result of retrograde metamorphism. Andalusite and staurolite and part of the plagioclase are developed as post-tectonic porphyroblasts. The gneisses have the same composition as the schists, but show more pronounced banding and are coarser.

The metavolcanics are greenish, mostly well-foliated rocks. They form a subordinate component in the metasedimentary sequence. One metatuff or volcanic metagreywacke (77624047) is an albite-actinolite/tremolite-chlorite-epidote/clinozoisite rock with minor carbonate and light green biotite, accessory sphene, iron oxide, and relict uralitised clinopyroxene. Relict microscopic bedding may be represented by laminae of fine-grained or porphyroblastic albite; the cleavage is parallel to this bedding and defined by nematoblastic amphibole. The porphyroblastic albite overprints the cleavage. Schist of unknown origin is exposed in the Arapi River and consists of 60-70 percent tremolite/actinolite with irregular patches of quartz-feldspar mosaic.

Metaplutonic rocks are common in float from the north and east flanks of a complex acidic to intermediate batholith straddling the main east-west watershed. The metaplutonics may be the metamorphic equivalents of the rocks of the batholith. They are mostly high-grade gneisses composed of quartz, feldspar, biotite, hornblende, diopsidic augite, garnet, muscovite, minor epidote, and clinozoisite with accessory zircon, sphene, rutile, apatite, and iron oxide. The feldspars are plagioclase (oligoclase to labradorite) and orthoclase. Some mineral assemblages in the gneisses are: quartz-plagioclase-orthoclase-biotite-garnet, plagioclase-hornblende-biotite-quartz, plagioclase-quartz-clinopyroxene-hornblende. A more massive rock contains up to 70 percent diopsidic augite and minor carbonate and antigorite.

The metaplutonic rocks are typically granoblastic; the gneissic structure is expressed by quartzo-feldspathic and mafic bands, and in more mafic rocks by bands enriched in pyroxene and hornblende. Post-tectonic retrograde metamorphism is expressed as minor sericitisation of feldspar and chloritisation of biotite and garnet.

The foliation of the metasediments and metavolcanics is usually steep and tightly folded. Microscopic wrinkling of the cleavage is evident in a few rocks.

The metasediments and metavolcanics are tentatively correlated with the Kemum Formation, and therefore may have a Silurian age. The metaplutonics possibly have a Permo-Triassic age assuming they are the metamorphic equivalent of the acidic to intermediate batholith. One K/Ar age on biotite from pelitic schist (Appendix I; 76627012) suggests a metamorphic event at 12.6 ± 0.3 m.y. This age is considered too young for the main metamorphic event, as unmetamorphosed diorite and granodiorite intruding the Tertiary volcanics as well as the metamorphics have an age range of 15-16 m.y. (Appendix I; 76629026, 76623013, 76623014). The age of the main metamorphic event may have been updated by a phase of retrograde metamorphism.

Serpentinite

Small outcrops of serpentinite occur along the track from Kebar to Mubrani near the crossing of the Asimi River. Both Loth (1925) and Molengraaf (1957b, 1958) have mapped this serpentinite as an elongate body 10 km long by 1.4 km wide, carrying some nickel and cobalt-bearing laterite. The age of the serpentinite is unknown.

Netotti intrusive complex (PMi)

The Netotti intrusive complex is a batholith exposed over an area of at least 40 km by 15 km although its exact limits are unknown. It straddles the main east-west divide of the Tamrau Mountains and may extend to the west beyond the map area. From airphoto-interpretation the body appears to be in contact with the low to high-grade metamorphics and Tertiary volcanics, limestone, and terrigenous sediments. To the south it is bounded by the Sorong Fault; its northern contacts are smooth curves, but the nature of these contacts is unknown.

Outcrops were sampled only between Mount Netotti and Kebar; most samples examined are float from the northern flank of the intrusive body. The majority of the rocks are medium to coarse and even-grained monzonite, diorite, granodiorite, granite, and syenite, moderately or locally strongly altered. Some finer-grained varieties are porphyritic. From the float, monzonite and diorite are the most common rock types.

The monzonite and diorite contain hornblende and/or biotite; in the granite and syenite the mafic mineral is almost invariably biotite, though one syenite sample contains rare orthopyroxene. The potassium feldspar is microcline and/or orthoclase which may be perthitic. Plagioclase ranges in composition from andesine in diorite to albite in granite. The accessory minerals sphene, zircon, apatite, and magnetite are widespread. A float sample of strongly altered, medium even-grained gabbro consists of hypersthene, olivine, augite, bytownite, minor hornblende, and pleochroic (from colourless to pale brown) mica.

Plagioclase and to a lesser degree potassium feldspar are altered to sericite; much plagioclase is also saussuritised. Hornblende is commonly altered to biotite or to epidote/clinozoisite and chlorite, and biotite is partly or wholly replaced by chlorite. Most diorite contains medium-grained granular bright yellow, pleochroic epidote. Part of the sphene and iron oxides are also alteration products. In the gabbro the olivine is almost completely replaced by serpentine and iddingsite, the bytownite by clinozoisite and minor light-coloured mica, and some of the hypersthene and augite by serpentine and epidote/clinozoisite. The widespread alteration is most probably the result of one or more phases of regional metamorphism.

The fault-controlled southern boundary of the intrusive complex is characterised by a zone of finely dissected terrain up to 500 m wide. North of Kebar in the Aponi River, the rocks in this zone are densely jointed, strongly sheared, folded in places, closely veined or banded and mylonitised, and moderately weathered. The main trend of shearing is northeast (50°-60°). Compositional banding (2-10 cm wide) is evident in float consisting of leucocratic and hornblende monzonite or diorite. Fragments of fine, even-grained andesite or diorite have been observed in plutonic rock boulders and occur as minor constituents in float in creeks which drain only the batholith (e.g., the Aponi River).

Hornblende from a granodiorite boulder from the Asimi River (7663046) gave a K-Ar age of 154 $\pm$ 3 m.y. (Late Jurassic) and hornblende from a diorite boulder from the Prori River (7664051) a K-Ar age of 224 $\pm$ 4 m.y. (Early Triassic). The Netotti intrusive complex, then, may correlate with the Permo-Triassic Anggi Granite and the Wariki Granodiorite near Manokwari (Robinson & Ratman, 1977, 1978); the anomalously young Late Jurassic K-Ar age of sample 76623046 may be explained by loss of argon as the result of post-Triassic recrystallisation.

Tamrau volcanics (Tvo, Tvy)

Volcanic rocks crop out along the coast, in the Wepai River, and in the upper reaches of the Wekareng River; Small intrusions probably related to these volcanics are emplaced in the metamorphic rocks and Netotti intrusive complex. The contact relations of the volcanics with other rock units were not examined in the field, but airphoto-interpretation suggests that they unconformably overlie the metamorphic rocks and are in fault contact with the Netotti intrusive complex.

The volcanics may be subdivided into a ?late Miocene to Pliocene subunit (Tvy) in the coastal area, and a late Oligocene to middle Miocene subunit (Tvo) farther inland, but north of the main east-west divide. The rocks of the subunits are slightly different in composition and degree of alteration, and have slightly different airphoto characteristics.

A limestone unit (Tl) mapped by Dutch geologists (Molengraaff, 1957b) in the Wekareng and Wesorpi Rivers partly separates the two volcanic subunits, although northwest of the mouth of the Prori River this limestone lies unconformably on the metamorphic rocks. Middle Miocene isotopic ages (16.2 ± 0.7, 15.4 ± 0.3 m.y.) from granodiorite and diorite boulders in the Wepai River (76623013 and 14), and late Miocene ages (9.2 ± 0.3, 11.5 ± 0.3 m.y.) from andesites on the coast at Saukris Point (Pl. 2, 76627033 and 35), 25 km northwest of Saukorem, appear to support the subdivision of the volcanics.

<u>Tvo</u>. The late Oligocene to Miocene volcanics were examined in the Wepai River and in the upper reaches of the Wekareng River. The rocks are massive or thickly bedded hornblende-andesite lava, and tuff and agglomerate with rare beds of recrystallised cherty limestone. Elongate serpentinite bodies, up to 20 m thick, in places trend parallel to the main structural grain (northwest to north-northwest) and are probably emplaced along faults. Airphoto-interpretation and scattered observations suggest that the volcanics are tilted to the north.

The lavas are light to dark, greenish or bluish grey and almost invariably strongly altered. They consist of small subhedral to euhedral phenocrysts of plagioclase (oligoclase to labradorite) and hornblende in a very fine-grained mainly feldspathic groundmass. Quartz is minor (5%), and augite and potassium feldspar are rare constituents. The opaques are mainly magnetite with some pyrite disseminated or in clusters. All rocks are moderately to strongly altered: plagioclase to sericite and/or saussurite; hornblende to chlorite, iron oxide, uralite, sphene, epidote, and carbonate; and the groundmass usually chloritised or uralitised. Locally bleached hornblende is commonly associated with magnetite dust. The tuffs are similar to the lavas in colour; purple to maroon colours are caused locally by a high iron content. They contain plagioclase, volcanic lithic fragments, and aggregates, grains, or veinlets of strained quartz in an indeterminate ironstained matrix.

The intrusive rocks which appear to be related to the volcanics are generally fine to medium-grained porphyritic altered diorites. The phenocrysts are subhedral to euhedral, normal or oscillatory zoned plagioclase (oligoclase-labradorite), and hornblende, with minor or rare ($<5\%$) quartz, clinopyroxene, and potassium feldspar. The minerals are altered as in the andesites, though in some of the intrusive rocks hornblende is partly altered to biotite. Zircon, apatite, and sphene are accessories in some of the rocks; the opaques are mostly magnetite, and pyrite is common as scattered crystals or in lensoid or streaky aggregates from a few millimetres to 3 cm long. A few small blebs of chalcopyrite are associated with pyrite in andesite pebbles in the Keweri River. The rocks are locally densely jointed or riddled with veinlets of quartz, carbonate, or epidote.

Tvy. The ?late Miocene to Pliocene volcanic rocks range in composition from pyroxene andesite to pyroxene dacite and, in contrast with the older volcanics, are mainly pyroclastics and volcanolithic sediments with minor lava and autoclastic breccia. The rocks usually have a massive appearance in outcrop and on aerial photographs, and commonly give rise to irregular, angular hilly landforms. Dips measured in the field and determined from aerial photographs are normally to the north.

Greyish colours predominate, but where altered the rocks are greenish or are stained purple or red by iron oxide. The lava fragments are porphyritic, with small to medium subhedral or euhedral phenocrysts of normal or oscillatory-zoned andesine-labradorite, augite, minor ($<5\%$) orthopyroxene, hornblende, and quartz in a matrix of feldspar microlites, magnetite dust, cryptocrystalline or cherty material, and/or brownish glass. Magnetite is a widespread opaque mineral, pyrite is a rare constituent, and apatite is a local accessory. The lavas are in many places vesicular or contain amygdules of zeolite, chlorite, quartz, or vermiculite, commonly lined with iron oxide. Biotite xenocrysts with deformed cleavage were observed in one dacite lava.

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All the volcanics are slightly to moderately altered: plagioclase is partly replaced by saussurite, sericite, and/or carbonate; augite by uralite, epidote, carbonate, or chlorite; and hornblende by chlorite and iron oxide. The matrix is normally cryptocrystalline or altered, but in places contains recognisable granular epidote and chlorite.

The pyroclastic rocks and volcanolithic sediments are made up of crystal and rock fragments. The rock fragments are lavas with a wide range of composition, texture, and degree of alteration, but consist mostly of fine-grained feldspar laths or microlites in a cryptocrystalline or partly opaque base.

Pyroxene andesite agglomerate sampled from Saukris Point is moderately fresh, and composed of dark grey angular fragments from 2 to 5 cm across in a moderately indurated fine to coarse-grained light brown/grey tuffaceous matrix.

Tertiary sediments (Tl, Ts)

Tertiary sediments - comprising limestone, sandstone, mudstone, shale, and calcareous sandstone - crop out along the Sorong Fault in the Kebar valley (Plate 1; Fig. 3). Limestone is also exposed on the coast north of the Prori River mouth, and trends westward inland as a broad ridge crossing the Wesorpi and Wekareng Rivers (Molengraaf, 1958); although it has not yielded a diagnostic fauna, it is correlated with the Tertiary limestone in the Kebar valley.

In the Kebar valley the limestone is commonly bounded by faults and is strongly deformed. At Janderaro the limestone dips 40^{o} north, and in the fault sliver at Kebar it is fractured and sheared; in a northern tributary of the Aifat River west of Senopi both limestone and terrigenous sediments are strongly deformed by faulting and contact relations are obscure. In the extensive karst plateau south of Senopi, however, the limestone is subhorizontal or is tilted gently northwards near the Sorong Fault.

The limestone lies unconformably on metamorphic rocks of the Kemum Formation south of Senopi and Janderaro. Beds of conglomerate and breccia with pebbles of quartz, slate and metasiltstone occur within the limestone in a northern tributary of the Aifat River west of Senopi, and at the mouth of the Prori River a chaotic limestone conglomerate with similar pebbles rests directly on metamorphic rocks. About 10 km inland, at the Wesorpi River, limestone appears to separate two subunits of the Tamrau volcanics.

Quartz-feldspar sandstone and light-coloured mudstone occur as fault wedges or slivers in the Kebar valley. Near Kebar and Senopi they appear to overlie Miocene limestone. South of Kebar, quartz-feldspar sandstone is faulted against the Kemum Formation and is cut by an east-trending fault system. The steeply dipping or vertical faults are indicated by deposits of iron oxide and locally by warm water springs (at about 50°C) depositing a thin cavernous, dirty white to pinkish, brittle soft sinter composed of magnesian calcite, gypsum, aragonite, quartz and plant material.

Shale and calcareous sandstone which dip southwards in the Kasi River east of Inam probably overlie the Miocene limestone which crops out between the Asimi and Kasi Rivers.

The limestone south of Senopi and Janderaro is early to middle Miocene, as is the bulk of the limestone at the east end of the Kebar valley, between the Asimi and Kasi Rivers. However, two anomalously young ages - N17 (late Miocene) or younger - were obtained for rocks in the Asiti River south of Senopi; limestone in a tributary of the Aifat River west of Senopi is possibly middle Eocene and late Oligocene; and one sample of foliated calcite-veined micrite from the hills between the Asimi and Kasi Rivers yielded a late Cretaceous (Campanian-Maastrichtian) age. In the last area, the limestone is cut by several steep east-trending faults which may have resulted in the exposure of older rocks.

No micropaleontological ages were obtained for the terrigenous sediments in 1976. They are likely to be in the range late Miocene to Pliocene.

The Miocene limestone from the karst plateau south of Senopi is a packed biomicrite which ranges from a brownish grey coarse to fine-grained argillaceous rock with quartz grains, shaly partings, and rare flat subbituminous coal fragments, to a clean light grey or cream rock. Packed biomicrite of similar age near Kebar is also impure in places; it is commonly partly recrystallised and may contain finely disseminated brown to black organic or clayey matter, and grains of megaquartz, composite quartz (including chert and metamorphic quartz), minor feldspar, accessory white mica, brownish glauconite, zircon, and opaque minerals. The fossil fragments in all the limestones include larger benthonic as well as planktonic foraminifera, algae, bryozoa, and molluscs.

The limestone was accumulated on an unstable shelf as forereef, backreef, and littoral deposits. The occurrence of limestone conglomerate with pebbles derived from the Kemum Formation suggests nearby hinterland with high relief.

The sandstone and mudstone near Senopi and south of Kebar range from cream to light grey, stained red or brown in places by iron oxide. The sandstone is usually quartz-feldspar arenite with 50 to 70 percent quartz, 10 to 20 percent feldspar, minor white mica, fragments of volcanic and metamorphic rocks, iron oxide, and accessory glauconite, tourmaline, and zircon. Some rocks contain sericite and minor chlorite in the matrix. The quartz grains are megaquartz and composite quartz which have been derived from a metamorphic-intrusive landmass. The thick and parallel-bedded sandstone has a medium porosity and is partly cemented by secondary quartz. The bedding in the mudstone is fine and parallel.

East of Inam in the Kasi River the sediments comprise massive or thickly bedded and pebbly lithic arenite, calcareous lithic arenite, pebble conglomerate with thin shale intercalations, and very fine, parallel-bedded, slightly micaceous shale with burrows and plant fragments.

The terrigenous sediments are interpreted as lake or shallow marine deposits.

Structure

Faulting and associated tilting and warping largely control the distribution of rock units and the geomorphology. The abrupt straight southern edge of the Netotti intrusive complex is defined by the northern margin of the east-trending Sorong Fault zone; the northern arcuate boundary of the complex also follows lineaments and faults (traced from aerial photographs). The contact between the older volcanics and the metamorphics appears to be a northeast-trending fault, and short, northeast and northwest-trending lineaments and faults are common in the older volcanics and the Netotti intrusive complex. The Tertiary sediments in the Sorong Fault Zone are cut by east-trending faults .

Faulting and uplift may have continued until the Pleistocene or Holocene, as remnants of old altiplanation surfaces are preserved in the mountains formed on the Netotti intrusive complex, and some faults are topographically expressed by steep, little dissected scarps. River terraces about 30 m high at the east end closure of the Kebar valley may have been formed as a result of westward tilting within the Sorong Fault Zone. Hot water springs occur along a fault near the Aremi River at the southern side of the Sorong Fault zone. Some faults are accompanied by lenses or narrow zones of serpentinite, the largest of which occurs near the Asimi River.

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The Sorong Fault zone is a complex left lateral transcurrent fault (Visser & Hermes, 1962), which is up to 9 km wide in the map area. The topographic relief across the fault in the Kebar valley area points also to large vertical displacements. The Kebar valley is a large graben 37 km long by 4 km wide within the Sorong Fault zone, and is bounded by other less conspicuous east-trending horsts and grabens. The origin of the graben is not clear; it may be related to en-echelon offsets in the main fault zone.

The Sorong Fault zone is part of a 2000 km long east-trending fault system extending from east Sulawesi to Wewak in Papua New Guinea. The fault system is thought to be a transform fault boundary between the Pacific and Indo-Australian lithospheric plates with a left lateral displacement of 350 km (Visser & Hermes, 1962; Tjia, 1973).

Mineralisation

The results of a reconnaissance geochemical survey carried out by the GSI/BMR party in 1976 were compiled by Hutchison (1977), who recommended follow-up of a copper-lead-zinc anomaly near Saukorem. Some nickel and cobalt-bearing laterite overlies the serpentinite body south of the Asimi River (Molengraaff, 1957b), and minor pyrite, chalcopyrite, and pyrrhotite mineralisation occurs in quartz pebbles in side creeks draining from the north in the Api River and in andesite pebbles in the Kewiri River.

THE NORTH COAST OF KEPALA BURUNG

Numerous geological observations were made along the north coast of Kepala Burung between Mansuar Island and Saukris (Pl. 2) with the support of an RAAF Iroquois helicopter and the MV Mujizat chartered from the American Evangelical Alliance Mission (TEAM). The few widely spaced observations do not justify the compilation of a geological map, and this section is restricted to short descriptions of the geology at the sample localities from east to west. The localities visited include several on islands northwest of Sorong in addition to those on the mainland.

East of the Mangenni River (T76627025/26)

Outcrops are made up of massive well-sorted coarse-grained lithic and crystal tuff with a few beds up to 50 cm thick of medium-grained crystal tuff; the sequence is tilted 15° to the northeast. The rocks are soft and weathered yellowish brown. A nearby small creek on the southeast side of the bay is choked with large blocks of flow-banded, autobrecciated rhyolite or dacite.

Saukris Point (T76627033/35)

Exposed volcanic breccia on the east side of the point contains dark grey hard angular basalt fragments from 2 to 40 cm across in a matrix of moderately indurated fine to coarse-grained brownish grey weathered tuff. The bedding dips 10-20° to the north-northwest.

In thin section the volcanic fragments have a porphyritic texture with fine to medium-sized phenocrysts mostly of plagioclase but also of augite and opaques, minor hypersthene and hornblende, and accessory apatite in a matrix of glass, microlites, or very small laths of feldspar and magnetite dust. The plagioclase (An_{60}) is subhedral to euhedral, tabular, commonly oscillatory zoned and may contain zonally arranged inclusions; the augite crystals are slightly smaller than the plagioclase, subhedral to euhedral and commonly twinned; and the hypersthene is subhedral to euhedral, non-pleochroic and rarely mantled by augite. The minerals are mostly fresh, although plagioclase is locally slightly altered to saussurite and commonly contains small ironstained patches. Small grains of greenish brown ironstained microcrystalline to crypotocrystalline chloritic material may be bowlingite pseudomorphs after olivine. The microlites in the groundmass may be supbarallel. The tuff matrix consists mostly of fine to medium angular crystal fragments of plagioclase, augite, opaques, hornblende, and hypersthene.

The K-Ar ages of rock samples 76627033 and 76627035 (both fragments of the breccia) are respectively: 9.2 $\pm$ 0.3 m.y. and 11.5 $\pm$ 0.3 m.y. (Appendix I). The K-Ar ages place these rocks in the late Miocene epoch, and they are tentatively correlated with the younger volcanics (Tvy) of the eastern part of the Mar 1:250 000 Sheet area, described above.

Wayos Point (T76627060)

A vertical fault zone 15 m wide separates pillow lava at the utmost point from a sequence of bedded marine tuff dipping 70° to the northwest. The pillow lava is a dark grey, fine to medium-grained and porphyritic basaltic andesite; abundant amygdales filled with prehnite, chlorite, calcite, and quartz-feldspar material occur in the selvages of the pillow structures. The lava consists of 40 percent plagioclase and augite phenocrysts in a holocrystalline matrix of corroded feldspar laths, augite, opaques (mainly magnetite), carbonate, quartz, and chlorite. The plagioclase is mostly tabular glomeroporphyritic secondary albite which is locally fringed by potassium feldspar; it is moderately sericitised and contains patches of carbonate. Augite occurs as fresh, subhedral to anhedral grains.

The marine tuff is composed of about 60 percent sand-size shards, streaks, ooids and irregular fragments of brownish palagonite commonly enclosing ?analcime and quartz-feldspar intergrowths. The other constituents are angular grains of quartz and feldspar, augite, fragments of volcanic rock, tests of planktonic foraminifera, and patches of carbonate. One very fine-grained bed is made up of microcrystalline angular corroded fragments of feldspar, quartz, opaques, tests of planktonic foraminifera, and cryptocrystalline or glassy material. Faint lamination as the result of changes in grain size is in places disturbed by bioturbation. The rocks are marine tuffs rather than tuffaceous sediments as there is no evidence of sorting, or reworking other than burrowing.

Kambrimi Point (T76627059)

Massive crystal tuff and agglomerate at this locality consist of rounded fragments up to 30 cm across in a matrix of crystal tuff. The tuff is dark brown-grey and consists of fine to medium plagioclase (An_{52}), augite, and minor basaltic hornblende and biotite crystals (60%) in a base of plagioclase laths, quartz-feldspar material (?devitrified glass), magnetite, and pyroxene. The plagioclase is partly glomeroporphyritic, slightly sericitised, altered to carbonate, and contains zonally arranged inclusions. Complex intergrowths of quartz and carbonate form ragged patches.

Between Jamursba Point and the Koor River (P10-76620024/25)

Massive greenish grey volcanic breccia (or conglomerate), and tuff are intermingled with limestone (?pepperite) at this locality. The finer-grained rocks consist of angular, irregularly shaped fragments of carbonate rock and fossils, volcanic fragments, and minor grains of plagioclase, augite, chert, composite quartz, palagonite, quartz-feldspar intergrowths, epidote, and hypersthene in a matrix of sparse biomicrite. The rocks are cut by carbonate veinlets. The microfauna in sample 76620025 indicates only a Tertiary age.

Opmarai Point (P9)

Low coastal terraces consist of subhorizontal, thickly bedded to massive, moderately indurated conglomerate (see also P8-76620023 and P6-76620021).

Wewe River (P8-76620023)

Outcrops examined on the coast consist of thin to very thickly bedded, moderately indurated polymict pebble conglomerate with a greyish brittle coarse sandstone matrix, and very coarse sandstone and grit. The sandstone is moderately well sorted with rounded grains which are cemented by carbonate; the porosity is 5-10 percent. The clasts in the sandstone are fine-grained volcanics, quartz, chert, palagonite, feldspar, carbonate rock, fossil fragments, and pyroxene. The beds dip 5^{o} to the northwest. The age of these sediments, and similar sediments at P9 and P6-76620021, is probably Pleistocene; the sediments indicate widespread uplift during that time along the north coast of Kepala Burung.

15 km southwest of Sansapor (P7-76620022)

The rock type at this locality is black slate with a well developed slaty cleavage; quartz veins mostly run parallel to the cleavage and framboidal and cubic pyrite are scattered throughout the rock. The cleavage dips 45^{o} to the southwest, and is defined by the preferred orientation of elongate composite grains and flakes of white mica and/or chlorite, lenticles and discontinuous laminae of composite quartz and minor feldspar, and anastomosing strings of carbonaceous material. Relict lamination is preserved as isoclinally microfolded colour banding. Irregularly folded and ruptured laminae of mosaic and sutured quartz, minor carbonate, and white mica may have been sandy or silty intervals which were too competent to adjust to the tight folding in the mudstone. Post-tectonic veinlets of carbonate cut the cleavage perpendicularly.

Near Sawasar Point (P6-76620021)

A coastal terrace is developed on weakly indurated, polymict pebble conglomerate with a matrix of coarse sandstone. Pebbles and matrix consist mainly of milky quartz and aphanitic dark grey to black volcanics and minor siliceous argillite, chert, jaspilite, and carbonate. The thickly bedded sequence dips 10^{o} to the northwest.

West of the Mega River (P5-76620020)

The outcrop consists of dense, hard and massive medium grey calcite-veined biomicrite with larger benthonic foraminifera of early to middle Miocene age.

West of Dore Point (P4-76620019)

The rocks are fine to coarse-grained marine crystal tuff veined by carbonate and quartz and composed of partly sericitised plagioclase, pyroxene, minor fragments of aphanitic grey andesite, blackish volcanics, and rare fragments of black slate and fossils. The tuff is partly cemented by carbonate. The thick to massive beds dip $20\text{-}25^{o}$ to the northwest.

Warsamson River (P3-76620016/18)

The coastal cliffs are formed of massive medium grey interbedded agglomerate and tuff. The rocks weather brown and commonly display spheroidal weathering. The fragments of the agglomerate vary from sand-size to blocks up to 80 cm across and consist of aphanitic and feldsparphyric, slightly vesicular andesite. The crystal tuff contains mostly plagioclase and pyroxene, with minor fragments of dark aphanitic volcanics and small amounts of carbonate. The bedding dips $10\text{-}15^{o}$ to the northwest.

Sorong Town Wharf (T76627057/58)

The exposed rocks are dark and medium grey, very hard, splintery, fine, and even-grained limestone in beds about 10 cm thick, with brecciated light greenish grey limestone in places.

a₇v

Southwest Jefman Island (P2-76620009/15)

Low wave-cut benches and huge tors are made up of polymict fault breccia marking the Sorong Fault zone. A crude, mostly massive layering strikes 68° (parallel to the regional trend of the Sorong Fault zone in that area) and dips very steeply or vertically. The layering is defined by abrupt changes in fragment size; the average size of the fragments is 1 to 10 cm across with a total range from a few millimetres to 60 cm across. The breccia is generally well indurated, although the finer-grained varieties are slightly friable. The contacts of the layers may be parallel, folded, irregular, wavy, discontinuous, or anastomosting. The weathered rocks are stained pink and red to medium brown and locally black by iron, and show spheroidal weathering; the fresh rocks are light pink to grey.

The breccia fragments consist mainly of hard polymict arenite and lesser amounts of black argillite (with pyrite), grey calcareous argillite, aphanitic and porphyritic basalt or andesite, pink granite, reddish chert, and limestone. The arenite is medium-grained and moderately sorted, and is composed of angular grains of quartz, potassium feldspar, sericitised plagioclase (mostly albite), very fine-grained to cryptocrystalline basaltic or andesitic volcanics, biotite, and rare carbonate, palagonite, and zircon.

Northwest Salawati Island (P1-76620001/8)

Boulders and pebbles of porphyritic volcanics and minor dark calcareous argillite and medium grey biomicrite were examined in a small creek. The volcanics are porphyritic andesite or basalt with medium to fine phenocrysts of plagioclase (An_{55}), augite, and minor hypersthene and opaques in a holocrystalline matrix of plagioclase laths, augite and opaques; some samples also contain clinoamphibole and patches of intergrown alkali feldspar and quartz. Some of the rocks are amygdaloidal; the vesicles are filled with chalcedony, prehnite, and colloform iron oxide. Larger benthonic foraminifera in the limestone give an early to middle Miocene age.

Southwest Mansuar Island (T76627051)

Light creamy brown fine-grained limestone contains abundant casts of small pelecypods and foraminifera which give only a general Tertiary age.

Northeast Batanta Island (T7662705/56)

In low sea cliffs at the northeast corner of Batanta Island, sandstone and conglomerate of the Marchesa Formation (Visser & Hermes, 1962) lie unconformably on weathered basalt or dolerite of the Batanta Formation. The conglomerate is 3 to 4 m thick and contains subrounded to subangular pebbles of greenish quartz up to 1 cm across and scattered rock fragments up to 1 metre in a matrix of poorly sorted fine to coarse sandstone with an abundant creamy calcareous cement. Four metres of poorly sorted sandstone similar to the matrix succeed the conglomerate, and grade upwards into 5 m of fine sandstone with an abundant silt and clay matrix together with scattered feldspar grains and small rock fragments. The poorly sorted coarse sandstone also forms lenses within the conglomerate. A sample of the coarse sandstone (7055) yielded microfossils dated (Appendix III) as probably middle Pliocene (N 20), and the fine sandstone (7056) yielded microfossils of early Pliocene (N 19) age.

NORTHEAST ARFAK MOUNTAINS

In 1976, Pieters and Harli Sumadirdja carried out reconnaissance fieldwork in the northeast Arfak Mountains, where Pieters made a traverse from Warmare via Mount Umcina to Mokuam (Pls. 3 and 4). Hutchison and Pieters also spent one week in the Menyambo area during which Pieters connected with his earlier survey at Mokuam, completing a traverse of the Arfak Mountains between the coast and the Wariori River.

Geomorphology

The Arfak Mountains form a north-trending rugged range with the higher peaks just below 3000 m above m.s.l. in the northern part (Gunung Mebu, 2985 m). Many primary streams occupy fault-controlled linear valleys running north and south, parallel to the axis of the range (e.g., the Prafi River); most secondary streams trend east and west. The mountain ridges have narrow crests with long steep straight slopes which meet to form V-shaped valleys. The streams are generally ungraded, and valleys are filled with coarse gravel and boulders. The drainage is mainly dendritic, but in many places is modified by recent faulting or tilting into a rectangular pattern with straight stream segments and abrupt changes in direction.

Landslides are common and locally the large supply of debris gives rise to braided rivers and long narrow stretches of alluvial flats. The youthful stage in river development and recent tectonism is also indicated by river capture, numerous waterfalls and rapids, and river terraces near Mokuam, Menyambo, and Warmare.

A disastrous landslide and flood occurred in 1973, when - after four days of continuous rain - an earlier landslide damming a lake about halfway up the Warmamori River collapsed (Fig. 6). Near the mouth of the river the resultant rock and mud flow killed seven people in a small village. All the way downstream from the lake to the coastal plain, the lower 30 to 80 m of the valley sides were stripped clean of soil and vegetation; the debris choked the river valley and was deposited where the river leaves the foothills in an alluvial fan which is an equilateral triangle with sides 2.5 km long. Large parts of the fan were raised from 1 to 2 m by the debris from this event. In the Ngemona River, 5 km south of Menyambo, an impressive waterfall tumbles about 150 m over a horizontal distance of 200 m, marking the northern edge of a high-altitude plateau; immediately upstream of the waterfall the river flows for 1 km in a low V-shaped valley superimposed on a massive ridge.

Metamorphic (Kemum Formation) and granitic rocks (Pk, Pkm, PM:)

Metamorphic rocks of the Kemum Formation (Visser & Hermes, 1962) were examined between the fault valley of the Prafi River and the Ngemona River, which is a tributary of the Wariori River. Low-grade metasediments crop out in the Sen and Endaba Rivers, and farther west (d'Audretsch and others, 1966). Schist, phyllite, and quartzite occur between Menyambo and Mokuam, in places associated with granitic intrusions. On a regional scale the metamorphic grade increases from southwest to nrotheast, according to d'Audretsch & others (1966).

The granitic intrusives are correlated with a Permo-Triassic granite batholith to the south near the Anggi lakes and with the contemporeneous Wariki Granodiorite (Robinson & Ratman, 1977, 1978), in the Manokwari Sheet area. The metamorphics are also locally intruded by diorite and leucogabbro which in the Manokwari Sheet area have a K-Ar age of 15.4 ± 0.5 m.y. (middle Miocene). Similar intrusives are more common in the volcanic terrain east of the Prafi River.

Fig. 6. Landslide and flood debris, Warmamopi River, Arfak Mountains.

Fig. 7. Limestone cliff controlled by fault at locality 77620023, Wabudori River, Supiori Island.

To the east the metamorphics are abruptly bounded by the Ransiki Fault, but metamorphics were not encountered in the fault zone. In places, generally on ridges, the metamorphics are overlain by remnants of Pleistocene fossiliferous calcareous sandstone. On the ridge west of the Sen River, 5 km north of Menyambo (H_{33} and H_{34}), the angular unconformity between the Kemum Formation and the calcareous sandstone is exposed in the floor of a limestone cave.

The low-grade metasediments are derived from argillite, siltstone, greywacke, and minor conglomerate and chert. The rocks are hard or very hard with a subconchoidal fracture. The metagreywacke and metaconglomerate are medium grey and thickly or massively bedded; the finer sediments are dark grey to brownish grey and show well-developed lamination and thin to thick bedding. Sedimentary structures such as graded bedding, small-scale cross-bedding and scour-and-fill are locally well preserved.

The metagreywacke is composed of poorly to moderately sorted angular to subangular quartz and subordinate feldspar in a matrix of the same minerals and lesser amounts of muscovite, biotite, carbonate, chlorite, clinozoisite/epidote, and opaques. Coarse metagreywacke and intraformational metaconglomerate also contain chips and pebbles of meta-argillite and metasiltstone. The rocks have a poorly developed, crude slaty or fracture cleavage at an acute angle to or parallel to the bedding; this cleavage is not penetrative on a microscopic scale. In places the rocks are hornfelsed; they are very hard and splintery and have developed a fine-grained mosaic of recrystallised quartz. Pyrite is a widespread constituent, disseminated or as euhedral crystals.

Medium to very dark grey phyllite, schist, and impure quartzite, and fine to coarse-grained light grey or pinkish quartzite make up the bulk of the metamorphics between Menyambo and Mokuam. The well-developed cleavage or schistosity is the result of parallel orientation of mica and to a lesser degree of metamorphic differentiation. The typical mineral assemblage of the phyllite and schist is: quartz, muscovite, biotite, minor plagioclase (commonly albite), potassium feldspar, opaques (magnetite, minor pyrite), and accessory tourmaline, zircon, sphene, and apatite. Some phyllite and schist are studded with garnet or may contain porphyroblastic and poikiloblastic biotite and andalusite; in other rocks, sillimanite forms aggregates of fibres or large prisms at the expense of biotite. Porphyroblastic biotite, andalusite, and sillimanite occur in rocks closely associated with granitic intrusions and are probably the result of contact metamorphism.

The light grey or pink quartzite is composed of quartz and minor albite-oligoclase, potassium feldspar, muscovite, biotite, clinozoisite, sphene, opaques, and accessories as in the schist and phyllite. The original quartz grains are completely recrystallised, resulting in an even-grained polygonal or slightly sutured texture. The darker quartzite contains higher proportions of biotite, clinozoisite, and opaques. Most rocks contain scattered pyrite but at P80, between Menyambo and Mokuam, joint planes are lined with fine-grained pyrite and the rocks are heavy and dark as the result of their high iron content.

Dykes of metamorphosed intrusive rocks were observed at a few places in the low-grade metasediments as well as in the phyllite, schist, and quartzite. At H25, in the Endaba River, heavily jointed, greenish grey meta-intrusive rock contains phenocrysts of quartz, plagioclase, and hornblende.

The acid intrusives range from granite to granodiorite in the stock-like bodies and from granite to pegmatite in pods and veins. In the Ingen River at P76, schist is regularly interlayered with 5 to 30 cm thick pegmatite veins. The sharp contacts follow the metamorphic foliation, but in places either the pegmatite veins bifurcate or schist has been thrust diapirically through pegmatite. The pegmatite veins are considered to be apophyses radiating outward from a large granite body. Granite or granodiorite stocks or dykes intrude the metamorphics in places, such as at H12 and H14, in the Siau River.

The granite and granodiorite are generally allotriomorphic-granular and contain muscovite, commonly biotite, brown and blue tourmaline, and accessory zircon and apatite. Some of the tourmaline crystals are 5 to 6 cm long (at P88 near Mokuam).

Dip and strike of bedding and metamorphic foliation were only measured around Menyambo. Bedding and lamination are preserved in the low-grade metasediments; contacts between mica schist or phyllite and quartzite are indications of bedding in metamorphics in which smaller-scale primary structures have been obliterated.

The crudely and weakly developed cleavage in meta-argillite, metasiltstone, and metagreywacke makes an acute angle with or parallels the bedding or lamination. Both bedding and metamorphic foliation strike west-northwest with steep dips north or south. In places the bedding is overturned, and in some outcrops bedding and metamorphic foliation undulate or are folded. At P76 near Menyambo the sequence of interlayered pegmatite veins and micaceous schist are deformed into open symmetrical folds which grade laterally into wavy banding; the fold wavelength ranges from 20 cm to 3 m and amplitude from 10 to 100 cm. The fold axes trend west-northwest and plunge gently to the west. Downstream from Menyambo small shear zones disrupt the metamorphic sequence in places, and thin pegmatite bands concordant with these structures are evident at H23.

As discussed above, the Kemum Formation has been dated as Silurian in the central part of Kepala Burung (Visser & Hermes, 1962) and Devonian in the Ransiki Sheet area (Rahardjo, 1975). The age of the regional metamorphism is not known.

The granitic rocks in this area have not been dated, but K-Ar ages for the granite batholith intruding metamorphics near Lake Anggi Gigi in the Ransiki Sheet area and from granodiorite stocks in the Manokwari Sheet area range from Late Permian to Middle Triassic (Appendix I).

Tertiary volcanics and associated sediments (Tv, Tel, Tl, Ts), and intrusives (Ti)

Between the coast and the Prafi River, the Arfak Mountains are formed by a belt of basaltic and andesitic volcanics, volcanic sediments, and limestone. The contacts between these rock types are probably conformable. From west to east lava and pyroclastics give way to volcanic sediments, which are probably contemporaneous; the volcanic sediments are overlain by limestone.

All these rock types are unconformably overlain by Plio-Pleistocene and Holocene alluvial sediments, and the volcanics and volcanic sediments are intruded by small bodies and dykes of diorite and leucograbbro.

The volcanics are separated from the metamorphics of the Kemum Formation by the Ransiki Fault zone, in which long sheared dyke-like bodies of hornblende diorite crop out. In many places the diorite is bounded to the east by thin sheets of strongly sheared and recrystallised limestone possibly of Eocene age. Calcareous arenite with clasts derived from both the metamorphic-granitic terrain and volcanic terrain forms one outcrop in the fault zone (P40).

The volcanics consist of basaltic or andesite lava, lava breccia, agglomerate, and tuff. Where fresh they are dark greenish grey, but are commonly altered or weathered to light or dark green and red. The lava is homogeneous and massive, and in places autobrecciated; it has an even-grained or porphyritic texture, and is rarely amygdaloidal. The main constituents are plagioclase (An_{50-60}) and augite, with minor hypersthene and magnetite, and rare olivine pseudomorphs and volcanic fragments. The groundmass may be very fine and crystalline - with plagioclase laths, augite granules, and magnetite dust - or partly glassy - with amber, orange, or brown palagonite containing ooids or lenses of spherulitic fibrous ?chlorite, feldspar microlites or laths, and augite and magnetite. Amygdules are filled with zeolite, chlorite, and chert with sericite. Plagioclase is to various degrees albitised and/or altered to kaolinite or sericite, and pyroxene is locally altered to uralite and/or chlorite. In many rocks the groundmass is partly indeterminate because of the presence of secondary iron. Close to the Ransiki Fault zone the rocks are commonly veined, sheared, fractured and slickensided; the vein minerals are epidote, chlorite and zeolite. The few andesites examined have a fine and even-grained texture and are composed of plagioclase (altered to albite, kaolinite, sericite, and/or carbonate) together with hornblende, minor opaques, augite, and quartz. The rocks are strongly altered and contain disseminated and vein epidote, interstitial, patchy, or vein chlorite, and carbonate. Both the andesite and the basalt contain scattered euhedral pyrite.

The volcanic sediments comprise dark greenish or brownish grey mudstone and siltstone and medium to dark grey greywacke sandstone, pebbly sandstone, and breccia with sandstone matrix. Thin beds of dark, impure micrite limestone are locally intercalated with the terrigenous sediments. The rocks are prone to weathering; in many outcrops they are brittle and stained brown, and spheroidal weathering is locally developed in massive beds.

The sandstone, greywacke, and breccia are very immature, with unsorted and angular detritus. Bedding is usually well developed; it varies from coarse to massive in sandstone and breccia to very thin in mudstone. Mudstone is commonly laminated as the result of subtle changes in colour or grainsize. In places the sediments show small-scale ripple marks, graded bedding, related sole mark, and flame structures, and mudstone is disrupted where overlain by coarser sediment.

All the sediments consist mainly of volcanic clasts and minor plagioclase, pyroxene, and magnetite crystals. Most rocks are calcareous and have a wide range in content of carbonate cement, and well-preserved tests of planktonic and benthonic foraminifera and fragments of algae, molluscs, and gastropods. The volcanic clasts are composed wholly or partly of glass, devitrified glass, palagonite, and/or cryptocrystalline feldspar, pyroxene, and hornblende. Most sediments contain interstitial zeolite, and zeolite fills the tests of foraminifera.

The composition, immature texture, and depositional structures of the sediments point to rapid deposition without much reworking in a marine environment. The detritus is derived from a volcanic arc, and may have originated as volcanic ash, lapilli, and bombs, or as slump debris from erosion. The slump debris possibly accumulated along the periphery of the volcanic arc and was subsequently remobilised in turbidity currents.

The limestone overlying the volcanic sediments consists of algal foraminiferal biomicrite which is a massive parted hard dense brittle cream or pale brown rock, together with minor fine-grained biocalcarenite and argillaceous micrite.

The clayey limestone in the Ransiki Fault zone is light to medium grey, sheared, brecciated, calcite-veined, and recrystallised. It forms a subvertical sheet, probably up to 80 m thick, which is cross-faulted in places.

The rocks intruding the volcanics and volcanic sediment include a dyke of pyroxene basalt porphyry at P55 and a small body of medium-grained leucogabbro at P60; similar rocks form float (e.g., at P26 and P70). In the Ransiki Fault zone a subvertical dyke-like intrusive body consists of hornblende microdiorite in which the hornblende occurs in streaky aggregates up to 3 cm long; rocks of similar composition but without the streaky texture form float in the Prafi River. The intrusive rocks contain no mineralisation other than scattered euhedral pyrite.

Assemblages of larger benthonic and planktonic foraminifera give a late Oligocene to middle Miocene age for the limestone overlying the volcanic sediments. The limestone is correlated with the Kais Limestone as defined by Visser & Hermes (1962). Larger benthonic foraminifera in only one sample of the volcanic sediments gave an early Oligocene (Tc) age. Planktonic and larger benthonic foraminifera from the limestone in the Ransiki Fault zone indicate a variety of ages - middle Eocene, late Oligocene to early Miocene (Te), and late Miocene (N_{17}). A middle Eocene age is likely for limestone which is overlain by the volcanics. The few outcrops of clastic sediment in the fault zone derived from the metamorphic as well as

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the volcanic terrain may correlate with the late Miocene to Pleistocene Befoor Formation described by Robinson & Ratman (1977, 1978).

A K-Ar age of 33.1 $\pm$ 0.8 yrs (early Oligocene) was obtained from plagioclase of a leucocratic pyroxene gabbro (77620049) collected by Professor Tjia of the National University of Malaysia immediately south of the summit of Gunung Mebu. Photo-interpretation suggests that Gunung Mebu is formed by a large intrusive body emplaced in volcanics.

The volcanic sediments and limestone have been tilted along a northwest-trending axis, and dip between 30 and 50^{o} to the northeast; well-developed dipslopes are visible on airphotos. Tectogenesis commenced after the limestone was deposited (probably middle Miocene), but before the late Miocene to Pleistocene Befoor Formation was deposited unconformably on the limestone and volcanics in the Manokwari Sheet area (Robinson & Ratman, 1977, 1978) and on the limestone in the northeast corner of the map area (Pl. 4).

The north-trending Ransiki Fault is a major zone of disturbance up to 200 m wide which separates the metamorphic terrain from the volcanic terrain. In this zone dyke-like bodies of sheared hornblende microdiorite are in fault contact with subvertical sheet-like bodies of sheared limestone to the east, and deformed altered volcanics to the east as well as to the west. The contacts between rock types in the fault zone show the effects of intense shearing; schlieren of highly altered volcanics are intermingled with microdiorite at P34, and lenses, fragments, or blocks of limestone are embedded in volcanics at P93 and P94. Subhorizontal slickensiding observed at various places along the fault zone suggests young strike-slip movements.

Late Tertiary and Quaternary sediments (Ql, Qt)

On the divide west of the Sen and Endaba Rivers and in the mountainous country southeast of the Ingen River, there are several scattered outliers composed variously of light or yellowish brown calcareous fossiliferous sandstone, pebbly sandstone, conglomerate, mudstone, and biocalcarenite. In the pebbly sandstone and conglomerate the clasts comprise medium to dark grey low-grade metamorphics, quartzite, granitic intrusives, and fossils in a matrix of sand to mud-size carbonate grains. The fossils include fragments or whole tests of molluscs, gastropods, algae, foraminifera, and echinoderms.

On a ridge crest west of the Sen River (9 km north-northwest of Menyambo) a sequence 50 to 80 m thick of sandy foraminiferal calcarenite

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with thin intercalations of siltstone and mudstone lies unconformably on metamorphic rocks. The limestone is flat and the contact with the steeply dipping metamorphics is exposed in the floor of a cave within the limestone. Larger benthonic foraminifera from the limestone are Pleistocene or younger. This unit may be correlated with the Pleistocene Manokwari Limestone (Robinson & Ratman, 1977, 1978), a raised reef limestone capping the low hills in the coastal area near Manokwari. The presence of Pleistocene shallow-marine sediments as outliers high in the Arfak Mountains means that the area must have been uplifted as much as 1000 m in recent times, and explains the very youthful stage of landform development in these mountains.

Near Warmare the northern front of the Arfak Mountains is characterised by alluvial fans of massive, poorly sorted, brownish pebble and boulder beds with scattered orange clay and black humus-rich soil horizons. The fan debris consists of basalt, andesite, metamorphics, and lesser amounts of granitic rocks. At P23 in the northern foothills of the mountains an abrupt change from unconsolidated to slightly compacted alluvial beds indicates at least two major stages of Holocene erosion in the hinterland. The valleys near Mokuam and Menyambo are flanked by river terraces up to 100 m high composed of a chaotic mixture of boulders, pebbles, sand, and mud.

SOUTHEAST ARFAK MOUNTAINS

In 1976 Hutchison and Memed carried out a traverse in the southeast Arfak Mountains from Ransiki to Lake Anggi Gigi which partly followed the Anggi Trail, a foot-track providing a major link between the mountain and coastal people.

Geomorphology

The map area (Pl. 5) may be subdivided into four geomorphological units: alluvial fans, terraces, and flats; foothills; mountainous terrain developed on volcanics; mountainous terrain developed on metamorphics and granite.

The lower, braided courses of the Ransiki River and the Momi River and smaller rivers farther north are bounded by alluvial fans; alluvial flats, low terraces, or terrace remnants were observed along parts of the upper course of the Momi River and along the Ungui River, a tributary of the Ransiki River.

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The rugged foothills flanking the lower course of the Ransiki River are developed on moderately consolidated coarse terrigenous sediments and limestone. Massive subhorizontal beds form steep cliffs; dip slopes in and near the Ransiki Fault zone indicate tilting to the northeast.

The mountainous terrain developed on basic and intermediate volcanics, comagmatic intrusives, and volcanic sediments is deeply dissected, and peaks rise to heights of about 2000 m above m.s.l. The V-shaped valleys, commonly scarred by landslides, are separated by sharp ridges. The drainage pattern is mostly dendritic, but in places it is controlled by jointing or faulting.

The mountainous terrain developed on volcanic rocks is separated by the prominent fault-line valley of the Ransiki River from mountainous terrain developed on metamorphic and granitic rocks, in which two distinct types of landforms are recognised:

- an elongate high-altitude plateau extending from Lake Anggi Gita northwards to the large waterfall in the Ngemona River (see Pl. 3), and
- high, sharp, and steeply dissected mountains surrounding the plateau.

The two large lakes at the southern end of the plateau have water levels at about 1920 m above m.s.l. (Anggi Gigi) and 1865 m above m.s.l. (Anggi Gita). Both have very small catchment areas; Anggi Gigi drains to the north via the Ngemona River into the Wariori River; Anggi Gita drains to the east into the Ransiki River. The lakes are partly bounded by small alluvial fans associated with short streams, but the Irai and Ngemona Rivers meander through an alluvial plain which extends north of Anggi Gigi. The plateau surface is characterised by hilly country, isolated mountains and wide valleys with alluvial plains and flats, and meandering streams. The average height of the surface gradually falls to the north from about 1900 m to 1700 m above m.s.l. In many places the plateau boundary is sharply defined by cliffs and waterfalls, and the plateau is probably an old erosion surface.

The rugged, sharply dissected mountains between the Anggi lakes and the Ransiki River reach heights of about 2500 m above m.s.l., from where the average height of the mountains decreases gradually to the southwest to about 1200 m above m.s.l. at a high prominent cuesta composed of southwesterly dipping Mesozoic and Tertiary sediments lying unconformably on the metamorphics (outside the map area, in the southwest corner of Pl. 5).

The native population is concentrated on the Ransiki plain, around the Anggi lakes and further north on the plateau. Several short air strips, maintained by government or missions facilitate communications in this area.

Metamorphic and granitic rocks

In this section rock types are described as they were observed by Hutchison and Memed during their traverse from Ransiki to Lake Anggi Gigi.

Poorly to moderately consolidated massive brown conglomerate crops out in the Ipra River, a small tributary of the lower Ransiki River (D65, Pl. 5). It is poorly sorted with subangular to subrounded pebbles, cobbles, and a few boulders in a soft matrix of smaller rock fragments. The clasts consist of a wide variety of volcanic rocks including basaltic and andesitic lava, agglomerate, and volcanic sediments. Float at this locality includes grey, green, and red lava, tuff, and agglomerate, with minor bioclastic limestone and a few large boulders of a coarse leucocratic intrusive.

Massive, moderately fractured, fine-grained quartzite is exposed in the middle reaches of the Momi River (D66-D67); in addition to quartz and feldspar, the rock contains small clusters of biotite and muscovite or sericite, and abundant pyrite. The quartzite is invaded locally by veins of pegmatite composed of muscovite, quartz, and feldspar. Slender prisms of sillimanite were found in one altered pegmatite composed of almost completely sericitised feldspar, quartz, biotite, and opaques.

Near D66 medium and even-grained, dark greenish grey intrusive rocks consist of plagioclase (An_{40}), clusters of dark ferromagnesian minerals, minor quartz, and accessory zircon. Commonly the dark clusters consist of altered or fresh olivine encompassed by a reaction zone of brown or green pleochroic or bleached hornblende; clusters of biotite also occur in places. The alteration products of olivine are serpentine, nontronite, opaques, and iddingsite. The composition and texture of the intrusive rocks suggests that they have been contact-metamorphosed.

In the upper middle reaches of the Momi River (D68) coarse-grained biotite granite crops out. At the junction of the Momi and Sric Rivers (D69) near Kampung Aboni, numerous large boulders include muscovite granite,

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quartz-biotite-hornblende-clinopyroxene diorite, quartzite, and meta-argillite. A boulder of biotite-muscovite granite contains small fresh subhedral garnet and muscovite-chlorite-serpentine pseudomorphs, probably after cordierite. The K-Ar ages of muscovite from sample 76623082 (225 ± 4 m.y.) and of biotite and hornblende from sample 76623083 (respectively 232 ± 4 m.y. and 243 ± 4 m.y.) indicate a Permo-Triassic time of emplacement for the intrusives. Photo-interpretation suggests that the boulders come from a batholith.

In the upper Hiouw River (D71) very weathered coarse-grained biotite granite is exposed, and on the ridge crest between the upper Hiouw River and Lake Anggi Gita (D72) decomposed coarse-grained leucocratic intrusive rocks crop out, represented by quartz grains in soft white kaolinitic clay. On the southern shore of Lake Anggi Gita (D73 and D74) large boulders of weathered coarse-grained biotite-muscovite adamellite occur on the grassy slopes.

At D75 many small angular pebbles and cobbles of fine-grained dark quartzite and mica schist in the soil profile indicate that the contact between the granite and metamorphics is between D74 and D75, and on the ridge southwest of Lake Anggi Gita (D76) weathered highly indurated and cleaved pink shale crops out. Small pebbles of quartzite and orthoquartzite are common in the soil along the ridge crest southeast of D76.

Thin to medium-bedded, medium grey argillite dipping north at 30° is exposed on the northeastern shore of Lake Anggi Gigi (D77). These rocks display a weak cleavage at about 20° to the bedding, and prominent lineation at the intersection of bedding and cleavage.

KARAS AREA AND ONIN PENINSULA

Reconnaissance geological observations of the Onin Peninsula and Karas area (Pl. 6) were undertaken between 26 August and 10 September 1976 from the Australian Army forward survey base at Karas airstrip. Before 30 August, Pieters examined parts of the Onin Peninsula, and subsequently Ryburn, Memed Masria, and Kastowo worked from Karas around Sebakor Bay.

The outlines of the mountainous Onin Peninsula (heights up to 1600 m above m.s.l.) and the neighbouring Kumawa Peninsula, south of the map (Pl. 6), are controlled by large, gently arched, northwest and southeast plunging anticlinal structures in limestone. On the flanks of these are subsidiary fold structures, examples of which are expressed in the three promontories at the western end and in the islands on the south side of Onin Peninsula.

The limestone terrains are characterised by well-developed, sometimes spectacular karst landforms including cone karst, pyramid and doline karst, and crevice karst.

The finely dissected hilly lowlands between the Onin and Kumawa Peninsulas are underlain by moderately consolidated sediments; to the north and east an extensive alluvial plain encroaches on the lowlands. In the hilly area north and south of Karas the drainage is mainly to the east and only very short streams flow into Sebakor Bay and the bay farther north. The drowned coastline of the Onin Peninsula and the Karas area indicates recent tectonic subsidence.

The only township in the area is Fakfak; the majority of the indigenous population lives along the coast.

Tertiary limestone (Tl)

Limestone of early to middle Tertiary age makes up the two large anticlinal structures forming the Fakfak Mountains and the Kumawa Mountains, to the northwest and southeast of Sebakor Bay (Pl. 9). In these areas, Visser & Hermes (1962) distinguished three limestone formations of similar time span - the Onin, Ogar, and Kumawa Formations, mainly on the basis of facies variation and geographic distribution. However, it is doubtful that the distinction between these units can stand on a formal stratigraphic basis, and they may ultimately have to be considered as facies variants or members of the one formation, which is in turn part of the New Guinea Limestone Group (Visser & Hermes, 1962).

Rocks at the northern end of the Kumawa Mountains are exposed along the southern shore of Sebakor Bay. They are mostly compact well-bedded limestone striking consistently east, and dipping gently to the north. The coastal section along the strike, probably does not span any great stratigraphic thickness, and all the outcrops appear to be from near the top of the 'Kumawa Formation'. Foraminifera give ages ranging from mid-Oligocene (Td) to late Miocene (upper Tf or younger), but there are some inconsistencies in the age determinations. The oldest likely date is middle Miocene, and the youngest is late Miocene. For example, well-bedded sandy limestone at locality Ry76624016 yielded upper Te to lower Tf large foraminifera, and thin-bedded marl at the nearby locality Ry76624011 yielded small foraminifera not older than N9, suggesting the rocks in this area are middle Miocene; however, compact limestone from the westernmost locality (Ry76624020) yielded foraminifera that were upper Tf (late Miocene) or younger.

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Karas Island appears to be an extension of the northwest-trending anticline forming the Kumawa Mountains, and the rocks of Karas are correlated with the limestone in these mountains. Well-bedded impure limestone exposed on a small island west of Karas contain foraminifera of probable N12 (late middle Miocene) age.

Limestone collected in 1976 from the Onin Peninsula ranges from well-bedded hard and dense or chalky biomicrite to fine and coarse-grained biocalcarenite; the colours are white, cream, or buff, in places with manganiferous dendrites on joint planes. Planktonic foraminifera yielded ages ranging from N5 to N16 (early to late Miocene).

Plio-Pleistocene sediments (Tps)

Marine and terrestrial sediments of Plio-Pleistocene age cover much of the larger Bomberai Peninsula east of the Fakfak and Kumawa Mountains and Sebakor Bay. Visser & Hermes (1962) mapped them as Buru Formation, merging northeastwards into Steenkool Formation without any intervening mapped boundary. According to Visser & Hermes, these two Plio-Pleistocene formations are laterally equivalent, but represent different facies. The Steenkool Formation is primarily non-marine with a significant proportion of conglomerate. The Buru Formation is mainly shallow marine and partly calcareous.

Buru Formation sediments were examined in a series of good coastal outcrops west and north of Karas Airstrip. Here the main lithology is semi-consolidated fine to medium-grained marine sandstone with variable mud-matrix content, commonly bioturbated or containing organic burrows. Some outcrops contain harder beds of calcareous sandstone or horizons of nodular calcareous concretions. Shell fragments, bivalves, and gastropods are common, and some beds are slightly glauconitic. The sandstones are mostly well bedded and dip gently westwards, probably away from a broad anticlinal axis that parallels the coast a short distance inland. Small-scale cross-bedding was noted in several outcrops. The coastal outcrops examined appear to represent much the same stratigraphic level.

Thick-bedded, slightly micaceous grey marine siltstone containing mollusc fragments is exposed in a bulldozed outcrop beside Karas Airstrip. Smaller foraminifera of N17 to N21 age (late Miocene to late Pliocene) were collected from here (Ry76624012), and small foraminifera of N11 to

N19 age from an exposure several kilometres farther west (Ry76624013). A short distance inland from the southeast corner of Sebakor Bay, soft, slightly calcareous grey mudstone with shell fragments yielded smaller foraminifera of N19 (early Pliocene) age (Ry76624022). This last outcrop is very near the base of the sequence, which in this area overlies the 'Kumawa Formation'.

WANDAMEN PENINSULA

Reconnaissance observations of the Wandamen Peninsula and the environs of Wandamen Bay (Fig. 8) were carried out from the Australian Army forward survey base at Wasior by Ryburn, Memed Masria, and Kastowo, between 12 and 19 September 1976.

The Wandamen Peninsula projects 60 km northwards into the western part of Sarera Bay; Wandamen Bay lies to the west of the peninsula. The Wondiwoi Mountains, up to 2200 m in altitude, form the axis of the peninsula, and the flanks of this range drop very steeply to the coasts on either side. Most streams draining the range are precipitous and inaccessible. The northern end of the peninsula is lower, and has a classic drowned-valley coastline, particularly in its extension, Roon Island (Fig. 8). The western side of the peninsula is a fault scarp, with a narrow alluvial-fan pediment.

Wandamen Metamorphics

Visser & Hermes (1962) briefly mentioned unnamed gneisses, which they mapped around the northern and eastern coast of the peninsula. The central part of the peninsula was left blank on their map. Our observations prove that this central part is also composed of amphibolite-grade gneisses; these rocks are provisionally named Wandamen Metamorphics.

The metamorphics were seen mainly in float in streams draining the western flank of the peninsula between Wasior and the Ibari River. For the most part they are strongly foliated quartzofeldspathic gneisses, including some lineated and augen textural varieties, containing muscovite, biotite, and less commonly garnet. Amphibolitic metabasite occurs in small amounts, and pelitic schists with garnet porphyroblasts are also present in float at the southern end of the peninsula.

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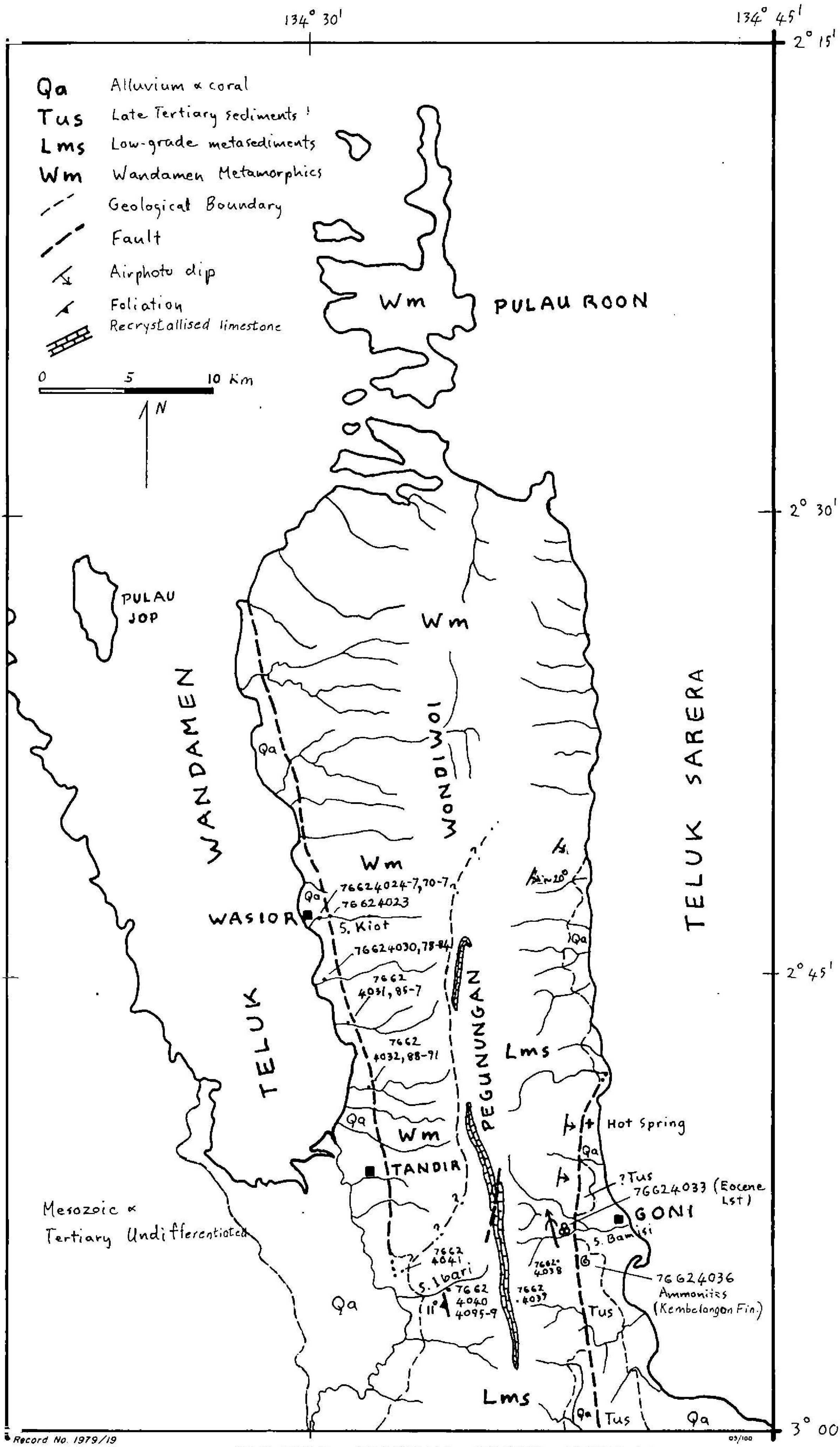

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Fig. 8 GEOLOGICAL SKETCHMAP—WADAMEN PENINSULA

Only a few outcrops of Wandamen Metamorphics were seen. At the swimming pool in the Kiot River, near Wasior, mylonitised quartzofeldspathic gneiss is exposed; the mylonitisation may be related to the major fault bounding the western side of the Wondiwoi Mountains. In the Ibari River, south of Tandir, banded marble is exposed and similar lithologies, some with mesofolds, were also seen on the crest of the range to the southeast of the Ibari River. In general, the degree of recrystallisation and metamorphic grade decreases southwards from Wasior.

Thin sections show that the quartzofeldspathic gneisses are orthogneisses derived from pre-existing granite, granodiorite, and quartz monzonite. Mineralogically they are a quartz-oligoclase-potassium feldspar-muscovite-biotite-garnet gneiss. Quartz is usually more than 20%, commonly 30%, and plagioclase may be more abundant than potassium feldspar, or vice versa. Most are probably granitic in composition rather than granodioritic, although some are rather low in quartz and are trending towards quartz monzonites. In rocks with about 20% quartz, the plagioclase is generally sodic andesine. The porphyroblasts in the quartzofeldspathic augen gneiss are all potassium feldspar - not plagioclase - and are probably relict megacrysts, similar to the megacrysts in some granites and monzonites from Kepala Burung. The margins of potassium feldspar 'porphyroblasts' are granulated, and microcline twinning and myrmekitic intergrowths are common. Almandine garnets (including atoll garnets) are commonly present as sparsely distributed semihedra, and most rocks also contain accessory clinozoisite or epidote, sphene, apatite, zircon, and opaques. In one rock from the Ibari River (Ry76624098), there are accessory euhedra of non-metamict allanite, which also occurs in granites in Kepala Burung.

The metabasic rocks, which are much less common, appear to be metamorphosed gabbros (or basalts) and diorites, although some may be basic metasediments. Some contain quartz, but potassium feldspar is absent or minor, and the plagioclase is commonly labradorite or andesine. Most contain hornblende and/or biotite, and almandine garnet. Several of the metabasic rocks appear to be retrograded group B eclogites, containing abundant garnet, some quartz, corroded clinopyroxene (?omphacite) with kelyphytic rims, and hornblende which is probably derived in part from pyroxene during retrograde metamorphism. Large zoisite euhedra are present in some of these eclogites (Ry76624079), and rutile is present in all, often jacketed by sphene.

In the <u>pelitic schists</u>, potassium feldspar is generally absent, and most contain an epidote mineral such as clinozoisite or zoisite (mostly alpha zoisite). Typically, they consist of quartz, oligoclase or andesine, muscovite, biotite, garnet, epidote, sphene, apatite, tourmaline, and zircon in decreasing order of abundance. Magnesian chlorite is present in some of the lower-grade examples, and plagioclase and biotite are absent in some others. Carbonate-bearing metasediments are also present in the south.

Preliminary calculations of equilibria involving zoisite, the grossular component of garnet, the anorthite component of plagioclase, quartz, and H_2O suggest that the quartzofeldspathic and pelitic gneisses have been metamorphosed at pressures of the order of 8 to 10 kilobars, at an estimated temperature of 600^oC. For the equilbrium:

$$4Zo + Q = Gr + 5An + 2H_2O$$

the effect of dilution of the grossular and anorthite components in garnet and plagioclase is to displace the equilibrium for pure components to higher pressures. It is likely that the quartzofeldspathic gneisses were metamorphosed under rather dry conditions, and conditions where the partial pressure of H_2O is less than the lithostatic pressure would also tend to displace this reaction to higher pressures (or lower temperatures). High pressures are also indicated by the equilibrium:

$$2Musc + Gr + 3Q = 2Kf + 3An + 2H_2O$$

in which the effects of solid solution in garnet and plagioclase tend to cancel each other. The presence of eclogitic rocks confirms the indications of rather dry metamorphic conditions at high lithostatic loads. It is quite probable that these rocks were originally basalt or dolerite dykes within the granitoids that were metamorphosed to form the quartzofeldspathic gneisses.

K-Ar muscovite and biotite ages from two quartzofeldspathic gneisses from Kiot River indicate very young metamorphism at about 4 m.y., or at least very recent uplift of rocks that were held hot and deep for a longer time. The type of metamorphism is quite unlike that of the Kemum Formation in eastern Kepala Burung, which is a relatively high-level metamorphism of pelitic sedimentary rocks producing low-pressure phases such as andalusite and sillimanite. Also, the metamorphism of the Kemum Formation antedates

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or is synchronous with the emplacement of granitoids in that area, in the late Permian to Early Triassic. The Wandamen Metamorphics are more likely to be related to the belt of Tertiary high-pressure metamorphism along the northern fall of the central ranges of Irian Jaya, which is known to contain blueschists in several areas (van der Wegen, 1971). From the general range of composition of the quartzofeldspathic gneisses, the abundance of potassium feldspar, and the presence of relict igneous minerals such as allanite, we are confident that part of the Wandamen Metamorphics was derived from granitoids which are correlatives of those in eastern Kepala Burung and therefore probably of Permo-Triassic age. The metamorphism was of a high-pressure, strongly dynamothermal type, and was probably Tertiary in age.

Kembelangan Formation

Blocks of carbonaceous sandstone and shale containing belemnite holes and two ammonites (locality Ry76624036) from a small stream about 3 km west-southwest of Goni, on the eastern side of the Wandamen Peninsula, are the only definite occurrence in this area of the widespread Mesozoic Kembelangan Formation. Other lithologies recorded in float are quartzite, quartzitic sandstone, and dark carbonaceous sulphide-bearing shale and siltstone. These rocks which are quite unmetamorphosed, are similar to Jurassic and Cretaceous rocks equivalent to the Kembelangan Formation in the Telefomin area of Papua New Guinea. The ammonites are awaiting identification.

It seems that the Kembelangan Formation near Goni occurs on the eastern (downthrow) side of a north-trending fault, and is not as extensive as shown by Visser & Hermes (1962). The formation is not shown on the map (Fig. 8), as it is overlain by Late Tertiary sediments or gravels, and is probably exposed only over a very small area.

Eocene limestone

Ribbon-bedded, fine-grained limestone containing (?middle) Eocene small foraminifera is exposed in the Bamisi River about 4 km west of Goni (Ry76624033). The limestone, which is a deep-water calcilutite or micrite, forms a tightly folded north-plunging anticline visible on aerial photographs. The core of the anticline contains sheared, slightly calcareous phyllitic shale and knobbly silicified fine-grained sediments. Boulders of highly fossiliferous compact limestone containing bivalve fragments were sampled lower down the Bamisi River, but could not be dated.

Visser & Hermes (1962) depicted a similar anticline at this locality, but with Triassic Tipuma Formation folded around a core of Permo-Carboniferous Aifam Formation, and surrounded by Mesozoic Kembelangan Formation. This identification of Eocene foraminifera in the 'Tipuma Formation' throws serious doubt on their interpretation and raises the possibility that all the rocks associated with the Eocene limestone are not as old as they thought.

Recrystallised limestone and phyllite (Lms)

At the base of the Wandamen Peninsula, between Goni and the Ibari River, the Wondiwoi Mountains are made up largely of low-grade metasedimentary rocks, including recrystallised limestone with numerous calcite-filled fracture veins, phyllite, metagreywacke with quartz veins, and quartzite or metachert. The grade of metamorphism appears to increase from east to west, although not much outcrop was seen on the traverse across the range west of Goni. Float from the Bamisi River includes some altered igneous rocks, of which a low-quartz granite or quartz monzonite and a hornblende diorite were identified in thin section. Both these rocks have undergone greenschist-type alteration, with the development of albite, chlorite, actinolite, and epidote. One quartz-rich metasediment has been metamorphosed in the biotite-zone. The low-grade metasediments extend some distance up the east side of the peninsula, and were seen in float at a hot-spring 6 km north of Goni.

The occurrence of the Eocene limestone within this low-grade metasedimentary terrain does not necessarily imply a similar age of deposition for all rocks, but calcareous lithologies are common in the metasediments, and the recrystallized limestone mapped along the crest of the range (Fig. 8) may well be the same age. On the other hand, the metasediments may represent the Kembelangan or Kemum Formations; some phyllite outcrops in the Bamisi River are very sheared, suggesting a melange-type terrain.

These rocks may be low-grade equivalents of the Wandamen Metamorphics, but they differ greatly in composition from the quartzofeldspathic gneisses in the Wasior area, which contain few if any metasediments. In the Ibari River, however, at the southern end of the area examined on the western side of the Wondiwoi Mountains, the metasediments, including phyllite semischist, and marble, are probably slightly higher-grade equivalents of the metasedimentary rocks on the eastern side of the range. The float in the Ibari River also includes some quartzofeldspathic schists derived from granitic rocks, and further work is required to resolve the relation between the low-grade metasediments and the high-grade Wandamen Metamorphics.

Late Tertiary sediments (Tus

To the south of Goni, low hills at the base of the eastern flank of the Wandiwoi Mountains are probably underlain by late Tertiary clastic sediments, possibly of the Steenkool Formation. Semi-lithified grit in float in the Bamisi River, near Goni, is probably from this unit.

Hot springs

A hot spring about 6 km north of Goni was visited at the request of the villagers, who were concerned that the spring might be a young volcano. Slightly effervescent hot water, at about 70 to 80^{o}C, emerges from alluvium, and has built a small mound of precipitates (silica and ?alum) about 2 m high. Foxy-brown hydrous iron oxides occur as a flocculent precipitate in the small stream beside the mound. Another hot spring reported to occur in the upper reaches of Kiot River inland from Wasior, was not visited.

The existence of hot springs is probably related to very young uplift of the peninsula, reflecting the young K-Ar ages obtained from the gneisses at Wasior. Warm rocks may occur at no great depth beneath the Peninsula, within the zone open to circulating groundwater, and faults probably play a part in the location of these springs. It is unlikely that the area has been subjected to recent magmatism.

Structure

As shown by Visser & Hermes (1962), there is a major fault bounding the western side of the Wondiwoi Mountains, with at least 2000 m of uplift on the eastern side. The eastern side of the peninsula is also bounded by a fault in the Goni area, but the displacement on this fault may not be as great. The Wandamen Peninsula may thus be a horst, or alternatively a cuesta, tilted towards the east. The eastwards decrease in metamorphic grade across the base of the peninsula suggests the latter alternative.

The existence of very young, relatively high-pressure metamorphic rocks implies recent rapid uplift, possibly from depths as great as 30 km. One possibility is that the Wandamen Metamorphics were trapped in an incipient subduction zone, formed along the advancing edge of the Birdshead (Kepala Burung) and Birdsneck block, during the clockwise rotation of this block in the Tertiary, as postulated by Robinson and Ratman (1977, 1978). Subsequent relaxation of rotation would then allow these rocks to rise buoyantly. Whatever the mechanism, the peninsula is an anomaly in the mainly sedimentary Birdsneck area, and major tectonic movements are required to explain its present disposition.

THE SCHOUTEN ISLANDS

The Schouten Islands comprise the large islands of Biak and Supiori, the small island of Bepondi, and several coral islets southwest and southeast of the larger two (Fig. 9).

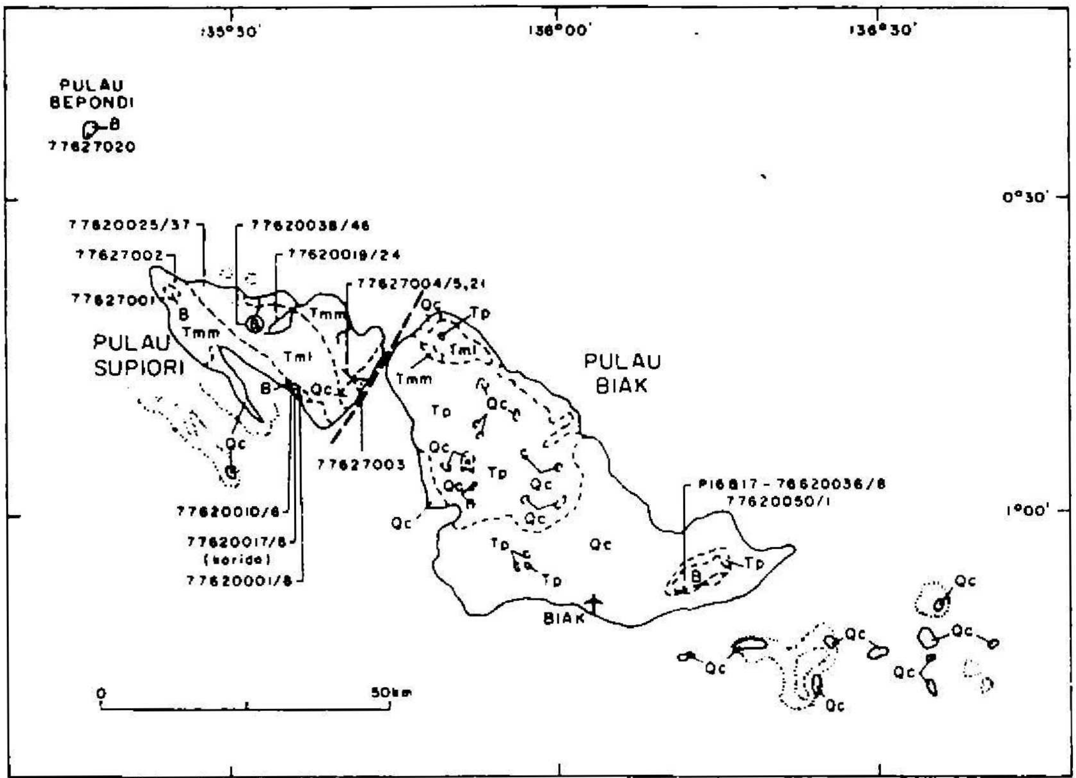
In 1976, Pieters made a half-day visit to southeast Pulau Biak, where an inlier of volcanic and ultramafic rocks is overlain by Neogene sediments and Quaternary limestone. In 1977, Pieters and Trail worked for about a month with a party of five GSI geologists mapping the Schouten Islands at 1:250 000 scale. Most samples collected by Pieters and Trail were taken to GSI headquarters at Bandung for petrographical and micropaleontological study; a few were sent to BMR, Canberra, for detailed petrographical and chemical examination.

In this section the work of the BMR geologists in the Schouten Islands is summarised; information from Visser & Hermes (1962) is used for a better understanding of the regional framework.

Basement rocks (B)

Small areas of basement outcrop are known from the southwest coast of Supiori, southeast Biak, and Bepondi, 25 km northwest of Supiori (Fig. 9).

On the southwest coast of Supiori, phyllite and schist are either intruded by or are faulted against basalt and gabbroic rocks; Visser & Hermes (1962) mentioned that the basic igneous rocks intrude as well as overlie the metamorphics. The greenish grey fine-grained phyllite and schist



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QUATERNARY	Qc	*Coral limestone and chalk*
UPPER MIOCENE TO PLIOCENE	Tp	*Chalky marl with interbeds of limestone and sandstone*
UPPER OLIGOCENE TO MIDDLE MIOCENE	Tmm	*Marls with interbedded fossiliferous limestone, greywacke sandstone and conglomerate*
UPPER OLIGOCENE TO MIDDLE MIOCENE	Tml	*Fossiliferous limestone*
BASEMENT; AGE UNKNOWN	B	*Metavolcanics, serpentinite, and basalt and gabbro*
	------	*Geological boundary*
	— — —	*Fault*
	P16 - 76620036	*Sample locality with fieldbook and rock sample reference number*
	Ⓐ	*Sample locality for K-Ar age determination*
	✢	*Airfield*

Fig. 9 Geology of Kepulauan Schouten.

represent metamorphosed basic volcanic rocks including tuff or volcanic sediment and lava flows.

The metatuff or metasediment has thin intercalations of very fine-grained quartzite and a well-preserved relict volcanoclastic texture with porphyroblasts of brownish green actinolite and albite, and minor epidote/clinozoisite, opaques, and relict augite, in a groundmass of the same minerals with chlorite and cryptocrystalline quartz. Most of the actinolite is probably formed after clinopyroxene. A weakly developed foliation is caused by subparallel alignment of elongate, locally wavy actinolite and streaky opaques. The steeply dipping, east-trending foliation is roughly parallel to thin layers, laminae, and lenses of quartz with minor epidote/clinozoisite and carbonate. These may be relics of chert intercalations and are refolded with the foliation; microscopic isoclinal folds and mesoscopic symmetrical open folds were observed. A float sample of colour-banded meta-basalt consists of a very fine-grained aggregate of interlaced fibrous actinolite, minor albite, chlorite, and opaques, and rare remnants of clinopyroxene.

The most widespread unmetamorphosed mafic igneous rock types in the basement are dark grey massive aphanitic basalt and brownish grey, fine to medium-grained gabbro. The main mafic mineral is augite, but hypersthene, primary hornblende, and olivine have also been observed. In many rocks plagioclase is altered to albite, epidote/clinozoisite, and carbonate; pyroxene to uralite, epidote/clinozoisite, and chlorite; and olivine to serpentine, magnetite, and bowlingite. Similar mafic igneous rocks make up the bulk of pebbles and cobbles in conglomerate in the overlying sediments, interbedded with Tertiary shallow-marine limestone, calcareous sandstone, and mudstone with shell and plant fragments.

The metamorphics are mineralised near the south point of Supiori, where they contain scattered or streaky pyrite, and pyritic quartz bands which are stained black or red by iron, coated by malachite, and carry specks of bornite. A rock chip sample yielded 8700 ppm (0.87%) Cu, 5 ppm Pb, 70 ppm Zn, 5 ppm Co, 8 ppm Ni, 40 ppm Cr, and 28 ppm Mn. A follow-up investigation is recommended to evaluate the copper potential of the metamorphic rocks and to determine the nature of the mineralisation.

A sample of gabbro (77620046) from the basement gave a whole-rock K-Ar age of 391 ± 30 m.y. (Early Devonian; Appendix 1). The sample has an extremely low potassium content and the possibility of an anomalously high age due to the presence of extraneous Ar^{40} must be considered.

At the northwest end of Bepondi Island blackish basalt breccia and conglomerate was mapped. Locally the conglomerate contains abundant fragments of weathered greenschist. The basalt is almost completely altered to a very fine-grained aggregate of mainly mafic secondary minerals and minor albite.

An oval area of very low hills in the southeast part of Biak Island is mostly underlain by altered basic volcanics, serpentinite, and serpentinised peridotite; whitish chert was encountered in one small outcrop. Two samples of basic volcanics examined are both basalt flows; one consists of a very fine-grained interwoven aggregate of mostly secondary mafic minerals (70% actinolite and tremolite) and minor albite, the other sample has a hyalo-ophitic texture and is composed of devitrified glass (including palagonite and quartzofeldspathic material), ragged crystals of plagioclase, augite, hypersthene, and rare ironstained volcanic xenoliths.

Cainozoic sediments (Tml, Tmm, Tp)

The basement rocks on Supiori, Biak, and Bepondi Islands are unconformably overlain by Cainozoic sediments. Visser & Hermes (1962) reported different sedimentary sequences from Supiori and the northern corner of Biak on the one hand, and the remainder of Biak on the other. The following description of the sediments is compiled from Visser & Hermes; the 1977 fieldwork mostly confirms their findings.

The oldest Tertiary sediments on Supiori and northwest Biak comprise late Oligocene to middle Miocene, massive dense fossiliferous limestone (Tml) which laterally grades into greenish and brownish compact marls, tuffaceous marls with interbedded fossiliferous limestone, and coarse greywacke (Tmm); in addition lenses of conglomerate with mainly basic igneous clasts were observed during the 1977 survey. These sediments are overlain by greenish and olive-brown foraminiferal marls (Tp) of late Miocene to Pliocene age which are in turn overlain by Quaternary reef limestone and chalk (Qc).

Much of Biak is covered by late Miocene to Pliocene, well-bedded or massive, white to buff chalky marl containing numerous interbeds of hard brown sandy and marly limestone and sandstone (Tp). The basement inlier in the southeast of Biak is locally overlain by small outcrops of older limestone which may be equivalent to the late Oligocene to Middle Miocene limestone on Supiori. The youngest sediments are, as on Supiori, Quaternary coral limestone and chalk; raised coral terraces occur as high as 100 m above m.s.l.

On Supiori the sediments are tilted to the northeast along a series of subparallel northwest-trending faults. The faults are easily recognised on aerial photographs as pronounced lineaments, and in the field they are associated with waterfalls (Fig. 7) and zones of shearing, slickensiding, folding and subsidiary faulting. Biak and Supiori are separated by a major northeast-trending transcurrent fault.

GAG ISLAND

Gag Island, which is about 8 km in diameter, is 160 km west-northwest of Sorong, at the western end of Irian Jaya. An extensive deposit of nickeliferous laterite on this island is currently being developed by P.T. Pacific Nikkel. Ryburn, Sumadirdja and Trail visited the island from 19 to 21 October 1976, and are indebted to Pacific Nikkel for excellent hospitality.

The island is almost entirely composed of rocks originating in the oceanic upper mantle and crust. The western part of the island (Fig. 10) is underlain by partly serpentinised harzburgite, on which the nickeliferous laterite is developed. This part of the island rises steeply from the sea, but levels out inland to undulating hummocky topography, with the highest point about 350 m above sea level. Vegetation on the ultramafic rocks is stunted and scrubby. The northeastern part of the island is lower and carries luxuriant vegetation; it is underlain by mafic rocks which appear to be mainly a dolerite dyke complex, similar to those reported from ophiolite sequences elsewhere in the world. There is a low coral platform around the northeastern part of the island on which the airstrip is built.

Ultramafic rocks (Juh)

The ultramafic rocks forming the southwestern two-thirds of the island are mainly massive, partly serpentinised harzburgite, with minor veins and dykes of orthopyroxenite. Inland, the ultramafic rocks are deeply weathered and extensively lateritised, but fresh exposures occur in sea cliffs, particularly on the western side of the island.

The harzburgites originally contained 80 to 90% magnesian olivine, but are now extensively serpentinised along meshworks of cracks between surviving olivine grains. The least serpentinised examples contain about 40% serpentine. The remaining olivines exhibit strain shadows typical of metamorphic (tectonite) harzburgites. Enstatite, also showing strain phenomena but generally unserpentinised, makes up the rest of these rocks, along with accessory chrome spinel (picotite). The orthopyroxene contains exsolution lamellae of calcic clinopyroxene. A few discrete grains of chrome diopside were noted in one sample (7041).

The orthopyroxenite 'dykes' that cut the harzburgite at many localities range in thickness from a few millimetres to about 10 cm, and are composed of coarsely crystalline enstatite or bronzite. These 'dykes' are not magmatic but are the products of reaction between the metamorphic harzburgites and silica-rich fluids circulating along fractures in the harzburgites.

One harzburgite sample from the western side of the island (locality 7047) was analysed for major and trace elements (Appendix II, analysis no. 9). With due allowance for the high water content caused by serpentinisation, this analysis is typical of metamorphic harzburgites that occur at the base of ophiolite sequences the world over (Coleman, 1977). The nickel value of 2050 ppm is slightly lower than typical values quoted by Coleman, but is in no way anomalous for these rocks. Occurrences of lateritic nickel on alpine ultramafac rocks are primarily due to concentration by weathering phenomena, and the mostly uniform nickel values in alpine ultramafic rocks are not a major factor in determining the location of lateritic nickel deposits.

The nickel mineralisation comprises a blanket deposit of iron-poor laterite with a wide range of thickness but averaging 12 m thick and lying directly on weathered harzburgite. Assessment of the grade of the mineralisation is continuing. This blanket deposit is overlain by overburden, comprising iron-rich laterite, averaging 3 to 5 m thick and ranging up to 20 m in thickness.

Sheeted dyke complex (Jud)

Mostly mafic rocks underlying the northeastern part of the island are juxtaposed against the ultramafic rocks by a prominent northwest-trending fault (Fig. 10). These mafic rocks are well exposed only on the east coast north of the bay in which the mining settlement is located. Where seen in good coastal outcrops, they comprise a sheeted dolerite dyke complex similar to that described from the Troodos Massif, Cyprus (Moores & Vine, 1971; Coleman, 1977), and other well documented ophiolite sequences.

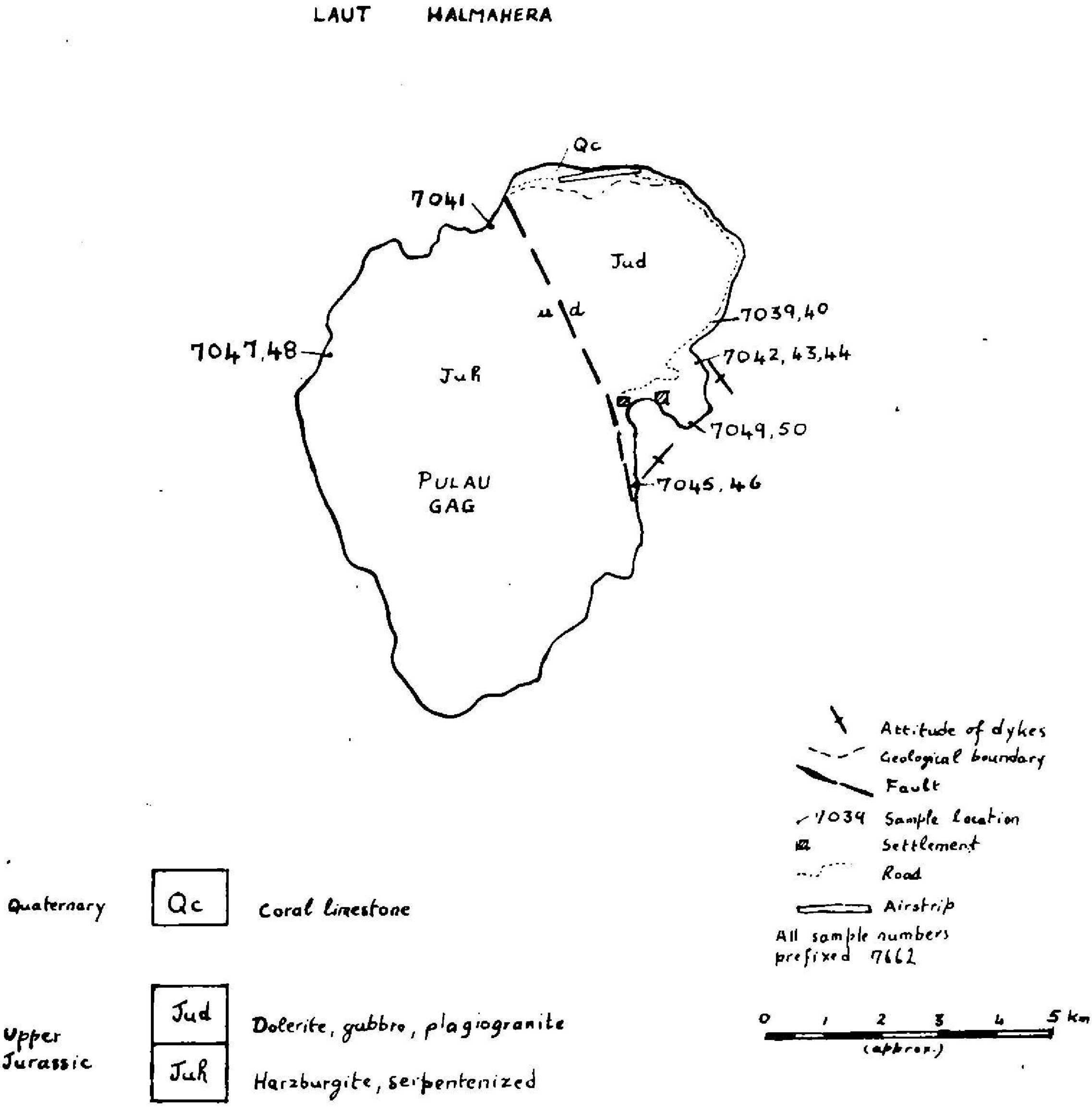

Fig. 10 GEOLOGY — GAG ISLAND

The complex consists of a series of subparallel dykes of dolerite, microdolerite, and basalt from a few centimetres to 5 m thick. The dykes mostly strike north to northwest, and dip vertically to steeply southwest, although some cut irregularly across the general trend. The outcrops appear to be composed entirely of dykes, with no identifiable host rocks.

This feature is characteristic of the sheeted dyke layer present in many ophiolite complexes (Coleman, 1977). The sheeted dyke layer generally overlies gabbros and underlies pillow lavas, and is believed to be formed by the injection of magma along vertical fractures that continually open where oceanic crust is generated along mid-ocean spreading ridges. Pillow lavas were not identified on Gag Island, but boulders of coarse gabbro are common on the beaches near the dyke-complex outcrops, and gabbro has been found in exploratory drilling at the settlement close to the fault (Fig. 10). In some outcrops the dyke complex includes up to 10% of light-coloured plagiogranite as dykes and less regular minor intrusions. Plagiogranite is a tonalitic differentiate that occurs in many ophiolite sequences, and has been recovered in dredge hauls from the deep ocean floor.

The basic dykes are altered, probably by the type of hydrothermal circulation believed to occur beneath mid-ocean ridges. Plagioclases are variably albitised and clinopyroxene is commonly uralitized or converted to chlorite, epidote, and carbonate. Iron-titanium oxides are partly altered to sphene. Prehnite occurs in several samples, and pumpellyite may be present in one microdolerite (7040). Up to 10% primary quartz is present in some of the more fractionated dolerites (e.g., 7045).

One sample of plagiogranite (7044) and one of 'gabbro' (7050) were examined in thin section. The plagiogranite contains about 35% primary quartz, 60% partly or completely albitised plagioclase, 5% hornblende altering to actinolite, and accessory opaque oxides and apatite; minor amounts of secondary chlorite and epidote are also present. The coarse 'gabbro' contains 30% heavily sausuritised plagioclase, 60% primary hornblende, and 5% secondary actinolite; this rock could be described as a diorite rather than a gabbro, but the original plagioclase composition is uncertain, and the rock was not chemically analysed.

Five dyke rocks, including one plagiogranite, from northeast Gag were analysed for major and trace-element composition (Appendix II, analyses 10-14). All are metamorphosed or hydrothermally altered to some degree, and the results, particularly for alkalis, should be treated with some caution. Major elements are generally similar to those reported by Coleman

(1977) from ophiolite dyke complexes elsewhere in the world, although the SiO_2 values are slightly higher and TiO_2 is somewhat lower than average. The dykes sampled on Gag appear to be more highly fractionated than normal. The plagiogranite (7044) contains 68% SiO_2 and is typical of plagiogranites reported by Coleman & Peterman (1975) and Coleman (1977). The high sodium content (4.7%) is probably due to some addition of this element from circulating hot seawater, and the rock could also be described as a quartz keratophyre, as the plagioclase is albitised. The other analyses can be broadly grouped under the term quartz dolerite, as all contain normative quartz (up to 12% in 7045), and have doleritic textures. A notable feature of all analyses is the very low K_2O content, typical of ophiolitic rocks in general.

Trace elements are similar to other ophiolitic dyke rocks and pillow lavas, although some variability is apparent, which may partly be the result of alteration affecting the less refractory trace elements. The plagiogranite values are closely similar to the average values given by Coleman (1977) for that group of rocks. The very high lead content (2400 ppm) in 7049 can be ascribed to secondary galena mineralisation, if all the sulphur content (400 ppm) is contained in galena. Base-metal sulphide mineralisation occurs in the upper parts of many ophiolite sequences.

Amphiboles from quartz dolerite 7042 yielded a K-Ar age of 148 $\pm$ 8 m.y. (late Jurassic). Although these amphiboles appear to be secondary, they are probably the result of alteration that took place at a spreading ridge, more or less contemporaneously with the emplacement of the dolerite dykes. However, the result should be used with caution, as it is a single determination only, and has a high uncertainty owing to the low K_2O content of the amphibole.

THE CYCLOOPS MOUNTAINS

In the latter half of 1977 a GSI party based at Sentani used helicopters to map the geology of parts of the Cycloops Mountains and Sarmi 1:250 000 Sheet areas. Pieters and Trail visited this party briefly, and Pieters also visited the Jayapura office of the Mines Department in 1976; on each of these visits reconnaissance traverses were made in the Cycloops Mountains (Fig. 11).

The Cycloops Mountains form a range 40 km long and 10-15 km wide extending along the north coast from Humboldt Bay in the east to Tanah Merah Bay in the west. The north flank of the range rises abruptly from sea level

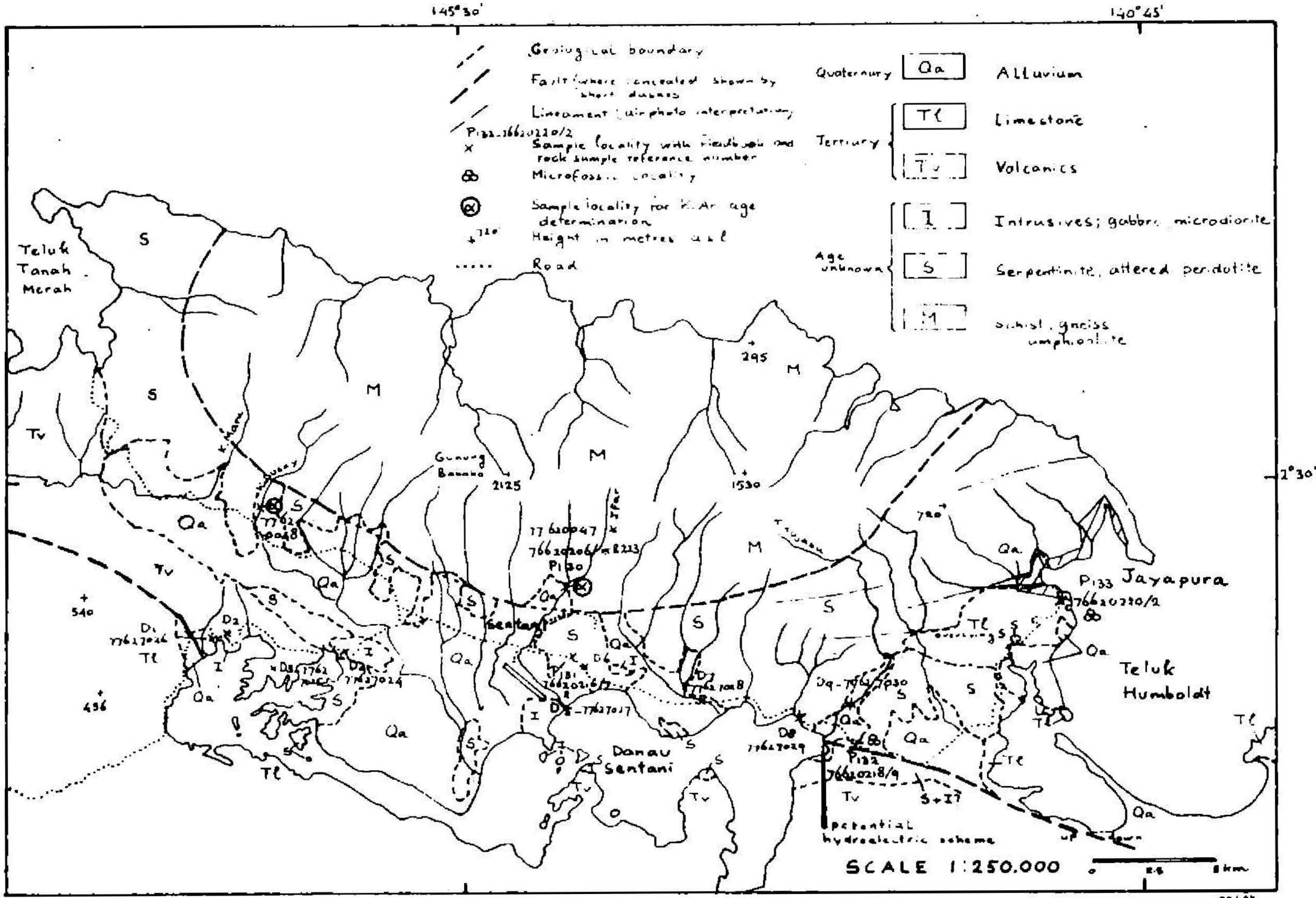

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Fig. 11 GEOLOGY - CYCLOOPS MOUNTAINS

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to a height of over 2000 m above m.s.l. (Mount Baboko, 2125 m). The southern flank is equally steep, but alluvial outwash fans, separated by low ridges, along the foot of the range slope into the irregularly shaped 25-km-long basin occupied by Lake Sentani. The lake surface is at a height of 70 m above m.s.l., and the lake drains through its southeastern arm into the Sunggrum River.

The sequence of geomorphological features between Humboldt Bay and Lake Sentani (Fig. 11) illustrates the formation of a lake from an arm of the sea or estuary by tectonic uplift. At the head of Humboldt Bay a small lagoon is almost cut off from the sea by a sand or mud bar. Between this lagoon and Lake Sentani a flat-floored depression about 10 to 20 m above m.s.l., enclosed by low hills represents a former part of Humboldt Bay.

Lake Sentani may have been a deep arm of the sea, a strait between Humboldt Bay and Tanah Merah Bay, or possibly a wide river valley. The present level of the lake at 70 m above m.s.l. and wave-cut platforms and terraces up to 50 m above the lake surface indicate recent uplift of about 120 m. The presence of sharks in the freshwater lake points to a marine or estuarine origin.

A suitable site for the generation of hydroelectric power occurs in the north~~west~~east corner of Lake Sentani, where serpentinite and limestone hills form a low divide about 2 km across between the lake and an alluvial plain about 50 m below the lake surface. It is recommended that the site be further investigated to determine its potential for the generation of electricity.

The Cycloops Mountains are formed by metamorphic, ultramafic, and mafic intrusive rocks. The metamorphics include schist, gneiss, and amphibolite - probably derived from intermediate to basic volcanics and intrusives, and volcanic and calcareous sediments. The ultramafics are mostly serpentinite and serpentinised peridotite. The mafic intrusives range from gabbro stocks to dolerite dykes. These basement rocks are unconformably overlain by Neogene limestone.

<u>Metamorphic rocks (M)</u>

Metamorphic rocks were sampled only in the Ifar, Dusay, and Kujabu Rivers, where they consist of acidic to intermediate schist and gneiss, and amphibolite (marble or metalimestone are described by previous workers - e.g., Baker, 1956). The most common mineral assemblage of the schist and gneiss is albite-epidote/clinozoisite-chlorite-muscovite with or without quartz and/or actinolite; one amphibolite studied in thin section has carbonate in addition to the above assemblage. Most rocks contain accessory sphene, opaques (mainly magnetite) and apatite. Garnet occurs in some acidic as well as basic metamorphic rocks, and some of the chlorite is possibly retrogressive after garnet, as the textures of many rocks point to an originally higher degree of metamorphism.

Most rocks have a moderately to well-developed foliation which is defined by metamorphic layering and preferred orientation of tabular and prismatic minerals; the foliation is folded on a mesoscopic scale. The majority of the rocks are porphyroblastic with large, commonly poikiloblastic crystals of epidote/clinozoisite (up to 2 cm across), albite, and garnet; other rocks are fine to medium and even-grained. Some of the porphyroblastic epidote/clinozoisite has microscopic S-shaped inclusions suggesting syntectonic recrystallisation.

K-Ar analyses (Appendix I) of muscovite from quartz-albite-epidote/clinozoisite-chlorite-muscovite schist and gneiss gave metamorphic ages of 20.6 $\pm$ 0.4 m.y. and 21.4 $\pm$ 0.4 m.y. (early Miocene); the age of formation of the original rocks is unknown.

Ultramafic rocks (S)

The belt of foothills along the inland flanks of the Cycloops Mountains is made up of serpentinite and altered peridotite intruded by gabbro and microdiorite.

The massive serpentinite is commonly weathered, ranging from yellow-green through brown-green to black, or from reddish yellow to brown; in places it is stained by secondary iron oxide. Thin veins of asbestos were observed where the road to Sentani leaves Jayapura (P133).

In most serpentinites the olivine is altered to serpentine, which is either mesh-textured or forms massive aggregates, and to opaques; pyroxene is altered to serpentine, clinoamphibole, chlorite, or opaques. Relict crystals of pyroxene are rare, but the occurrence of bastite suggests that much of the serpentinite is derived from harzburgite. Baker (1955, 1956), who studied the ultramafic rock suite in detail, concluded that harzburgite and dunite were the most widespread parental rock types. Fine-grained clusters of rounded pyrope-garnet were found in serpentinite at P133.

Intrusives (I)

Gabbroic rocks were sampled at a road cutting through the hills which fringe Lake Sentani 7 km west of Sentani Airport (D4). The bluish grey fresh medium-grained gabbro consists of plagioclase, augite, and minor olivine.

Dykes of dolerite emplaced in serpentinite crop out in a quarry along the road northeast of Sentani Airport (P131, D5). The rocks are fine-grained, even-grained or feldsparphyric, hypidiomorphic-granular to sub-ophitic, and are cut by veinlets of prehnite. They are composed of plagioclase (An_{54}), secondary actinolite, and minor opaques; the actinolite is probably altered clinopyroxene. One sample shows more advanced alteration and consists of very fine-grained actinolite, chlorite, epidote/clinozoisite and minor opaques, and is riddled with patches and veins of prehnite.

Volcanics (Tv)

Volcanic rocks were collected only along the road immediately west of Lake Sentani (D1, 2). Black aphanitic basalt occurs in spheroidal structures which measure about 1 m across and are separated by soft white or red material; the structures are reminiscent of pillow lavas. In thin section the rock at D1 has a hyalo-ophitic texture with small olivine and augite phenocrysts in colourless or pale brown fresh glass. The quenched augite occurs as anhedral to subhedral, long, strained and swallow-tailed laths with deformed twin lamellae and cleavage; the earlier crystallised olivine is subhedral to euhedral with ?pyroxene microlites perpendicular to its crystal faces.

Sediments (Tl)

South of Jayapura at P133 serpentinite is unconformably overlain by discontinuous beds of conglomerate or breccia up to a few metres thick, in which clasts of serpentinite and altered peridotite are cemented by limestone. The conglomerate and breccia are overlain in turn by massive, micritic, strongly veined limestone. In quarries along the road from Jayapura to Lake Sentani the basal conglomerate or breccia is missing and limestone directly overlies serpentinite.

The rocks sampled at an old limestone quarry along the Jayapura-Sentani road (P132) about 1.5 km east of Lake Sentani include white to creamy, massive cavernous biomicrite and greyish biocalcarenite. Larger benthonic foraminifera in the rocks from P132 indicate only a general Tertiary age, but from P133 they given an age of Miocene or younger.

ECONOMIC GEOLOGY

Previous workers have described:

- copper-lead-zinc mineralisation near Saukorem and a small area of nickel-cobalt-bearing laterite in the Mar 1:250 000 Sheet area (Molengraaf, 1957a & b);
- occurrences of uranium, antimony, copper, lead, and zinc in the hinterland of Manokwari, in the eastern Kepala Burung (D'Audretsch & others, 1966).

These occurrences lie in the area to be investigated by BMR/GSI geologists during the systematic mapping program in 1978 and 1979, as do the four geochemical anomalies recommended for follow-up by Hutchison (1977).

During the reconnaissance investigations described in this report, the following were observed:

- copper staining in a quartz band in metamorphic rocks forming a small area of basement near the south end of Supiori Island. A chip sample of the band yielded 0.87% copper.
- pebbles with very small quantities of pyrite, chalcopyrite, and pyrrhotite in the Kewiri River and tributaries of the Api River in the Mar 1:250 000 Sheet.
- coal in float in a tributary of the Aifat River, near Senopi in the Mar 1:250 000 Sheet area. The sample (Appendix III) is a perhydrous sub-bituminous coal possibly suitable for liquefaction, but with high ash (40%) and sulphur (2%).
- a site with potential for the generation of hydroelectric power at the eastern end of Lake Sentani, 10 km southwest of Jayapura, the provincial capital.

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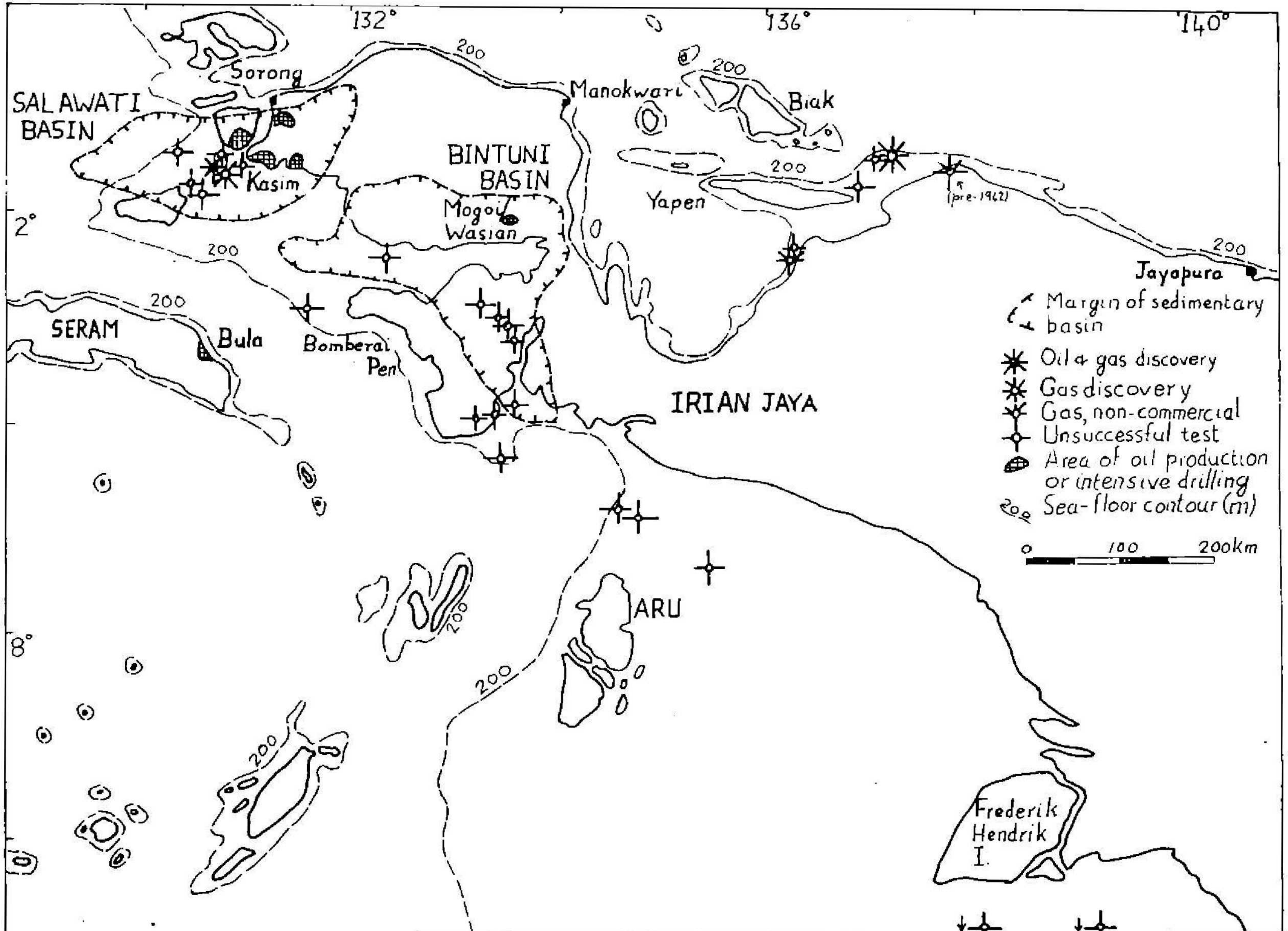

Record No. 1979/19

Figure 12 – Petroleum exploration wells – 1971-1977

A lateritic nickel deposit, currently being evaluated for commercial production, was visited at Gag Island. Similar deposits overlying the ultramafic rocks in the Cycloops Mountains are estimated to contain a total of 54.85 x 10^6 tons of proven ore with an average content of 1.15% Ni and 1.42% Co, and additional possible reserves of 60 x 10^6 tons of ore (D' Audretsch & others, 1966). Molengraaf (1957b) recorded a small occurrence near Kebar.

The petroleum prospects of the areas visited in 1976 and 1977 are not great; however, the prospects of other nearby areas are considerably better.

The appearance of basement rocks in Biak, Supiori, and Bepondi Islands indicate that the calcareous sediments of these islands overlie a basement ridge trending north-northwest and intermittently exposed over at least 150 km. Gas was tested at a rate of 21.6 million cubic feet per day from Tertiary sediment in an offshore well drilled by Tesoro and partners in 1973 100 km east of Biak (Fig. 12). One other offshore well drilled by this partnership in the eastern part of Sarera Bay tested non-commercial gas and a further three were dry. Onshore wells drilled at two locations about 150 km east of Biak (Visser & Hermes, 1962) intersected high-pressure methane. Though some of this may have been marsh gas, a gas province may be located in Tertiary sediments east of Biak.

The petroleum potential of the Bomberai Peninsula (including the Onin Peninsula and Karas) has recently been downgraded by the drilling of eight unsuccessful wells in that area since 1970. At least one of these wells drilled through the Tertiary sequence into the Mesozoic.

Visser & Hermes (1962) concluded that the chance of finding economic accumulations of oil in Irian Jaya is remote, and point to the absence of source rocks in Paleozoic to early Tertiary sediments. They noted that in the Salawati and Bintuni Basins (in the southern part of Kepala Burung) source rocks appear to be present and bioherms provide traps, but that migration has been hampered and the traps may not have been sealed in time.

Their conclusions have been upset by the recent discovery of several large oil fields at the western end of Kepala Burung in the Salawati Basin, both in the southern part of Salawati Island and on the mainland opposite (Fig. 12). The reservoirs are highly porous pinnacle reefs of the Kais Formation sealed by argillaceous limestone and shale of the Klasafet

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Formation (Vincelette & Trend Exploration staff, 1973). To a much lesser extent gas has also been found in the underlying Sirga Formation.

In the Bintuni Basin, two small oil reservoirs, in which production rates declined rapidly, were found in the early 1950s. In spite of the lack of success in recent exploration of the southern part of this basin in the Bomberai Peninsula, Conoco and Total in partnership with Pertamina recently began intensive exploration of the northern part adjacent to the Salawati Basin.

Apart from areas noted above, the only other petroleum exploration drilling undertaken in Irian Jaya since 1962 has been the drilling of unsuccessful offshore wells in the Arafura Sea between the Aru Islands and Frederik Hendrik Island. Appendix V lists petroleum exploration wells drilled in Irian Jaya between 1971 and 1977, and appendix VI records gravity and magnetic traverses undertaken by oil exploration companies in the same period. Both have been compiled from the relevant Bulletins of the American Association of Petroleum Geologists.

The value of a regional approach to petroleum exploration has recently been demonstrated in Mexico (Metz, 1978), where the national oil company has traced a Cretaceous barrier reef for hundreds of kilometres to outline a huge region with potential for petroleum production. It is rarely possible for even the largest oil companies to practise such an approach except in very general terms, as their access to information is commonly limited to their permit areas, and it would be desirable in Irian Jaya to attempt to map on a regional scale other areas of reef limestone which may be highly prospective for petroleum.

CONCLUSIONS AND RECOMMENDATIONS

The wide variety of rock types, ages, and geological environments encountered during the 1976/77 investigations indicates that highly complex geology and a great variety of mineralisation will be uncovered by systematic geological mapping. This will result in a great demand for laboratory and specialist services and will provide invaluable training for host-country field and laboratory personnel.

There would also be great value in extending the geological and geophysical mapping programs to include a wide-ranging regional study of formations with petroleum potential, extending into areas of poor exposure and even offshore.

It is anticipated that the mineral occurrences noted in Kepala Burung both by previous workers and by the recent investigators will be re-examined by BMR/GSI mapping parties in 1978/79. In addition to this it is recommended that:

- a brief re-examination be made of the copper mineralisation at Korido in the Schouten Islands;
- a specialist be engaged to report briefly on the desirability and feasibility of generating hydro-electric power in Irian Jaya, particularly near the larger towns such as Jayapura, Manokwari, and Sorong.
- a request be made to Pertamina, if necessary through the Minister for Mines, to provide project geologists with access to classified information, and to collaborate in a wide-ranging regional study of formations with petroleum potential throughout Irian Jaya.

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APPENDIX 1

K-Ar AGES FROM IRIAN JAYA

The analytical work for the K-Ar age determinations was carried out by The Australian Mineral Development Laboratories, Adelaide.

Sample no.	Rock type	Location and 1:250 000 Sheet area	Mineral	Age, m.y
76623013	Granodiorite	Kali Wepei, Mar Sheet	Hornblende	16.2±0.7
76623014	Diorite	Kali Wepei, Mar Sheet	Hornblende	15.4±0.3
76623046	Granodiorite	Kali Asimi, Mar Sheet	Hornblende	154±3
76623082	Granite	Kali Sric, Ransiki Sheet	Muscovite	225±4
76623083	Diorite	Kali Sric, Ransiki Sheet	Biotite	232±4
			Hornblende	243±4
76624026	Gneiss	Wasior, Wandamen Peninsula, Steenkool Sheet	Biotite	7.2±0.2
			Muscovite	3.68±0.1
76624027	Gneiss	Wasior, Wandamen Peninsula, Steenkool Sheet	Biotite	3.03±0.1
			Muscovite	3.68±0.1
76624051	Diorite	Kali Prori, Mar Sheet	Hornblende	244±4
76627012	Schist	Kali Kewiri, Mar Sheet	Biotite	12.6±0.3
76627033	Andesite	Tanjung Saukris, Mar Sheet	Whole rock	9.2±0.3
76627035	Andesite	Tanjung Saukris, Mar Sheet	Whole rock	11.5±0.3
76627042	Microdolerite	Pulau Gag, Pulau Waigeo Sheet	Amphibole	148±8
76629026*	Diorite	Kali Uramo, Manokwari Sheet	Hornblende	15.4±0.5
76629035*	Granite	Kali Wariki, Manokwari Sheet	Biotite	246±4
76629041*	Granite	Kali Waramoi, Manokwari Sheet	Biotite	222±4
			Muscovite	229±4
76629110*	Granite	Kali Ibarregah, Manokwari Sheet	Biotite	227±4
			Muscovite	234±4
77620046	Gabbro	Pulau Supiori, Korido Sheet	Whole rock	391±30
77620047	Schist	Kali Ifar, Pegunungan Cycloops Sheet	Muscovite	21.4±4
77620048	Schist	Kali Ifar, Pegunungan Cycloops Sheet	Muscovite	20.6±0.4
77620049	Leucogabbro	Gunung Mebu, Ransiki Sheet	Plagioclase	33.1±0.8

* Results discussed Robinson & Ratman (1977)

APPENDIX II

CHEMICAL ANALYSES OF ROCK FROM IRIAN JAYA, 1976-77

Major and trace-element analyses of 25 rocks from Irian Jaya are presented, together with calculated data and CIPW norms (Table 1). The analyses were carried out by XRF and atomic absorption techniques, by Australian Mineral Development Laboratories, Adelaide.

The first 15 analyses are of ophiolitic rocks from the Schouten Islands, Gag Island, and the Cycloops Mountains. Analyses 16 to 22 are of Tertiary volcanic and intrusive rocks from the Arfak Mountains, and north coast of the Kepala Burung. Analyses 23 to 25 are of older granitoids from the Anggi Lakes area, and one from the Mar 1:250 000 Sheet area.

Locality Index for Table 1

Analysis No.	Sample No.	Locality	Rock Type
1	77620001	Korido, Supiori Island	basaltic metatuff
2	77620005	" , " "	augite gabbro
3	77620012	Kali Maraduri, "	f-g augite gabbro
4	77620013	" " , "	augite gabbro
5	77620014	" " , "	augite basalt
6	77620044	" " , "	feldsparphyric basalt
7	77620045	" " , "	microgabbro
8	77620046	" " , "	olivine gabbro
9	76627047	West Gag Island	harzburgite
10	76627040	Northeast Gag Island	microdolerite
11	76627042	" " "	quartz dolerite
12	76627044	" " "	plagiogranite
13	76627045	" " "	quartz microdolerite
14	76627049	" " "	microdolerite
15	76620217	Sentani Quarry, Cycloops Mnts	feldsparphyric dolerite
16	76620045	Warmare, Manokwari 1:250 000 Sheet area	porphyritic basalt
17	77620049	Mt Mebu, Ransiki "	augite leucogabbro
18	76629026	Mt Berangan, Manokwari "	scoriaceous basalt

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Analysis No.	Sample No.	Locality	Rock Type
19	76623013	Kali Wepai, Mar 1:250 000 Sheet area	diorite
20	76623014	" " " " "	diorite
21	76620167	Tanjung Manganeki, " "	porphyritic augite andesite
22	76627035	Tanjung Saukris, " "	basalt clast from volcanic rudite
23	76623056	Kali Asimi, Mar 1:250 000 Sheet area	biotite-hornblende monzonite
24	76623082	Kali Sric, Ransiki 1:250 000 Sheet area	muscovite granite
25	76623083	" " " " "	biotite-hornblende-pyroxene diorite

TABLE 1: CHEMICAL ANALYSES AND CIPW NORMS OF ROCKS FROM IRIAN JAYA, 1976-77

Analysis no.	1	2	3	4	5	6	7	8	9	10	11	12	13
Registered BMR number	7762-0001	7762-0005	7762-0012	7762-0013	7762-0014	7762-0044	7762-0045	7762-0046	7662-7047	7662-7040	7662-7042	7662-7044	7662-7045
SiO_2	50.60	49.83	48.47	49.23	50.21	54.81	45.47	44.14	41.14	52.97	52.15	68.01	54.15
TiO_2	1.18	1.28	.65	.93	1.21	.57	.25	.08	.02	.47	.63	.47	.82
Al_2O_3	13.12	13.27	15.18	15.86	12.95	17.93	18.85	19.63	1.11	16.03	16.54	14.98	15.30
Fe_2O_3	4.41	2.19	1.70	4.07	3.26	1.46	3.05	.85	2.46	2.03	2.29	2.91	3.79
FeO	8.30	10.69	6.51	7.00	9.52	6.38	7.34	3.39	5.25	4.95	4.95	1.65	4.95
MnO	.21	.25	.15	.15	.23	.24	.16	.08	.13	.15	.13	.03	.15
MgO	6.65	6.86	9.75	6.23	6.96	3.41	8.51	12.05	40.60	5.55	6.80	1.36	3.76
CaO	10.11	10.35	11.89	10.76	9.50	7.63	13.93	14.54	1.19	8.20	11.43	3.90	6.88
Na_2O	1.98	2.18	1.58	2.89	2.28	3.05	.76	.99	.26	4.44	2.16	4.70	4.08
K_2O	.05	.06	.11	.07	.04	.60	.02	.01	.01	.06	.16	.13	.03
P_2O_5	.10	.14	.10	.12	.13	.21	.08	<.01	.01	.07	.08	.09	.09
H_2O+	2.58	1.78	2.71	1.47	2.04	2.78	.71	2.73	5.69	3.55	1.84	1.45	3.21
H_2O-	.30	.17	.34	.21	.21	.34	.08	.27	.19	.37	.18	.27	.19
CO_2	.04	.05	.09	.12	.14	.15	.05	.05	.35	.30	.05	<.05	2.20
SO_3	.34	.23	.02	.01	.43	.12	.06	.05	.02	.02	.01	.03	.03
total	99.97	99.33	99.25	99.12	99.11	99.68	99.32	98.87	98.43	99.16	99.37	100.03	99.63
- CALCULATED DATA AND CIPW NORMS* -													
mg number	54.72	54.71	73.00	56.57	55.48	49.70	65.29	86.61	92.38	64.61	68.38	41.52	50.06
plag. %an	61.51	58.74	71.79	55.19	56.44	56.47	88.18	86.76	45.45	38.63	65.68	32.06	36.26
colour index	.50	.51	.51	.44	.50	.26	.45	.42	.96	.36	.40	.12	.32
K_2O/Na_2O	.03	.03	.07	.02	.02	.20	.03	.01	.04	.01	.07	.03	.01
FeO total	12.27	12.66	8.04	10.66	12.45	7.69	10.09	4.15	7.46	6.78	7.01	4.27	8.36
q	6.32	3.66	.19	-	4.84	10.91	-	-	-	1.62	5.62	28.45	12.32
c	-	-	-	-	-	-	-	-	-	-	-	.24	1.42
or	.31	.36	.68	.43	.25	3.67	.12	.06	.06	.37	.97	.78	.18
ab	17.34	18.97	13.89	25.13	20.01	26.74	6.53	7.82	2.38	39.46	18.78	40.55	35.94
an	27.71	27.00	35.35	30.95	25.92	34.69	48.75	51.23	1.98	24.84	35.95	19.13	20.45
ne	-	-	-	-	-	-	-	.50	-	-	-	-	-
wo	9.72	10.25	10.31	9.33	8.84	.89	8.61	9.90	.81	6.44	8.97	-	-
di en	5.08	5.36	6.86	5.00	4.67	.42	5.09	7.53	.65	3.83	5.66	-	-
fs	4.36	4.59	2.70	4.02	3.90	.46	3.09	1.35	.06	2.28	2.75	-	-
en	12.06	12.21	18.38	9.92	13.30	8.38	10.29	-	19.35	10.69	11.75	3.45	9.75
hy fs	10.36	10.46	7.22	7.97	11.09	9.28	6.24	-	1.88	6.36	5.70	4.87	10.08
fo	-	-	-	.72	-	-	4.31	16.67	62.60	-	-	-	-
ol fa	-	-	-	.63	-	-	2.88	3.28	6.69	-	-	-	-
mt	4.09	4.19	2.69	3.53	4.16	2.57	3.30	1.40	2.60	2.29	2.32	1.40	2.80
il	2.32	2.50	1.28	1.82	2.38	1.12	.48	.16	.04	.94	1.23	.91	1.62
ap	.25	.34	.25	.29	.32	.52	.19	-	.03	.17	.20	.22	.22
cc	.09	.12	.21	.28	.33	.35	.12	.12	.86	.72	.12	-	5.21
- TRACE ELEMENTS (ppm) -													
Ba	10	<10	<10	<10	<10	140	10	<10	<10	15	30	35	<10
Ce	<20	<20	<20	<20	<20	<20	<20	<20	10	<10	15	15	15
La	<20	<20	<20	<20	<20	<20	<20	<20	<10	<10	<10	<10	<10
Nb	< 4	4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Pb	8	< 4	< 4	1500	8	8	< 4	< 4	13	46	360	24	150
Rb	< 2	< 2	< 2	< 2	< 2	9	< 2	< 2	< 2	3	6	3	2
Sr	80	75	75	100	80	380	240	140	4	350	145	220	115
Th	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2
U	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2
Y	28	32	16	10	28	20	< 4	< 4	< 4	12	14	16	18
Zr	55	65	30	46	60	42	< 4	< 4	< 4	36	38	80	55
Cr	30	45	520	70	35	1	10	680	1450	65	190	6	20
Cu	110	95	95	14	125	20	285	48	16	70	18	4	7
Ni	50	50	180	95	45	14	40	260	2050	36	70	4	36
V	480	500	310	420	490	140	650	95	50	260	250	50	360

* Oxidation state of iron standardized to Fe_2O_3 = 0.2 total Fe as Fe_2O_3

TABLE 1 CONTINUED: CHEMICAL ANALYSES AND CIPW NORMS OF ROCKS FROM IRIAN JAYA, 1976-77

Analysis no.	14	15	16	17	18	19	20	21	22	23	24	25
Registered BMR number	7662-7049	7662-0217	7662-0045	7762-0049	7662-9026	7662-3013	7662-3014	7662-0167	7662-7035	7662-3056	7662-3082	7662-3083
SiO_2	52.01	49.14	47.84	48.31	55.85	62.25	54.31	54.94	51.70	67.69	75.41	55.09
TiO_2	.67	.65	.59	1.44	.81	.61	.37	.71	.96	.41	.03	1.63
Al_2O_3	14.93	17.29	15.59	16.26	15.26	14.50	18.35	16.38	17.45	15.96	13.87	16.27
Fe_2O_3	4.15	1.56	7.08	5.41	3.46	.65	1.91	5.24	4.24	.20	.03	1.13
FeO	7.55	5.85	1.85	8.13	2.50	4.30	4.00	3.05	4.70	2.30	.35	8.25
MnO	.21	.15	.16	.24	.12	.11	.13	.17	.19	.05	.02	.20
MgO	4.24	7.90	6.70	4.29	7.00	4.56	6.00	4.42	3.82	.74	.10	3.46
CaO	7.11	13.41	12.03	9.29	7.47	5.72	9.41	6.92	9.41	2.44	.19	8.05
Na_2O	4.06	1.99	2.20	2.79	4.56	3.16	2.94	3.66	3.20	3.16	4.60	3.12
K_2O	.06	.07	.17	.54	.91	1.48	1.03	1.63	1.62	5.59	4.27	1.20
P_2O_5	.07	.07	.07	.14	.32	.15	.12	.20	.46	.14	.05	.18
H_2O+	3.51	1.69	3.62	2.45	.44	1.70	1.55	1.91	1.21	.76	.52	1.13
H_2O-	.29	.07	1.68	.43	.22	.08	.11	.59	.39	.14	.13	.09
CO_2	.30	.05	.10	.05	.05	.10	.05	.10	.10	.10	.05	.15
SO_3	.08	.16	.01	.02	.02	.08	.09	-	.02	.01	.01	.29
total	99.24	100.05	99.69	99.79	98.99	99.45	100.37	99.92	99.47	99.69	99.63	100.24

- CALCULATED DATA AND CIPW NORMS* -

		14	15	16	17	18	19	20	21	22	23	24	25
mg number		45.58	70.83	64.49	42.39	73.54	67.55	72.51	55.92	50.00	39.96	37.17	45.43
plag. %an		39.42	63.99	63.35	56.18	32.41	44.02	57.64	43.11	51.27	28.31	.77	50.43
colour index		.39	.45	.47	.42	.36	.24	.30	.31	.33	.07	.02	.31
K_2O/Na_2O		.01	.04	.08	.19	.20	.47	.35	.45	.51	1.77	.93	.38
FeO total		11.29	7.25	8.23	13.00	5.62	4.88	5.07	7.77	8.52	2.48	.38	9.27
	q	3.83	-	.34	.71	1.20	19.07	4.49	4.77	1.38	21.34	32.17	8.98
	c	-	-	-	-	-	-	-	-	-	.85	1.59	-
	or	.37	.42	1.07	3.30	5.48	8.96	6.22	9.92	9.80	33.42	25.49	7.17
	ab	36.07	17.15	19.82	24.42	39.32	27.37	25.40	31.89	27.73	27.05	39.31	26.70
	an	23.47	38.76	34.27	31.30	18.85	21.52	34.56	24.16	29.16	10.68	.30	27.17
	ne	-	-	-	-	-	-	-	-	-	-	-	-
	wo	4.64	11.79	11.75	6.31	6.88	2.46	5.01	3.84	6.23	-	-	4.63
di	en	2.01	7.66	7.00	2.65	4.69	1.55	3.29	2.03	3.03	-	-	2.17
	fs	2.63	3.32	4.15	3.67	1.64	.75	1.36	1.69	3.10	-	-	2.41
	en	9.08	10.44	10.78	8.40	13.07	10.07	11.96	9.30	6.71	1.86	.25	6.55
hy	fs	11.87	4.53	6.40	11.62	4.58	4.86	4.93	7.72	6.86	2.64	.48	7.30
	fo	-	1.36	-	-	-	-	-	-	-	-	-	-
ol	fa	-	.65	-	-	-	-	-	-	-	-	-	-
	mt	3.82	2.38	2.82	4.33	1.84	1.61	1.67	2.58	2.81	.81	.12	3.02
	il	1.34	1.26	1.19	2.83	1.57	1.19	.72	1.39	1.87	.79	.06	3.13
	ap	.17	.17	.18	.34	.77	.36	.29	.49	1.12	.34	.12	.43
	cc	.72	.12	.24	.12	.12	.23	.12	.23	.23	.23	.11	.35

- TRACE ELEMENTS (ppm) -

	14	15	16	17	18	19	20	21	22	23	24	25
Ba	15	10	50	130	400	280	190	150	190	1750	30	240
Ce	10	10	10	<20	40	50	30	20	20	60	40	50
La	<10	<10	<10	<20	20	<10	10	10	<10	30	10	20
Nb	< 4	< 4	< 4	< 4	8	< 4	< 4	< 4	< 4	6	75	10
Pb	2400	490	38	4	120	26	16	100	540	50	19	14
Rb	3	2	2	7	19	50	32	28	65	130	720	30
Sr	65	135	260	270	940	265	520	365	710	385	6	335
Th	4	< 2	< 2	4	3	8	2	2	2	5	12	6
U	2	2	< 2	< 4	2	4	2	2	3	2	6	3
Y	4	12	14	26	12	22	10	20	18	6	38	18
Zr	26	44	32	50	125	150	80	80	65	175	20	150
Cr	13	450	230	12	260	240	75	40	13	6	6	50
Cu	36	95	50	290	32	28	42	44	100	3	13	22
Ni	6	120	50	12	120	16	16	14	10	< 2	2	8
V	430	230	270	600	180	150	120	280	410	30	<10	200

* Oxidation state of iron standardized to Fe_2O_3 = 0.2 total Fe as Fe_2O_3

APPENDIX III

MICROPALEONTOLOGICAL AGE DETERMINATIONS; SAMPLES FROM IRIAN JAYA

All samples have the prefix 7662. They have been examined by D.J. Belford and J.C. Chaproniere.

Results are:

0001	:	Early to middle Miocene (upper e to lower f)
0002	:	Early to middle Miocene (upper e to lower f)
0003	:	General Tertiary age only
0015	:	No foraminifera found, age not known
0020	:	Early to middle Miocene (upper e to lower f)
0023	:	No foraminifera found, age not known
0025	:	Late Oligocene to middle Miocene
0026	:	Early Miocene (zones N.5-N.6)
0027	:	Not older than middle Miocene (zone N.11 or younger)
0028	:	Probably not older than middle Miocene (zone N. 9)
0029	:	Not older than late Miocene (zone N.16 or younger)
0031	:	General Miocene or younger age only
0032	:	Early Miocene (upper e)
0034	:	General Tertiary age only
0035	:	Not older than middle Miocene (zone N.9)
0039	:	General Tertiary age only
0040	:	General Tertiary age only
0048	:	Early Oligocene (c)
0064	:	Indeterminable smaller foraminifera; age not known
0065	:	Eocene, probably middle Eocene
0077	:	Age not known; fauna insufficient
0096	:	Early to middle Miocene (upper e to lower f)
0097	:	Late Oligocene to early Miocene (zone N.3 to zone N.4)
0098	:	Age not known, fauna not diagnostic
0100	:	Age not known, no foraminifera found
0108	:	Age not known, no foraminifera found
0112	:	Age not known, no foraminifera found
0113	:	General younger Tertiary age only
0114	:	Age not known, fauna not diagnostic
0140	:	Late Miocene (upper f) or younger
0141	:	General Tertiary age only

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0147 :	Late Miocene (zone N.17) or younger
0148 :	General Tertiary age only
0150 :	Fauna very poorly preserved; possibly late Oligocene to early Miocene (e, undifferentiated)
0151 :	General Tertiary age only
0158 :	General middle Oligocene to middle Miocene age only (d to lower f)
0160 :	Age not known; no foraminifera found
0161 :	Age not known, no foraminifera found
0163 :	Age not known, no foraminifera found
0164 :	Age not known, no foraminifera found
0165 :	Age not known, no foraminifera found
0188 :	Late Miocene (N.17) or younger
0189 :	Late Miocene (N.17) or younger
0190 :	Middle Miocene (lower f)
0191 :	Not older than middle Miocene (zone N.9)
0192 :	General Tertiary age only
0194 :	Early to middle Miocene (upper e to lower f)
0198 :	Age not known, no foraminifera found
0199 :	This sample is lithologically and faunally very similar to late Oligocene limestone from the Wabag area, PNG; the fauna consists of planktonic foraminifera seen in thin section only. The age must be given as uncertain; this sample is associated with 0200 (see below).
0200 :	Eocene, probably middle Eocene
0202 :	Early to middle Miocene (upper e to lower f)
0205 :	General Miocene or younger age only
0218 :	Age not known, no foraminifera found
0219 :	General Tertiary age only
0222 :	Miocene or younger age only
3010 :	Age not known, fauna not diagnostic
3027 :	Early Miocene (zone N.8)
3028 :	Early to middle Miocene (upper e to lower f)
3029 :	Early to middle Miocene (upper e to lower f)
3030 :	Early Miocene (upper e)
3033 :	Age not known, no foraminifera found
3034 :	Age not known, no foraminifera found
3035 :	Early to middle Miocene (upper e to lower f)

3036	:	Age not known, no foraminifera found
3037	:	Age not known, no foraminifera found
3039	:	Early to middle Miocene (upper e to lower f)
3040	:	Late Oligocene-middle Miocene
3042	:	Late Cretaceous (Campanian to Maastrichtian)
3044	:	Late Cretaceous
3072	:	Pleistocene or younger
3073	:	Age not known, fauna not diagnostic
3074	:	Pleistocene or younger
3095	:	Pleistocene or younger
3096	:	Age not known, no foraminifera found
3097	:	Pleistocene or younger
3098	:	Age not known, no foraminifera found
3099	:	Pleistocene or younger
3100	:	General younger Tertiary age only
4010A	:	General Tertiary age only
4010B	:	Probably late middle Miocene (top lower f, N.12)
4011A & B	:	Age not known, fauna not diagnostic
4011C	:	Not older than middle Miocene (N.9)
4012	:	Late Miocene to middle Pliocene (N.17 to N.21)
4013	:	Middle Miocene to early Pliocene (N.11 to N.19)
4014	:	General younger Tertiary age only
4016	:	Early to middle Miocene (upper e to lower f)
4017	:	Middle Oligocene to middle Miocene (d to lower f)
4018	:	Late Miocene (upper f) or younger
4019	:	General younger Tertiary age only
4020	:	Late Miocene (upper f) or younger
4021	:	Not older than Miocene (zone N.4)
4022	:	Early Pliocene (N.19)
4033	:	Eocene, probably middle Eocene
4035	:	Age not known, no foraminifera found
4037	:	Age not known, no foraminifera found
4038	:	Age not known, no foraminifera found
7029	:	Age not known, no foraminifera found
7051	:	General Tertiary age only
7053	:	General younger Tertiary age only
7054	:	Age not known, fauna not diagnostic
7055	:	Probably middle Pliocene (N.20)

7056	:	Early Pliocene (N.19)
7057	:	Age not known, no foraminifera found
7058	:	Age not known, no foraminifera found
7062	:	Age not known, no foraminifera found
7064	:	Age not known, no foraminifera found
7065	:	Age not known, fauna not diagnostic
7068	:	Middle Pliocene (N.20)
7069	:	Middle Pliocene (N.20)
9002	:	Late Pliocene to Pleistocene (N.21 to N.22)
9006	:	General Tertiary age only
9008	:	Early to middle Pliocene (N.19 to N21)
9009	:	Late Miocene to middle Pliocene (N.17 to N.20)
9011	:	Late Miocene to middle Pliocene (N.17 to N.20)
9012	:	Middle Pliocene (N.20) or younger
9013	:	Late Pliocene to Pleistocene (N.21 to N.22)
9014	:	Late Pliocene to Pleistocene (N.21 to N.22)
9015	:	Late Pliocene to Pleistocene (N.21 to N.22)
9016	:	Pleistocene or younger
9017	:	Late Miocene (N.18) or younger
9017a	:	Late Miocene (N.18) or younger
9019	:	Middle Pliocene (N.20)
9021	:	Age not known, no foraminifera found
9027	:	Age not known, no foraminifera found

APPENDIX IV

ANALYSES OF COAL FROM KEPALA BURUNG, IRIAN JAYA

by

Dr L. Hamilton, CSIRO, Fuel Geoscience Unit

Introduction

A rounded float sample of coal 1.5 cm thick collected in the Kepala Burung region of Irian Jaya was received from P.E. Pieters of the Bureau of Mineral Resources (Canberra). This coal is of interest because of the scarcity of information on coal geology from this part of the world. No publications on the petrology of coal from Irian Jaya are known. Three occurrences of coal in Irian Jaya are recorded on a paper by M. Simanjuntak & S. Wijaya, 1976 - 'Coal Resources and Potential in Indonesia', AAPG Memoir 25, pages 84-88. The locality of the sample received is $0^{o}22'$S, $132^{o}54'$E in the Awi River (a tributary of the Aifat River) and near an outcrop of the Miocene New Guinea Limestone group which consists of 'calcarenite, calcilutite and marl overlying sandstone and sandy shale with coal films and plant remains'.

The Bureau of Mineral Resources speciment number is 76620193 (locality shown in Fig. 3) and the CSIRO laboratory number is LN 57707.

Coal petrography

The specimen is a very finely laminated bright coal consisting of clarite with thin vitrite layers. The volumetric maceral composition averaged from two sets of point count measurements is given below:

vitrinite	50%
exinite	26%
sclerotinite	2%
semi fusinite	0.5%
inertodetrinite	0.5%
mineral matter	21%

In general the coal has a high exinite content and a low inertinite content. The exinite is chiefly sporinite with lesser cutinite. Other common

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exinite macerals in this coal are liptodetrinite (in part ?bituminite), suberinite, resinite, exudatinite, and fluorinite. Such a petrographic composition is more typical of Tertiary than of older coals, although the sample studied may not be typical of a seam. Furthermore the fungal remains in the coal are typical of the sclerotinite in Tertiary coals.

The average reflectivity of vitrinite from 34 measurements made in immersion oil (RI = 1.55) with light of wavelength 546 nm is 0.44%, which characterises the coal as being of sub-bituminous rank.

Mineral matter

The mineral matter in the coal was freed by treatment with oxygen plasma in a 'low-temperature asher'. The residue was X-rayed and was found to consist of kaolinite, sericite (or illite, the main XRD peak being 10Å), and quartz.

Microscopic observation of a smear mount of this material showed that it resembles powdered shale. Aggregates of fine micaceous minerals with a maximum individual grainsize of about 10 m dominate the material; angular quartz fragments up to 150 m diameter are less common than the micaceous aggregates. Some aggregate grains are foliated and some less common aggregates have outlines reminiscent of feldspar crystals up to 0.4 mm long. Most aggregate grains are subangular.

About 1% pyrite and marcasite was observed in polished section.

Chemistry

Proximate and ultimate analyses were made on a 3.7 g sample of the coal. Analysis was not duplicated because the coal is not representative of a known seam and high accuracy is therefore unwarranted.

Proximate Analysis	Air dried	Dry Ash Free
Moisture	2.6%	-
Ash	40.3%	-
Volatile matter	30.2%	53.0%
Fixed carbon	26.9%	47.0%

Ultimate Analysis	
Carbon	74.7%
Hydrogen	6.2%
Nitrogen	1.6%
Sulphur (total)	2.6%
Oxygen (by difference)	14.9%

The weight of mineral matter determined from oxygen plasma treatment is 43.3%. This is in fair agreement with the ash analysis and the point count analysis (which is about 42% when converted from volume to weight).

Discussion and conclusion

Practical conclusions on the utilisation of the coal cannot be drawn until the seam is located and sampled adequately. In the small sample received the 'ash' (i.e., the mineral matter) content is very high and the fine grainsize and dispersed distribution of the mineral matter would present difficulties to the upgrading of the coal by washing.

It is a perhydrous coal of sub-bituminous rank. Although it should have a high tar yield (16% d.a.f.) it is a non-swelling coal, unsuitable for coking; however, it might be suitable for liquefaction under favourable conditions. An Australian coal of chemical composition near that of the Irian Jaya coal occurs at Millmerran in the Clarence-Moreton Basin of Queensland. This is one of the most suitable coals in Australia for conversion to oil, but it is of slightly hgiher rank and contains much less ash (17.4%) and sulphur (0.7%) than the Kepala Burung sample. The Kepala Burung coal may be of economic interest if it can be found at a convenient location in large quantities with a low ash yield.

The rank and composition of the coal suggest it is of Tertiary age and there is no sign of metamorphism in the coal beyond that which accompanies burial to about 1 km. The coal is possibly weathered, but oxidation appears to be relatively slight. This coal is somewhat similar to the coaly material believed to be the source of the petroleum in Bass Strait (G.H. Taylor, personal communication).

Acknowledgements

Maceral analyses were made by M. Smyth and L. Hamilton; X-ray diffraction analyses by A. Horne; chemistry by N. Watson; and oxygen plasma treatment by R. Cosstick.

APPENDIX V
(from Bulletins of the American Association of Petroleum Geologists)

PETROLEUM EXPLORATION WELLS - IRIAN JAYA - 1971 to 1977

BOPD = Barrels oil per day.
MMCFD = Million cubic feet gas per day.
41° = API gravity of oil.
P & A = Plugged and abandoned.
D & A = Drilled and abandoned.

Year/Operator	Well Name	Latitude South Longitude East	Completion Date	Depth (m)	Remarks
1971 Phillips	TBB-IX	01°37'25" 130°33'29"	24/1/71	1652	P & A
	TBD-IX	01°36'33" 130°48'56"	6/2/71	1231	P & A
	TBE-IX	02°25'04" 132°29'47"	16/3/71	2343	P & A in pre-Tertiary
	TBF-IX	01°46'18" 130°43'22"	31/5/71	4447	P & A in pre-Tertiary
	ASE-IX	04°02'28" 133°31'50"	17/8/71	4216	P & A
1972 Phillips	TBK-IX	01°26'03" 130°13'28"	10/5/72	1747	P & A
	ASF-IX	03°51'26" 133°40'43"	15/12/72	4759	P & A in Mesozoic
Trend	Kasim-1	01°19'38" 131°02'15"	20/10/72	1401	Oil discovery 2300 BOPD, 42°
	Seget-1	01°24'41" 130°59'17"	23/11/72	1102	P & A in Kais Fm.
	Kasim-2	01°19'48" 131°04'03"	15/12/72	1217	P & A in Kais Fm.
1973 Petromer Trend	Jaya-1	01°20"13" 131°03'51"	6/5/73	1143	Oil discovery in Kais Fm. at 892 m, 10,950 BOPD, 44°.
	Walio-1	01°23'27" 131°04'52"	18/7/73	933	Oil discovery in Fm. at 849 m, 1000 BOPD, 33°.
	North Kasim-1	01°18'11" 131°01'49"	1/12/73	1625	Oil discovery in Kais Fm. at 1510 m, 31,600 BOPD, 27°.
	Klanal-1	01°26'43" 131°11'04"	?	+914	Drilling ahead at 31/12/71
Phillips	TBH-IX	01°33"47.2" 130°58'55.6"	9/1/73	1070	P & A in Kais Fm.
	TBJ-IX	02°50'55.8" 131°42'35.2"	8/11/73	2150	P & A in Jurassic(?).
	TBL-IX	01°21'30" 130°59'04"	7/2/73	1629	P & A in Kais Fm.
	TBM-IX	01°26'14.6" 130°49'37"	10/3/73	2439	P & A in Kais Fm.
Tesoro	E-1	02°29'04" 136°11'20"	30/3/73	2289	P & A Non-commercial gas.
	A-1	02°22'40" 136°14'44"	15/5/73	3598	P & A
	R-1	01°22'21" 137°17'45"	26/6/73	2307	Gas discovery in Tertiary at 1770 m. 21.6 MMCFD.
	P-1	01°42'02" 136°51'06"	2/8/74	4596	P & A
	O-1	01°25'17" 137°00'17"	23/8/73	1412	P & A

APPENDIX V (continued)

Year/Operator	Well Name	Latitude South Longitude East	Completion Date	Depth (m)	Remarks
1974 Pertamina	Orba 1	01°06'07" 131°27'45"	8/10/74	2120	P & A basement quartzitic sandstone.
Petromer Trend	Walio 3	01°24'00" 131°06'30"	22/4/74	928	Oil discovery in Kais at 760 m, 6900 BOPD, 36°.
Phillips	TBN-1X	01°18'03" 131°01'27"	11/5/74	1927	Oil discovery in Miocene limestone at 1785 m. 12,186 BOPD, 24°.
	TBC-1X	01°32'03" 130°34'21"	8/6/74	2501	Wet gas discovery in Miocene limestone at 1950 m, 135 MMCFD.
	TBA-2X	01°33'41" 130°31'10"	25/8/74	2516	Oil & gas discovery in Miocene limestone at 2105 m 4305 BOPD, 59°, +8.5 MMCFD.
	ASM-1X	05°14'30" 135°32'09"	9/11/74	3822	P & A in Paleozoic.
1975 Gulf	Besiri 1	03°42'27" 133°17'18"	20/4/75	3992	D & A in Cretaceous limestone.
	Jamusura 1	03°43'12" 133°13'07"	28/5/75	1375	D & A in New Guinea limestone.
	Aroba 1	02°49'36" 133°15'00"	3/7/75	1668	D & A in New Guinea limestone.
Pertamina	Sele Selatan-1	01°25'44" 131°09'54"	22/5/75	1016	Oil well in Kais Fm.
	Sele Utara-1	01°24'22" 131°09'35"	18/10/75	1201	P & A in Kais Fm.
Petromer Trend	114-140	01°19'30" 131°14'45"	25/3/75	1971	P & A in Kais Fm.
	124-290	01°19'26" 131°26'01"	14/5/75	1071	P & A in Kais Fm.
	310-650	01°18'10" 131°30'41"	14/6/75	1046	P & A in Kais Fm.
	330-340	01°22'08" 131°29'38"	27/8/75	2610	P & A in Alfam Fm.
	220-235	01°19'40" 131°00'47"	16/8/75	1347	Oil discovery in Kais; 8,900 BOPD.
	243-639	01°29'53" 131°14'27"	8/10/75	800	P & A in Kais Fm.
	204-327	01°24'39" 131°01'34"	4/11/75	1075	P & A in Kais Fm.
	159-195	01°25'09" 131°57'34"	4/12/75	1283	P & A in Kais Fm.
Phillips	Salawati A-1X	01°19'48" 130°58'13"	3/5/75	1780	Oil discovery in Kais Fm.
	Salawati K-1X	01°12' 4" 130°52'19"	3/9/75	3488	D & A in granite.
	Salawati A-2	01°20'05" 130°58'21"	19/9/75	1739	Oil discovery in Kais Fm.
Sun	Mandala-1	02°58'28" 133°33'12"	6/12/75	3788	D & A in Klasafet Fm.
1976 Petromer Trend	102-460	1°26'36" 131°05'41"	2/4/76	1120	D & A in Kais Fm.
	252-175	1°20'19" 131°07'15"	4/6/76	1214	Discovery in Kais Fm.
	137-363	0°59'22" 131°27'07"	26/5/76	1894	D & A in ?Permo-Carb. Alfam Fm.
	136-238	0°59'32" 131°25'58"	8/8/76	1504	D & A in Kais Fm.
	314-255	1°20'40" 131°10'32"	3/9/76	1663	D & A in Kais Fm.
	247-243	1°26'34" 131°17'15"	15/9/76	1117	Discovery in Kais Fm.
	371-420	1°04'09" 131°35'09"	24/9/76	1712	D & A in ?Permo-Carb. Alfam Fm.
	59-133	1°00'01" 131°16'31"	17/1/77	3017	Suspended gas well in Oligocene Sirga Fm.
	K9-185	1°07'34" 131°35'12"	13/10/76	253	D & A in Kais Fm.

APPENDIX V (continued)

Year/Operator	Well Name	Latitude South Longitude East	Completion Date	Depth (m)	Remarks
1976 contd. Phillips	Salawati F-1X	1°17'45" 130°57'57"	2/1/76	2286	Oil discovery in Kais Fm.
	Salawati N-1X	1°14'27" 130°55'59"	5/5/76	4141	Gas discovery in pre-Kais (Oligocene)
	Salawati C-1X	1°19'10" 130°55'27"	6/6/76	2404	P & A in Kais Fm.
	Salawati E-1X	1°18'45" 130°56'27"	27/8/76	2179	Oil discovery in Kais Fm.
	Salawati L-1X	1°09'18" 130°55'22"	22/11/76	3523	P & A in Kais Fm.
Sun	Terie-1	2°52'10" 133°27'43"	11/8/76	4196	D & A in Kais Fm.
	Wami-1	2°15'18" 133°20'45"	23/10/76	3361	D & A in Kais Fm.
1977 Pertamina	Linda A-1	01°22'45" 131°08'54"	28/2/77	1575	D & A in Kais Fm.
	Linda B-1	01°22'37" 131°07'17"	4/7/77	1411	D & A in Kais Fm.
	Linda A-2	01°22'19" 131°08'34"	23/5/77	1234	Suspended oil well in Kais Fm.
Petromer Trend	191-251	1°18'46" 131°06'12"	14/2/77	1532	P & A in Kais Fm.
	189-195	1°17'20" 131°04'44"	9/3/77	1861	P & A in Kais Fm.
	270-210	1°20'31" 131°06'27"	14/3/77	1219	P & A in Kais Fm.
	Seget 1 re-entry	1°24'40" 130°59'24"	29/3/77	1330	P & A in Kais Fm.
	270-283	1°20'49" 131°05'35"	29/3/77	1286	P & A in Kais Fm.
	234-197	1°26'47" 131°18'58"	17/5/77	1128	P & A in Kais Fm.
	260-195	1°27'55" 131°17'30"	14/6/77	1521	P & A in Kais Fm.
	Walio Deep	1°23'37" 131°06'18"	6/8/77	1052	P & A in Aifam Fm. (Permo-Carb.)
	260-120	1°27'51" 131°19'31"	4/7/77	1036	P & A in Kais Fm.
	234-175	1°26'48" 131°19'24"	26/7/77	1052	P & A in Kais Fm.
	193-233	1°18'47" 131°08'52"	13/9/77	2182	P & A in Klamoegoen (Miocene).
	385-370	1°24'39" 131°34'26"	6/11/77	2350	P & A in Kembelangan (Jurassic-Cretaceous).
Phillips	Salawati C-2X	1°19'03" 130°55'39"	4/1/77	2321	Confirmation in U. Miocene.
	Salawati D-1X	1°19'51" 130°59'40"	12/2/77	1817	Oil discovery in U. Miocene.
	Salawati V-1X	1°20'19" 130°57'19"	11/3/77	2041	D & A in U. Miocene.
	Salawati W-1X	1°19'21" 130°59'35"	2/6/77	1808	D & A in U. Miocene.
	Salawati A-6	1°20'20" 130°59'30"	26/6/77	1765	D & A in U. Miocene.
	Pili-1X	1°22'13" 130°55'11"	22/7/77	2000	D & A in U. Miocene.
	Salawati O-1X	1°15'05" 130°52'59"	17/10/77	3757	P & A in lower Tertiary.
	Salawati E-2aX	1°18'51" 130°56'31"	15/1/78	2182	Confirmation in U. Miocene.

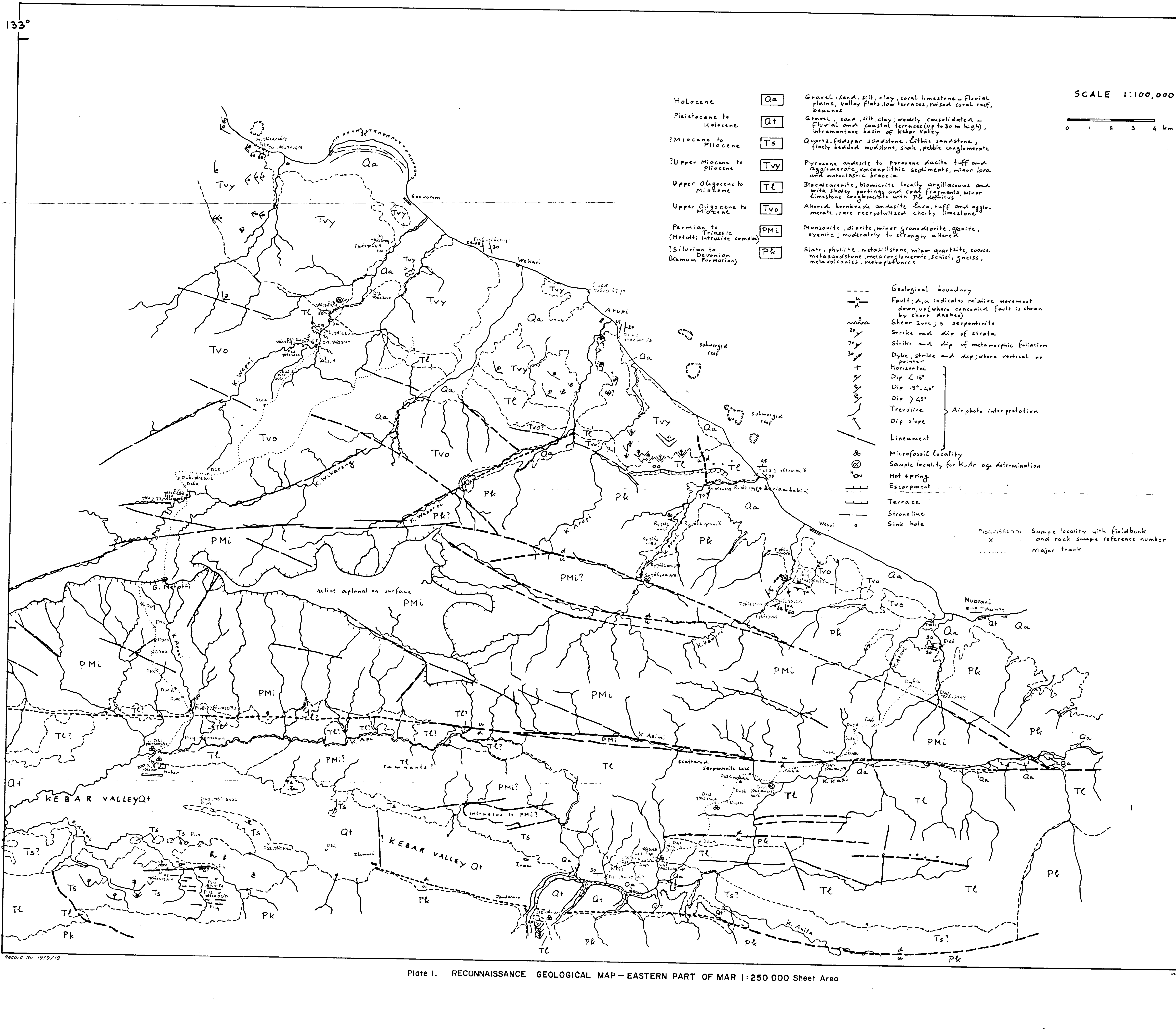
APPENDIX VI

PETROLEUM EXPLORATION - GRAVITY AND MAGNETIC TRAVERSES IN IRIAN JAYA -1971 TO 1977

(from Bulletins of the American Association of Petroleum Geologists; distances in miles)

Year	Operator	Area	Gravity		Magnetic	
			Land	Sea	Sea	Air
1971	Gulf	Indonesia*	-	12,537	12,537	-
1972	Gulf	Irian Jaya	-	-	-	4,350
1973	Pexamin	Arafura Sea	-	-	3,200	-
1974	Champlin	Arafura Sea	-	215	215	-
"	Amoseas	Mimika-Eilanden	350	-	-	-
1975	Amoseas	Mimika-Eilanden	284	-	-	-
1976	Amoseas	Irian Jaya	200	-	-	-
1977	Phillips	Teluk Berau	-	-	600	-

* Probably includes concessions in Irian Jaya.



Record No 1979/19

Plate 1. RECONNAISSANCE GEOLOGICAL MAP – EASTERN PART OF MAR 1:250 000 Sheet Area

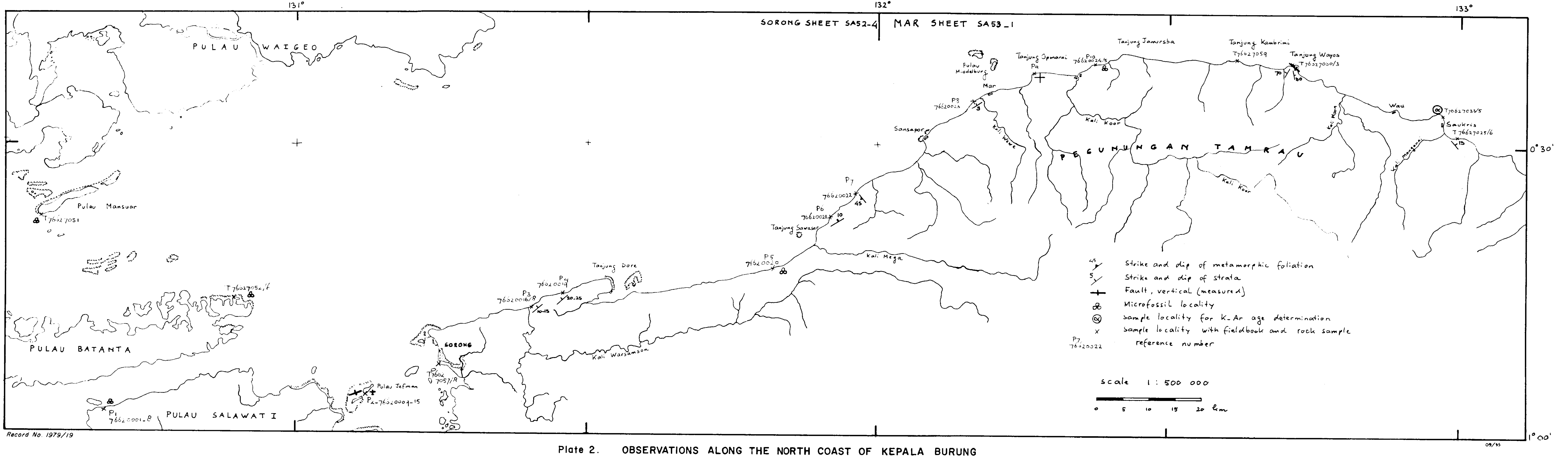
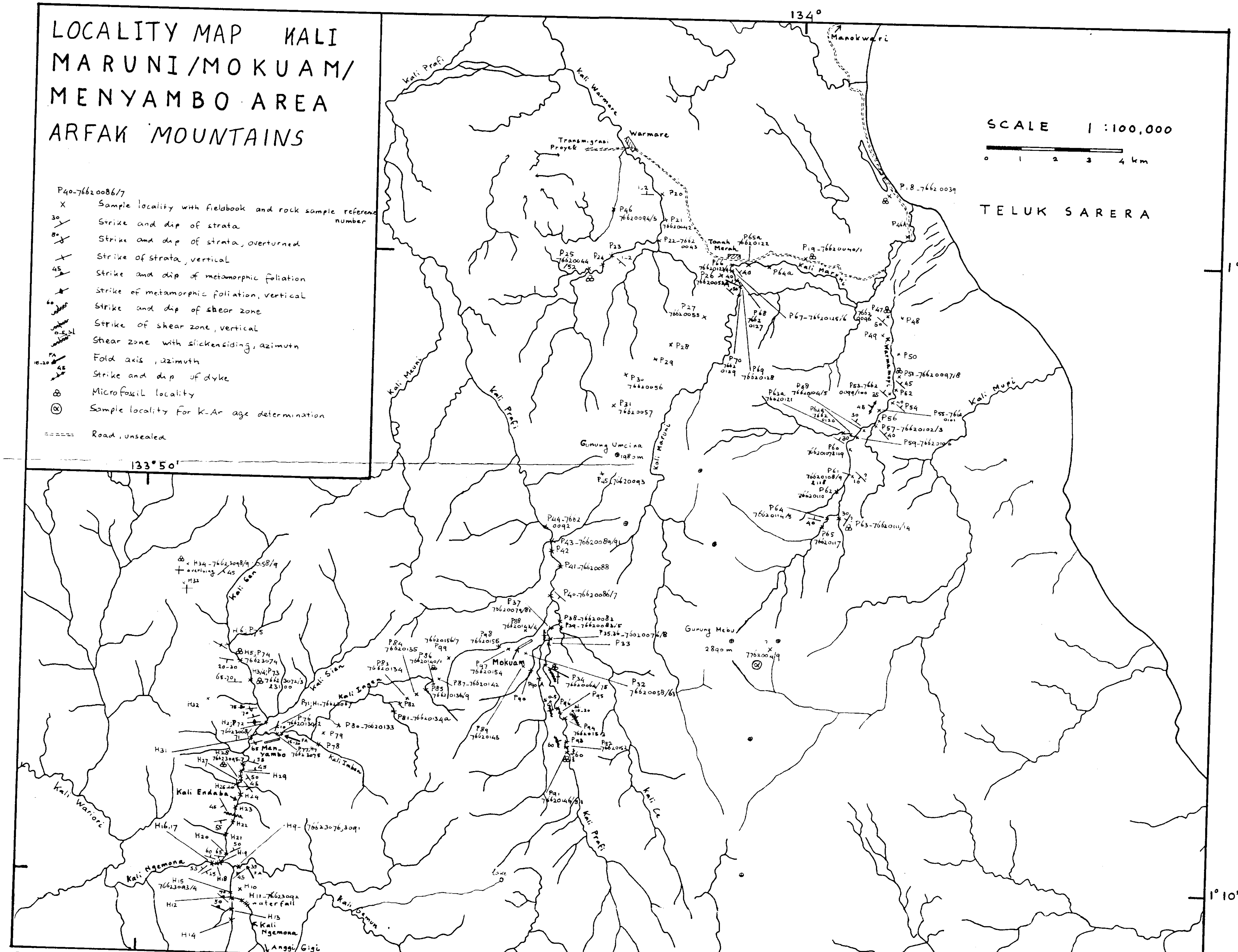


Plate 2. OBSERVATIONS ALONG THE NORTH COAST OF KEPALA BURUNG



Record No. 1979/19

Plate 3. LOCALITY MAP — KALI MARUNI /MOKUAM/ MENYAMBO AREA, ARFAK MOUNTAINS

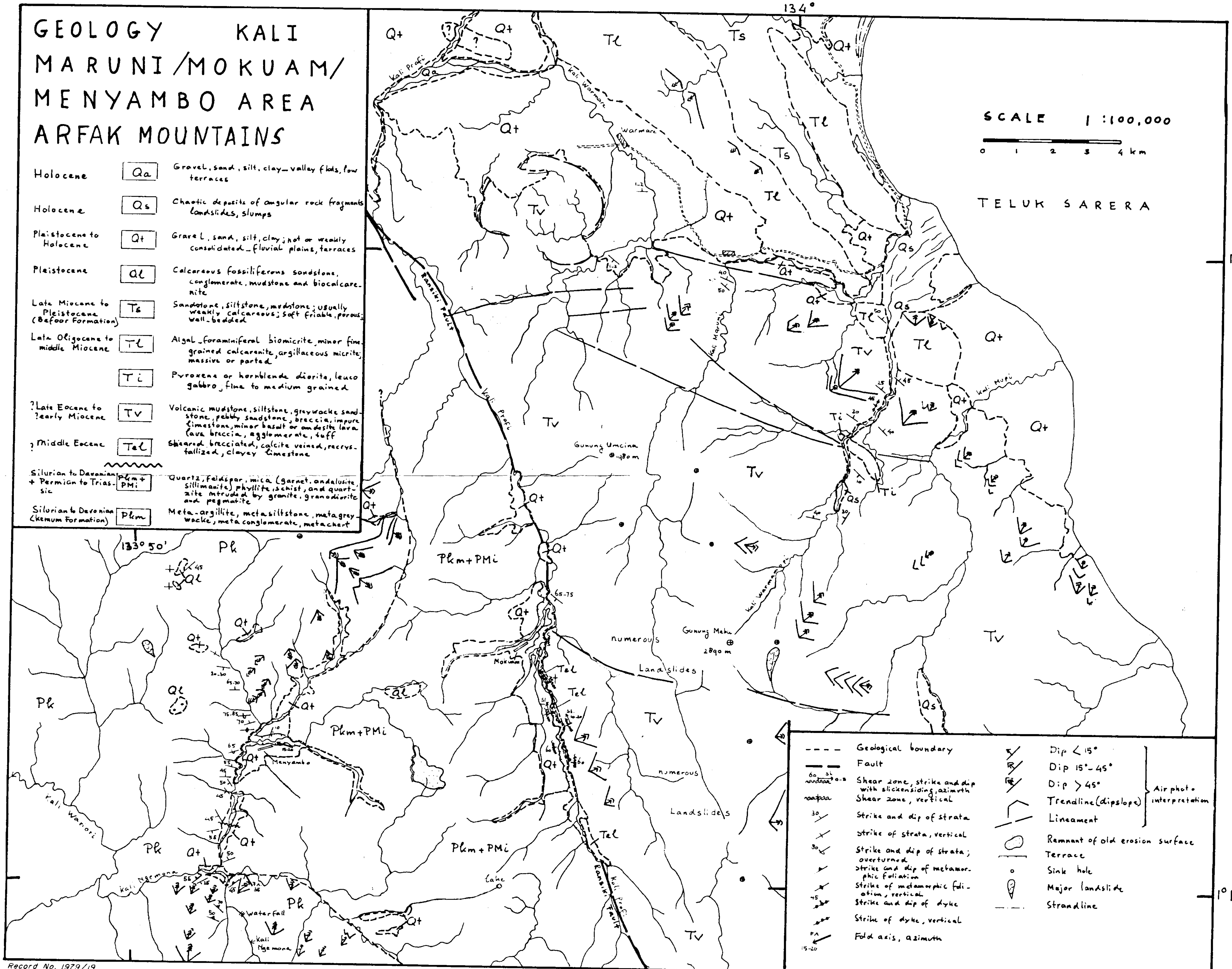
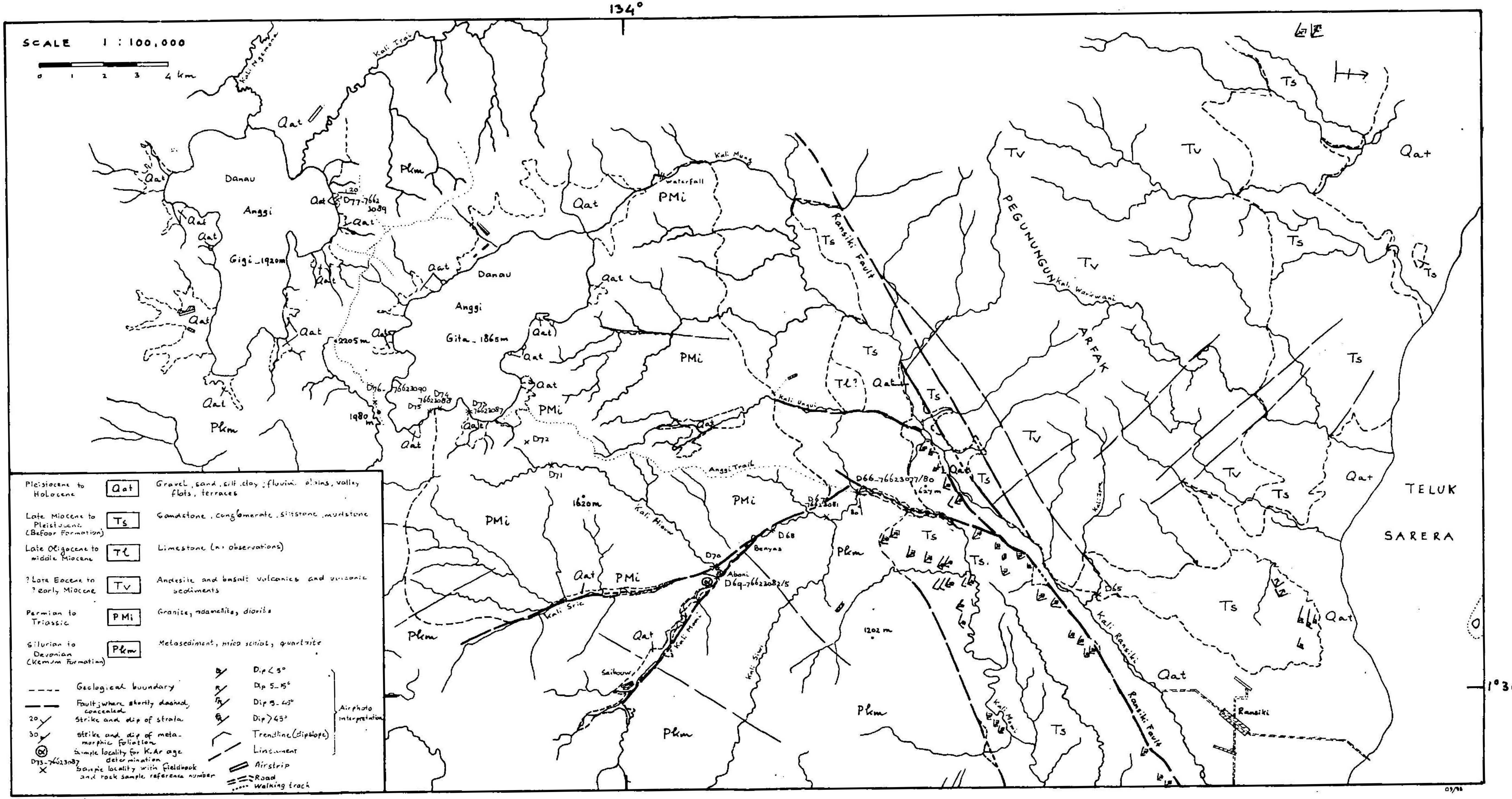


Plate 4. GEOLOGY KALI MARUNI /MOKUAM/ MENYAMBO AREA, ARFAK MOUNTAINS



Record No. 1979/19

Plate 5. GEOLOGY BETWEEN RANSIKI and LAKE ANGGI GIGI

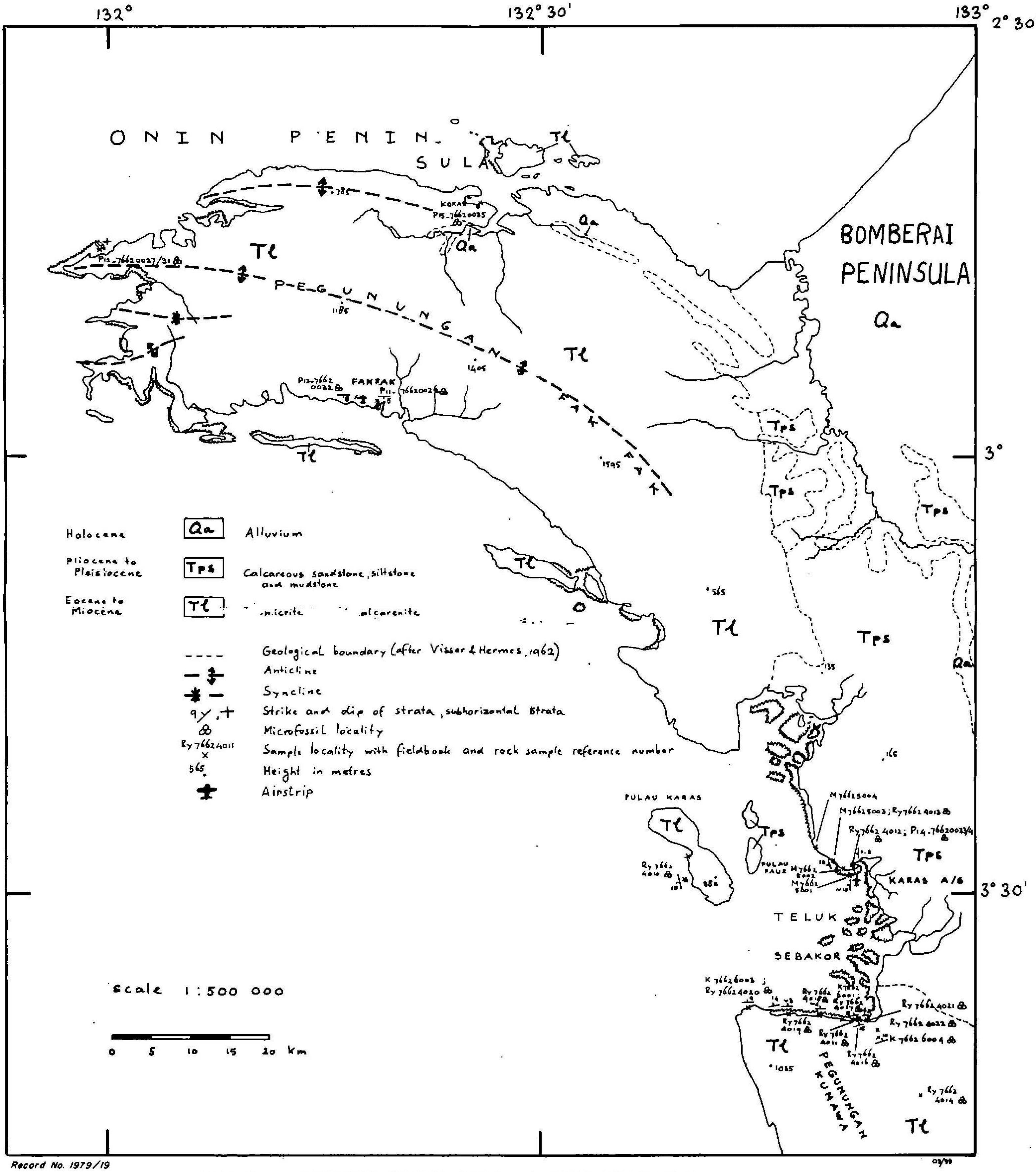


Plate 6. GEOLOGY—KARAS AREA and ONIN PENINSULA