COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 105

REPORT PNG 1

Geology and Mineral Deposits Port Moresby/ Kemp Welch Area, Papua

BY

K. R. YATES and R. Z. DE FERRANTI

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DEPARTMENT OF NATIONAL DEVELOPMENT

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SECRETARY: R. W. BOSWELL, O.B.E.

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SUMMARY

This report sets out the results of a geological and geochemical investigation of the Astrolabe Mineral Field, Papua. The following programme was completed:

1. Mapping of the Astrolabe Mineral Field at a scale of 400 feet to 1 inch, and collection of geochemical samples from streams draining the area;

2. Mapping the Geboria, Tupuseleia, Gaile, and Gea 1:50,000 Sheet areas, and collection of geochemical samples from streams draining the areas.

Rocks ranging from Upper Cretaceous to Pleistocene occur in the Port Moresby/ Kemp Welch area, but only those of Eocene (Port Moresby Beds), Oligocene (Sadowa Gabbro) and Pliocene (Astrolabe Agglomerate) age crop out extensively. The Port Moresby Beds consist of a lutite and a chert facies. The lutite facies is confined to the Astrolabe Mineral Field and comprises calcareous to argillaceous lutite, shale, and limestone; elsewhere chert, limestone, and calcareous sandstone of the chert facies are dominant. The Sadowa Gabbro intrudes the Port Moresby Beds and forms a discordant basic batholith which extends well beyond the area mapped. The batholith may comprise a number of overlapping intrusions, and the contact metamorphic grade ranges from the albite-epidote to the pyroxene hornfels facies.

The Astrolabe Mineral Field was worked sporadically for copper and gold from 1906 to 1942; mining ceased when New Guinea was invaded. Between 80,000 and 85,000 tons of copper were produced, mainly from the Laloki, Dubuna, and Sapphire-Moresby King mines.

Copper mineralization occurs within shale and siltstone of the lutite facies in the Port Moresby Beds, but because of the structural complexity and poor outcrop it was not possible to determine whether or not the ore occurred in a specific stratigraphic horizon. The orebodies are lenticular and their boundaries generally conform to the enclosing sediments; faulting and brecciation are common, particularly along the margins of the lodes, but a structural control of ore deposits is not evident. The mineral assemblage is pyrite, marcasite, chalcopyrite, and sphalerite, with minor galena, arsenopyrite, specularite, and gold. The sulphide to gangue ratio is 5:1. Detailed mineragraphic studies suggest that the ore is syngenetic.

The Laloki mine was the most productive on the field; current inferred reserves are 265,000 tons of ore assaying 4.6 percent copper and 4.1 dwt/ton gold. The ore is associated with steeply dipping black shale in a succession of calcareous to non-calcareous lutite and sedimentary breccia. The reopening of the Laloki mine, or any other in the field, depends on the development of a suitable treatment process for the ore.

Manganese ore of battery grade has been won from the Pandora mine in the Rigo area, and further discoveries are possible.

Geochemical samples collected from stream sediments averaged 10 samples per square mile. In addition, magnetite concentrates were collected, and rocks and gossans were sampled. All the samples were analysed for copper, zinc, nickel, and cobalt. Two anomalous areas showing significantly high total copper values were found in the Astrolabe Mineral Field. An area of 20 square miles of combined moderately high copper and zinc values near the Kemp Welch River is thought to be related to slight composition changes in the Sadowa Gabbro.

INTRODUCTION

It was decided that the detailed mapping of the Astrolabe Mineral Field, Papua, should be accompanied by a survey of the geologically similar area to the south-east, as far as the Kemp Welch River. As a result, in the latter half of 1964 the geology of the Geboria, Tupuseleia, Gaile, and Gea 1:50,000 Sheet areas was mapped in conjunction with a programme of geochemical sampling (Pls 9 to 12). The Astrolabe Mineral Field, which may be considered as the area covered by the accompanying 1:12,000 geological map (Pl. 8), was mapped at 400 feet to 1 inch, and geochemical samples collected from streams draining the area.

The field party consisted of K.R. Yates, R.Z. de Ferranti, and D. French, who were assisted for a short period by I.R. Pontifex and J.F. Ivanac. The geochemical sampling programme was planned by A.L. Mather. Detailed petrological studies of samples submitted by the party were made by A.S. Joyce. During his stay in the field I.R. Pontifex collected mineralized specimens from as many mines as possible to study the mineragraphy of the deposits. Some details of the results obtained by Joyce (1965) and Pontifex (1965) are included in this Report, and the complete data have been incorporated in separate BMR Records.

Location and Access

The area described in this Report is bounded by longitudes 147°15'E. and 147°45'E., and latitudes 9°20'S., and 9°50'S. (Fig. 1). It is part of the Port Moresby and Rigo Sub-Districts of the Central District of Papua. The western boundary of the Geboria Sheet area is 7.5 miles east of Port Moresby. Two graded unsealed roads, which connect Port Moresby with the rubber plantations of the Sogeri Plateau and the administrative centre of Kwikila, provide the main access to the area. Subsidiary roads are common in the Sogeri district, but south-east of Bootless Inlet the only road is the main coastal road, and this terminates immediately east of the Kemp Welch River. Good walking tracks link the villages throughout the area. Small coastal vessels provide a shipping service between Port Moresby and Kapa Kapa.

Population and Local Industries

The main centres of population are Tupuseleia (1128 persons), Kapa Kapa (829), Gaile (789), Barakau (426), and Saroa (406). Australians live mainly in the Sogeri Plateau, Laloki River, and the Kwikila/Kemp Welch River areas. Kwikila is a newly established administrative centre with a population of about 40 Australians.

Most of the population is employed in subsistence agriculture, growing coconuts, bananas, paw-paw, taro, and yams in small gardens scattered throughout the area. The only economically important products are rubber and copra, grown in plantations at Sogeri, Kemp Welch River, and Rigo.

Climate and Vegetation

The average annual temperature in the western part of the area ranges from 75° to 85°F, and in the eastern part from 69° to 88°F. Because of its higher elevation, the Sogeri Plateau has a slightly cooler climate than the coastal areas. The average annual rainfall ranges from 38 inches at Port Moresby, to 55 inches at Kemp Welch River, and about 110 inches at Sogeri. Rainfall in the area along the coast is seasonal with the maximum precipitation from December to March.

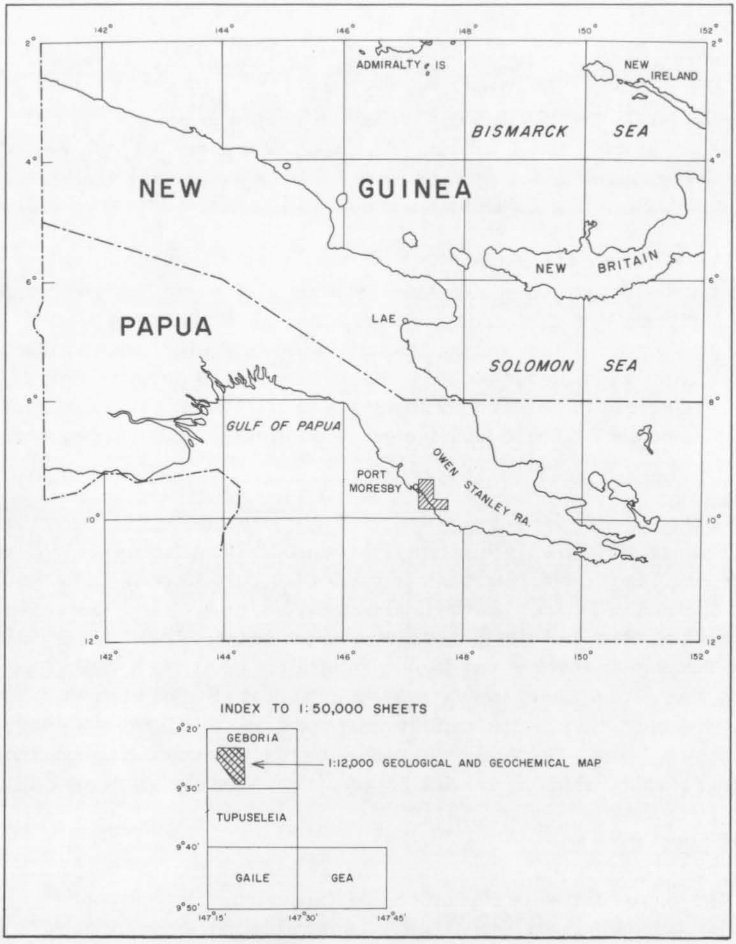

Fig. 1. Locality Map.

Vegetation ranges from savannah woodland containing scattered eucalypts and tall grasses, e.g. kunai, to tropical rainforest on the Astrolabe Range, the Sogeri Plateau and along all major watercourses. Geological mapping is easiest in the period August to December when the tall grasses which obscure rock outcrop are burnt by local hunting parties.

Water Resources and Power

All major creeks are perennial, and only the small watercourses are seasonally dry. The Sirinumu Dam was completed in 1963 to control the flow of the Laloki River through the Rouna Falls hydroelectric power station, which supplies power to Port Moresby. Excavation and construction are currently in progress to increase the capacity of this hydroelectric scheme.

Map and Air-photograph Coverage

To facilitate detailed mapping of the Astrolabe Mineral Field, special air-photographs of the field were flown in July 1964 by Queensland Aerial Survey Company Pty Ltd, under contract to the Bureau of Mineral Resources. With the aid of these photographs, 38 map sheets at a scale of 1:4800 and contoured at 10-feet intervals were compiled by Queensland Aerial Survey Company Pty Ltd, and Australian Aerial Mapping Pty Ltd, towards the end of 1964.

Other maps covering the area are:

Type	Scale	Name of Sheet and number	Produced by	Date	Available from
Topographic	1:50,000	Geboria 5229/1 Tupuseleia 5229/11 Gaile 5228/1 Gea 5328/11	Royal Australian Survey Corps	1965	Division of National Mapping, Canberra.
Military	1:63,360	Port Moresby Uberi Gaile Kapa Kapa Kemp Welch River	Australian Army Survey Corps	1943	Royal Australian Survey Corps
Planimetric	1:100,000	Port Moresby 5229	Royal Australian Survey Corps	1963	Division of National Mapping, Canberra.
Photomap	1:63,360	Port Moresby Uberi Gaile Kapa Kapa Kemp Welch River	Division of National Mapping	1957	Division of National Mapping, Canberra

Aerial photographs covering the area are:

Scale	Name	Flown by	For	Date	Available from
1:50,000	Port Moresby Uberi Gaile Kapa Kapa Kemp Welch River	Adastra Airways Pty Ltd	Division of National Mapping	24/10/56 23/6/57 18/11/56 8/5/57 21/6/57	Division of National Mapping, Canberra.
1:24,000	Astrolabe	Queensland Aerial Survey Company Pty Ltd	Bureau of Mineral Resources	11/ 7/64	Division of National Mapping, Canberra.

PHYSIOGRAPHY

The Port Moresby/Kemp Welch area may be divided into six physiographic units, from north-east to south-west:

- (i) The Sogeri Plateau
- (ii) The foothills and ranges
- (iii) The coastal hills
- (iv) The alluvial plains
- (v) The barrier reef
- (vi) The continental shelf

These units are illustrated on a perspective block diagram of the area between Port Moresby and the Kemp Welch River (Fig. 2, cf. Mabbutt, 1965).

The Sogeri Plateau is undulating and ranges from 1500 to 2500 feet above sea level. The plateau is underlain by the Astrolabe Agglomerate, which is folded into a broad syncline, plunging gently to the north-west. The south-western limb of the syncline forms the Astrolabe Range; the north-eastern limb forms deeply dissected ranges drained by the Goldie and Hiwick Rivers.

Most of the plateau is drained by the Laloki River and its tributaries. In the upper reaches of the Laloki River incised meanders occupy the centre of the syncline, but at Sogeri Patrol Post the river swings west and cuts through the south-western limb of the river and predates the uplift of the Astrolabe Range, the crest of which is now 1200 feet above the Sogeri Patrol Post. Streams flowing north-west off the plateau into the Hiwick River have captured part of the Laloki drainage.

The Sogeri Plateau is bounded by agglomerate cliffs up to 800 feet high, below which lie the foothills. This is an area of deep youthful valleys and narrow ridges which forms a zone of varying width around the plateau. Adjacent to the Astrolabe Range, the zone of foothills is about 2 miles wide; below Hombrom Bluff it is less than a mile wide. North of the Hiwick River to the east of the Geboria Sheet area and occupying the northern one third of the Gea Sheet area at least, is a wide zone of foothills which grade into the coastal hills, but to the north-west the boundary is again distinct.

The streams in the foothills have a dendritic drainage pattern which becomes pinnate along the steeper slopes of the Astrolabe Range. Stream gradients are generally steep and waterfalls are numerous.

The topography of the coastal hills is more mature, and marked by a greater geological control than in the foothills zone. Rounded ridges and belts of low hills, commonly parallel to the regional strike, are separated by broad valleys floored with alluvium and black soil. The highest hills are less than 1500 feet above sea level, and the relief averages 500 feet. Streams in this zone form a dendritic pattern which tends to be rectangular in areas of sedimentary rocks.

The coastline between Port Moresby and Kapa Kapa shows evidence of submergence and refilled drowned river valleys, forming broad alluvial plains. The small streams

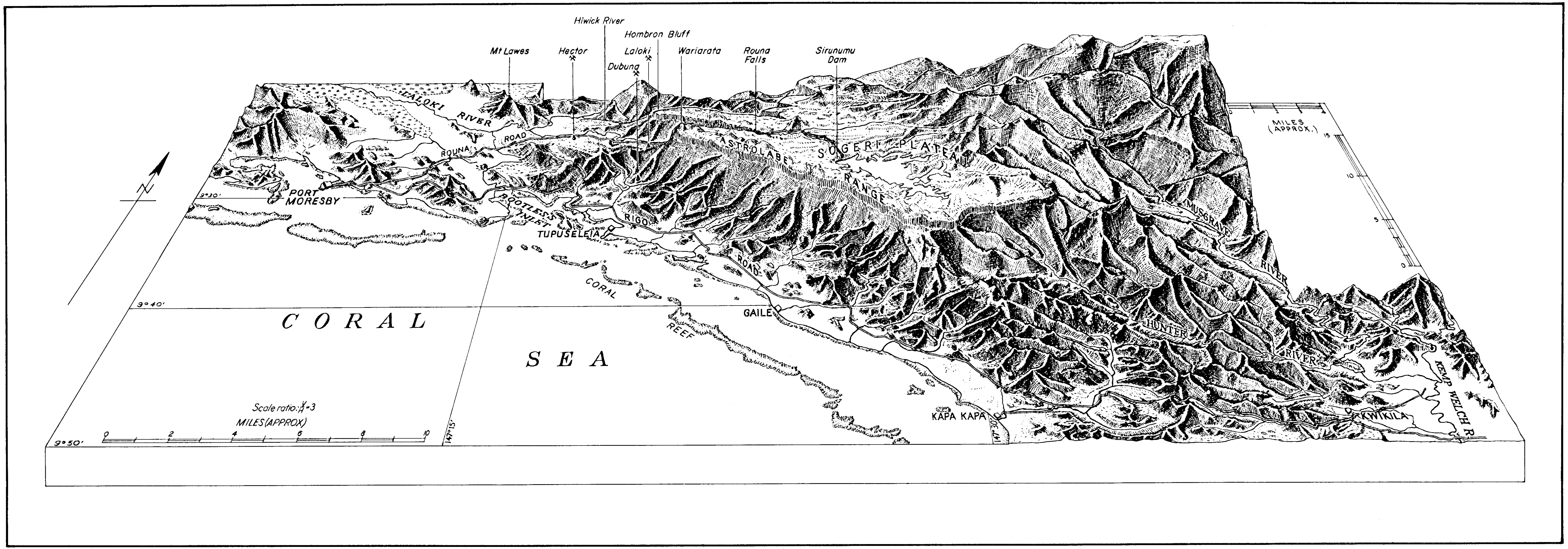

Fig. 2 Physiographic block diagram of area between Port Moresby and Kemp Welch River

draining areas of low rainfall around Bootless Inlet and Konebada Bay have not yet filled their drowned valleys completely, but south of Barakau Mission, the large streams draining the Astrolabe Range have completely filled their valleys, producing a straight coastline.

Alluvial plains also border the Goldie and Laloki Rivers on the western edge of the Geboria Sheet area, and the Kemp Welch and Musgrove Rivers on the western edge of the Gea Sheet area.

Barrier reefs occur from Samarai in the east, to Yule Island northwest of Port Moresby. Between Bootless Inlet and Kapa Kapa, coral reefs form a discontinuous barrier parallel to the coast, and 3 to 5 miles distant. The back reef zone is very shallow, and the maximum depth is about 100 feet. Fringing reefs cover large areas adjacent to rocky parts of the coastline.

The steep outer wall of the barrier reef is commonly more than 100 feet high above the sea floor, which slopes steeply down to the continental shelf, more than 300 feet below sea level.

PREVIOUS INVESTIGATIONS

The first recorded geological observation in the Astrolabe Mineral Field was made by Macgillvray (1852) in 1850 when he observed the Astrolabe Range from H.M.S. Rattlesnake and recognized the distinct synclinal structure of the Astrolabe Agglomerate. In 1871, missionaries of the London Society began work in the Port Moresby area and explored the area immediately east of the town. Revs W.G. Lawes, J. Chalmers, and T. Beswick, and the naturalist A. Goldie explored the coastal belt from Port Moresby to the Kemp Welch River between 1864 and 1879, but it was not until 1882 that Chalmers and Lawes climbed the Astrolabe Range. About the same time, an American geologist, William Denton, died while working on the range, leaving no record of his observations. Gibb-Maitland in 1891 noted that beds similar to those at Port Moresby extended south-east beyond the Kemp Welch River, while the rocks in the Laloki River area had a different lithology.

Following the discovery of copper mineralization in the Laloki River area in 1906, geological interest in the area increased and E.R. Stanley was appointed Government Geologist at Port Moresby in 1911. From then until 1916, Stanley wrote a number of valuable reports on the individual copper mines of the field. A summary of the mining activities at this time was prepared by Carne (1913), who discovered limestone at Bootless Inlet, which was later recognized as lower Miocene by Chapman (1914). After an expedition across the Owen Stanley Range via the Kemp Welch River in 1916, Stanley concentrated on the stratigraphy and geological history of Central Papua in his reports (until 1924).

From 1920 to 1929, Anglo-Persian Oil Company on behalf of the Australian Commonwealth Government conducted an oil exploration programme in Papua. Consequent on this work, Mongomery (1930) wrote a very thorough report on the stratigraphy and palaeontology of the Port Moresby/Bootless Inlet area, incorporating a large number of petrographic observations. By nature of its structural complexity, the area received only cursory examination by oil prospecting companies in the following years (Pallister, 1938; Pratt, 1939).

As a result of the activity of Mandated Alluvials N.L. at the Sapphire and Moresby King mines from 1936 to 1942, and the simultaneously renewed interest in the Laloki mine, Fisher (1941) examined and reported in detail on the geology and the prospects of these mines.

At the same time C.S.I.R., Melbourne, investigated the mineralogy of the ores, and ore dressing problems.

A geological reconnaissance from Kapa Kapa to the Kemp Welch River was made by G.A.V. Stanley and J.E. Thompson (Australasian Petroleum Company) in 1947, in order to examine the stratigraphic succession previously outlined by E.R. Stanley (1919b). Their well-documented observations were most useful during the current survey.

The Bureau of Mineral Resources established a regional office in Port Moresby in 1949, and since then a number of small reports (all unpublished) concerning raw materials for cement manufacture, dam sites on the Laloki River, and manganese deposits at Rigo, have been written; e.g. Ward (1949a, b), Noakes (1949), Condon (1949), Edwards (1950, 1951), Edwards & Best (1952), and Perry (1954).

During 1948 and 1949, M.F. Glaessner, while not engaged in work for the Australasian Petroleum Company, spent much of his spare time in mapping the geology of the Port Moresby area. Although only a small portion of the area mapped by Glaessner (1952) overlaps the area described here, his stratigraphic and palaeontological observations have proved invaluable.

In 1949 and 1950, at the request of Mandated Alluvials N.L., the Bureau of Mineral Resources carried out a geophysical survey of copper mines in the Astrolabe Mineral Field (Oldham, 1950; Tate, 1951). This geophysical work, together with an offer of free inspection of the mining leases, stimulated the interest of the Zinc Corporation, and as a result King (1950) prepared a comprehensive account of all the major copper occurrences.

Prior to 1954, very little effort had been made to study the geology of the entire Astrolabe Mineral Field, most investigations being confined to the mines and their immediate surroundings. Following the work of Glasson (1954), Spratt (1957) prepared the most recent and comprehensive geological map of the main copper-bearing area.

Recent investigations have been related to diamond drilling at the Laloki mine (Witcher, 1960; Davies, 1961a), and dam sites and the hydroelectric project on the Laloki River. Thomas (1962) made a reappraisal of the copper potential of the area.

A survey of the Port Moresby/Kairuku area was conducted by the CSIRO Division of Land Research and Regional Survey in 1962 and their report contains sections on the geology and geomorphology of the area (Mabbutt and others, 1965).

STRATIGRAPHY

Rocks ranging from Upper Cretaceous to Pleistocene occur in the Port Moresby/Kemp Welch area, but only those of Eocene (Port Moresby Beds), Oligocene (Sadowa Gabbro), and Pliocene (Astrolabe Agglomerate) age crop out extensively. In Table 1, the evolution of stratigraphic nomenclature within the area, from 1893 to 1952, is tabulated to enable ready correlation with the stratigraphic sequence described here. For reference, the interpretations by Glaessner (1959) and Eames (1962) of the Dutch Tertiary letter classification with respect to the European succession are shown in this table. The only difference between their interpretations which affects this report is the position of the base of the 'e' stage in relation to the Oligocene/Miocene boundary. In the following discussions, the base of the 'e' stage is considered to be the Oligocene/Miocene boundary, in agreement with Eames.

TABLE 1 EVOLUTION OF STRATIGRAPHIC NOMENCLATURE

PORT MORESBY/KEMP WELSH AREA

				TERTIARY STAGES													
				GLASSNER (1959)	EAMES (1962)	MAITLAND (1893)	STANLEY (1911)	CARNE (1913)	WADE (1914)	STANLEY (1919a)	STANLEY (1919b)	STANLEY (1920)	STANLEY (1921-24)	MONTGOMERY (1930)	STANLEY, G.A.V., (1947)	GLASSNER (1952)	YATES & de FERRANTI (1965)
CAINOZOIC	QUATERNARY	RECENT													Raised coral reefs		ALLUVIUM, SCREE
		PLEISTOCENE						Astrolabe volcanic series							*Raised river gravels		ARARABU CONGLOMERATE
	TERTIARY	PLIOCENE		h g	h g	Basalt and other volcanics	Volcanic agglomerate	*Port Moresby Beds		Basalts and agglomerate and (Late Tertiary)			*Astrolabe volcanic agglomerate and interbedded river gravels		*Astrolabe Series	*Astrolabe Agglomerate and Tuff	KWIKILA AGGLOMERATE ASTROLABE CONGLOMERATE
		MIOCENE	U					*Limestone and calcareous shale Bootless Inlet		Orbitoides limestone at Bootless Inlet Eriama Series					Gidobada Series i.e. Volcanics Limestone Volcanics		SIRO CONGLOMERATE
			M	f	f		Newer slates and limestones (Tertiary)										
			L		e						Port Moresby Series consisting probably of Rigo Beds	*Bootless Inlet Limestone (Pre-Miocene to Miocene)	*Bootless Inlet Limestone (Eriama Series)	Metamorphosed limestone		*Siro Beds	GIDOBADA LIMESTONE DOKUNA TUFF - BOOTLESS INLET LIMESTONE
		OLIGOCENE	U	e						Port Moresby Series (Tertiary)			Port Moresby Series	Bootless Inlet limestone. Green and dark tuffs. Port Moresby-Bootless Inlet dist.			
			M	d	d		Port Moresby Series (Tertiary)	Altered and indurated sediments intruded by gabbro and basalt							Bootless Inlet (gritty orbitoidal limestones, tuffs.)	*Dokuna Tuff and Agglomerate	SADOWA GABBRO (INTRUSION)
			L	c	c						Port Moresby Beds	Port Moresby Series (Lower Tertiary)	Lower beds of Kemp Welsh littoral and adjoining coastline. (Pre-Miocene)				
		EOCENE	U	b	b									Upper Port Moresby Beds. Port Moresby limestone with nummulites and discocyclines	*Port Moresby Group or Eriama Group or Kemp Welsh Group	*Port Moresby Group	PORT MORESBY BEDS
			M		a_1		Basic dykes										
			L	a													
		PALAEOCENE			a_1		Older slates and limestones (age indefinite)						Basic dykes				
MESOZOIC									Port Moresby Beds	Astrolabe Kemp Welch Series				Cretaceous Lower Port Moresby Beds	*Cretaceous Lower Port Moresby Group (pink limestone)	Upper Cretaceous Borgo Limestone	BORGO LIMESTONE
PALAEOZOIC											*Gidobada Series						
PRECAMBRIAN						Port Moresby Beds	*"Lalokite" gneiss etc				*Kemp Welch Series (intruded by basic dykes		*Astrolabe-Kemp Welsh series. Basic plutonic rocks.				

xxxxxxxxxxxx Unconformity

* Definite Age Proposed

The stratigraphic units of the area are described in ascending chronological order.

UPPER CRETACEOUS

Bogoro Limestone

The pink foliated limestone in the Bogoro Inlet area was first examined and described by Montgomery (1930) who thought it belonged to the 'd' Stage. Samples collected by G.A.V. Stanley (1947) were examined by Glaessner, who recognized a Cretaceous foraminiferal fauna, but the limestone was still placed in the 'Lower Port Moresby Group' (Table 1). The unconformity between this limestone and the Port Moresby Beds was inferred from palaeontological and some structural evidence by Glaessner (1952), who proposed the name Bogoro Limestone.

The Bogoro Limestone is a uniform pale to salmon-pink limestone which generally is intensely sheared, or contorted, or both. The shear planes contain veinlets of white calcite. Locally, where the shearing has been less intense, slightly fractured massive pink limestone is preserved.

The formation is restricted to the extreme south-western corner of the Geboria Sheet area and occurs as scattered lenses generally less than 400 yards long and 100 yards wide. Intermittent lenses were found by Glaessner (1952) extending beyond the mapped area in a very narrow belt trending north-west as far as the Laloki River. In good exposures 0.5 miles west of Bautama Mission the maximum observed thickness is about 50 feet.

Foraminifera from the limestone indicate an Upper Cretaceous age. Genera identified include Globotruncana spp., Pseudoguembelina sp., Pseudotextularia sp., and Racemiguembelina sp. (Belford, 1965). This fauna is similar to that determined by Glaessner. The fine grainsize of the Bogoro Limestone and the presence of small pelagic foraminifera indicates a bathyal environment of deposition. The map prepared by Glaessner (1952) shows almost all outcrops of the Bogoro Limestone in fault contact with the surrounding Port Moresby Beds (Eocene). No evidence for these faults has been found. On the other hand unsheared arenaceous glauconitic limestone containing Eocene foraminifera belonging to the Port Moresby Beds, unconformably overlies highly sheared Bogoro Limestone west of Bautama Mission, indicating that the area was deformed during the Palaeocene.

EOCENE

Port Moresby Beds

Table 1 shows that a considerable number of names have been applied to the older rocks of the area. The name 'Port Moresby Beds' was introduced by Maitland (1893) for the rocks in the immediate vicinity of Port Moresby. E.R. Stanley (1911) considered that the rocks in the Laloki mine area and north of Rigo into the Astrolabe-Kemp Welch Series were Precambrian, but by 1924 he had concluded that the Port Moresby Beds (Series) were Lower Tertiary. The terminology of Montgomery (1930) is discussed by Glaessner (1952), who concluded that the 'Metamorphosed limestones' and the 'Tuffs of the Laloki and Dubuna mines' were simply lithological variants of the same stratigraphic unit. From field evidence, the distinction between Cretaceous Lower Port Moresby Beds and Eocene Upper Port Moresby Beds was also proved untenable. Glaessner (1952) introduced the term 'Port Moresby Group', but this term is considered not valid since there are no constituent formations and the name

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'Port Moresby Beds' has been used here. The Port Moresby Beds as defined include Stanley's Rigo Beds and some of his Astrolabe - Kemp Welch Series and Eriama Series.

Within the map area the Port Moresby Beds crop out along the coastline in a belt 4 to 5 miles wide trending south-east from Port Moresby to Kapa Kapa. It is probable that they extend well beyond these limits. Because of structural complexity and the lack of distinctive markers no stratigraphic sequence can be recognized within these beds. There is undoubtedly considerable repetition of beds across the strike, and the apparent thickness of the succession far exceeds the true thickness, which is probably less than 5000 feet.

The Port Moresby Beds are Eocene; they overlie the Bogoro Limestone unconformably, are intruded by the Sadowa Gabbro, and are unconformably overlain by the Dokuna Tuff and Bootless Inlet Limestone.

Lithology

Two lithological facies can be distinguished in the Port Moresby Beds. They were indirectly recognized by Maitland (1893) and by all later workers in the area, and are here named the lutite facies and chert facies.

Lutite Facies

Sedimentary rocks belonging to the lutite facies are confined almost entirely to the Astrolabe Mineral Field. They are best developed in the area bounded by the Laloki River; the old Rigo road, and the Astrolabe Range. Along strike this facies grades into the chert facies near Rabuka village. Rock types representative of this facies, listed in their order of abundance, are:

(1) Grey, greenish-grey, green, or banded red calcareous to argillaceous lutite. Lamination is common, but bedding plane partings generally are 6 to 12 inches apart. Slump structures have been observed only in diamond drill cores, and current bedding seems to be absent. Small veinlets of calcite, zeolite, and some quartz are common.

(2) Black, grey, green, and red shale, distinguished from the other lutites by its greater fissility.

(3) Red to pink massive calcilutite or limestone which occurs as small scattered lenses. The larger outcrops of this rock type are shown on Plate 9, e.g., west of Sapphire mine and at Hospital Hill.

(4) Red and grey calcilutite and lutite breccia, found mainly in the Laloki mine area. The breccia commonly contains angular to subrounded fragments of grey and red, or only grey, lutite in a fine-grained matrix of clay, calcite, quartz, chlorite, and plagioclase. The fragments are far more abundant than the matrix and range from 1/8 to 3 inches across. The fine breccia in part grades into an arenite. Veining and cementing by calcite or zeolite is common. From a study of diamond drill cores from the Laloki mine, Davies (1961a) concluded that the breccia was sedimentary and resulted from slumping of partly lithified sediments.

(5) Minor dark grey tuffaceous beds found at the Laloki and Dubuna mines (see Montgomery, 1930, and Davies, 1961a). Fragments in the tuff are of basic volcanics, and as the proportion of fragments decrease, the tuff grades into the lutite.

Sandstone or conglomerate is virtually absent from the succession. Planktonic foraminifera are poorly preserved or absent.

Chert Facies

The Port Moresby Beds, from Bootless Inlet to Rigo, generally belong to this facies. Characteristic features are the presence of chert in beds and nodules, the interbeds of fossiliferous limestone, the small content of terrigenous material, and the absence of breccia.

Typical rocks in their order of abundance are:

(1) Buff, pink, maroon, light grey laminated calcilutite, in beds 4 to 6 inches thick. The clay content is variable, and some of the darker lutites, which contain more clay than calcite, are more correctly termed calcareous lutite. Small pelagic foraminifera, mainly Globigerinidae, are common. Angular grains of basic plagioclase and quartz are accessary constituents together with rare fragments of basic volcanic rocks. Glauconite is present locally. Calcite veining is widespread.

In coastal exposures from Bootless Inlet to Kapa Kapa, the thin-bedded buff calcilutites are characterized by the presence of chert nodules. The nodules are ovoid with their long axes parallel to the bedding, and range from 6 inches to 6 feet in length. Concentric banding is common in the chert. The rocks above and below the nodule are moulded around it. Smaller nodules (up to 3 inches in diameter) of iron oxide pseudomorphing pyrite have a similar habit.

(2) Thin-bedded light grey chert. This rock is locally unimportant, but is more abundant in the vicinity of Port Moresby (Glaessner, 1952).

(3) Light grey calcarenite or detrital limestone. This rock type is confined to the Bogoro Inlet area, where it has been found immediately overlying the Bogoro Limestone (fossil locality number 5, Table 2): it corresponds with the 'limestone - grits' of Montgomery (1930). The rock consists predominantly of larger foraminifera and fragments of limestone, cemented by calcite. Rounded siltstone fragments and angular quartz and basic plagioclase grains constitute about 10 percent of the detritus. Glauconite (?) is present in most outcrops and imparts a green speckled appearance to the rock. Fragments of basic volcanic rocks are uncommon.

(4) Fine-grained light-grey calcareous sandstone, interbedded with calcilutite south-east of Manugoro. The predominant detrital constituents are rounded fragments of calcilutite, subangular to subrounded quartz, and plagioclase feldspar (andesine). Minor siltstone fragments, bleached biotite, muscovite, chlorite, and glauconite(?) are present. A fine-grained calcite cement constitutes less than 10 percent of the rock.

The nummulitic limestone interbeds found in the vicinity of Port Moresby (Glaessner, 1952), were not seen in our area.

Sedimentary Environment

The predominance of fine calcareous muds and planktonic foraminifera in the Port Moresby Beds indicates a forereef to bathyal environment of deposition. The nummulitic limestones in the vicinity of Port Moresby (Glaessner, 1952), and the light grey calcar-

TABLE 2

FOSSIL LOCALITIES PORT MORESBY/KEMP WELCH AREA

The following is a list of localities of fossiliferous samples collected during the survey. The locality numbers correspond with those shown on the accompanying geological maps.

LOCALITY NUMBER	FORMATION	AGE	*PHOTO REFERENCE SET	RUN	PHOTO NUMBER	POINT NUMBER	1:50,000 SHEET	METRIC GRID REFERENCE EASTINGS	NORTHINGS
1	BOGORO LIMESTONE	UPPER CRETACE-OUS	Port Moresby	4	5019	Y105	Geboria	530650	8950075
2			"	"	"	Y113	Tupuseleia	530625	8949800
3	PORT MORESBY BEDS	EOCENE	Port Moresby	4	5019	Y102	Geboria	530900	8950000
4			"	"	"	Y104	"	530775	8950025
5			"	"	"	Y105	"	530650	8950075
6			"	"	"	Y106	"	530575	8950100
7			"	"	"	Y112	Tupuseleia	530550	8949475
8			"	"	"	Y293	Geboria	530250	8950725
9			"	"	"	Y296	"	530925	8951175
10			"	"	"	Y18	Tupuseleia	531950	8948775
11			"	"	"	Y114	"	532050	8948800
12			Gaile	1	5029	Z044	"	531600	8948925
13			"	"	"	Z093	"	535725	8948450
14			"	"	5031	Z126	"	543350	8944775
15			Kapa Kapa	1	5043	Y51	Gaile	553700	8918075
16			" "	"	5045	Z472	Gea	559500	8917050
17			" "	2	5079	Z132	"	558425	8914900
18			" "	"	5077	Z147	"	561575	8915975
19	Small inclusion in gabbro		Gaile	4	5037	Z274	"	575900	8922175
20	BOOTLESS INLET LIMESTONE	LOWER MIOCENE 'e' STAGE	Port Moresby	4	5019	Y289	Geboria	530800	8952800
21			"	4	5019	Y311	"	531600	8952950
22			"	"	"	Y297	"	532500	8950500
23	DOKUNA TUFF		Gaile	1	5029	Z538	"	534750	8951000
24	GIDOBADA LIMESTONE	UPPER LOWER MIOCENE 'f' STAGE	Kapa Kapa	2	77	Z195	Kapa Kapa 1:63,360	1.7 miles east of Ginegolo.	
25							Gea	570800	8915050
26	ARARABU CONGLOMER-ATE	PLEISTO-CENE	Kemp Welch River	2	5073	Z179	Gea	577450	8913425

* These aerial photographs are held in store at the Bureau of Mineral Resources, Canberra.

enite in the chert facies, indicate that neritic reefs developed in some areas. In the Bogoro Inlet area the Port Moresby Beds were deposited around small shoals of Cretaceous Bogoro Limestone.

The rock fragments in the Port Moresby Beds indicate a source area containing fine-grained sedimentary rocks and minor basic volcanics. The presence of detrital unstrained quartz, andesine, mica, zircon, and tourmaline suggests that granitic rocks were also present. There is no evidence to indicate derivation from a predominantly metamorphic terrain.

Age

Fossiliferous samples have been collected from 16 localities within the Port Moresby Beds (see Table 2). All samples were examined by Belford (1965), who distinguished two Eocene foraminiferal faunas. The foraminifera within the calcarenites of the chert facies from three localities (5, 10, and 12) are distinct from the small planktonic keeled Globigerinidae found in the calcilutites from the other localities. The former are of the 'larger' type and are associated with algae; genera and species identified are:

Locality 5:	*Halkyardia bikiniensis* Cole
	Heterostegina sp. cf. *H. saipanensis* Cole
	Cycloclypeus? sp.
	Amphistegina sp.
	Borelis sp.
	Eorupertia sp.
	Globigerinidae
	Indeterminable smaller Foraminifera: rotaliids, miliolids
Locality 10:	*Discocyclina* sp. (fragments)
	Halkyardia bikiniensis Cole
	Heterostegina sp. cf. *H. saipanensis* Cole
	Amphistegina sp.
	Eorupertia sp.
	Globigerinidae
	Distichoplax biserialis (Dietrich) (alga)
Locality 12:	*Discocyclina* sp.
	Planorbulinella sp.
	Amphistegina sp.
	Globigerinidae (very rare)
	Indeterminable smaller Foraminifera
	Distichoplax biserialis (Dietrich) (alga)

Glaessner (1952) considered that the Port Moresby Beds were probably deposited in the upper Eocene, because of the presence of *Pellatispira*, a restricted upper Eocene genus, in an outcrop close to the Bogoro Limestone. No restricted upper Eocene genera were recognized by Belford (1965) in samples from locality 5, which is adjacent to the Bogoro Limestone.

PLATE 1

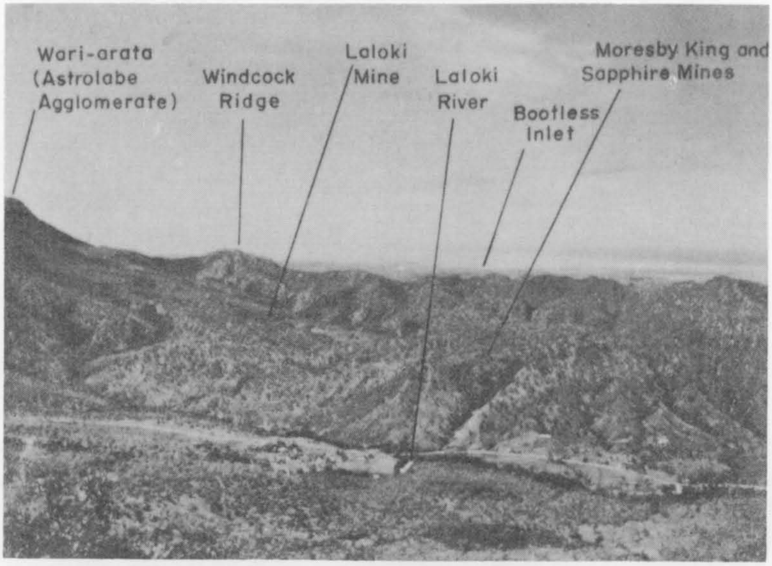

Figure 1:

View southwards from Hombrom Bluff, showing eastern half of Astrolabe Mineral Field.

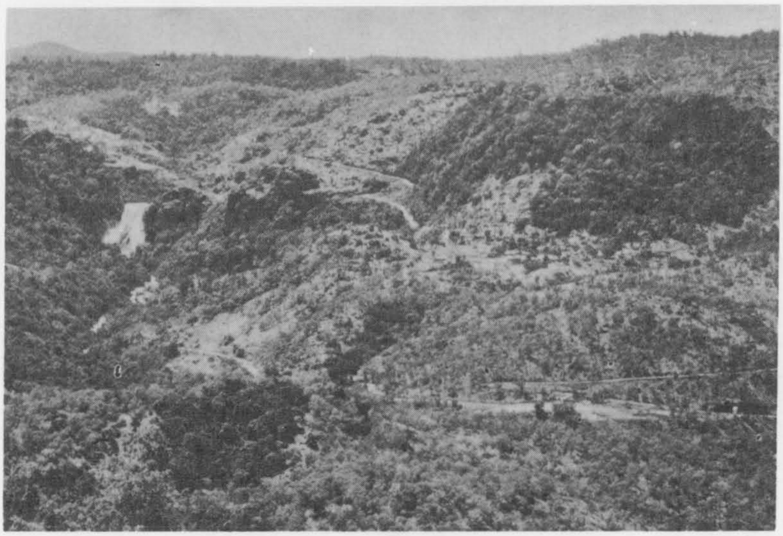

Figure 2:

Rouna Falls viewed from Hombrom Bluff. Base of falls is Astrolabe Agglomerate - Siro Conglomerate boundary. Note the flat surface of the Sogeri Plateau.

PLATE 2

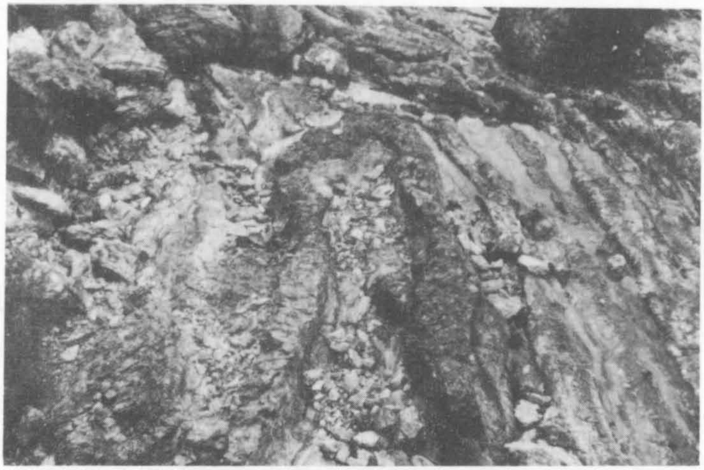

Figure 1:

Vertically plunging minor fold outlined by thin chert bed in calcilutite of Port Moresby Beds. Scattered chert nodules are visible in background. Note prismatic compass near centre of photograph.

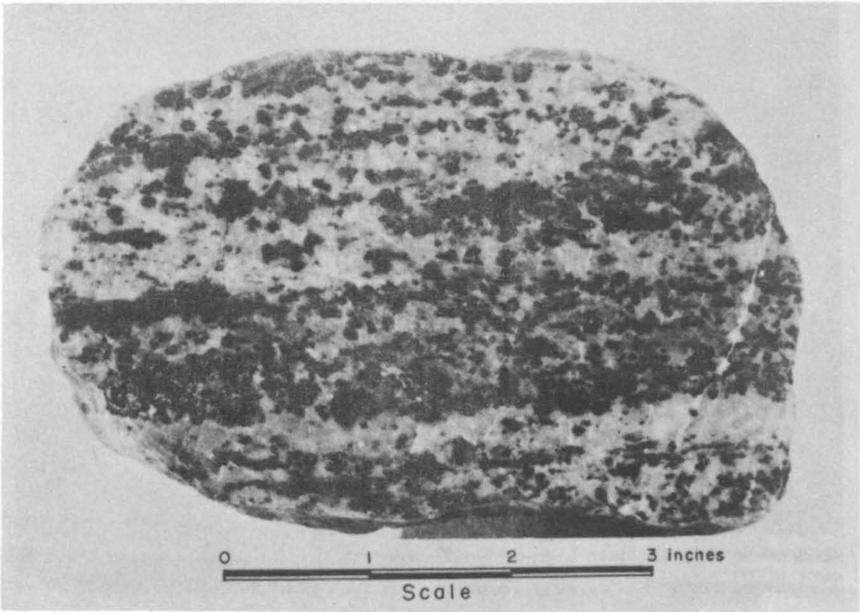

Figure 2:

Coarse-grained banded variety of Sadowa Gabbro.

PLATE 3

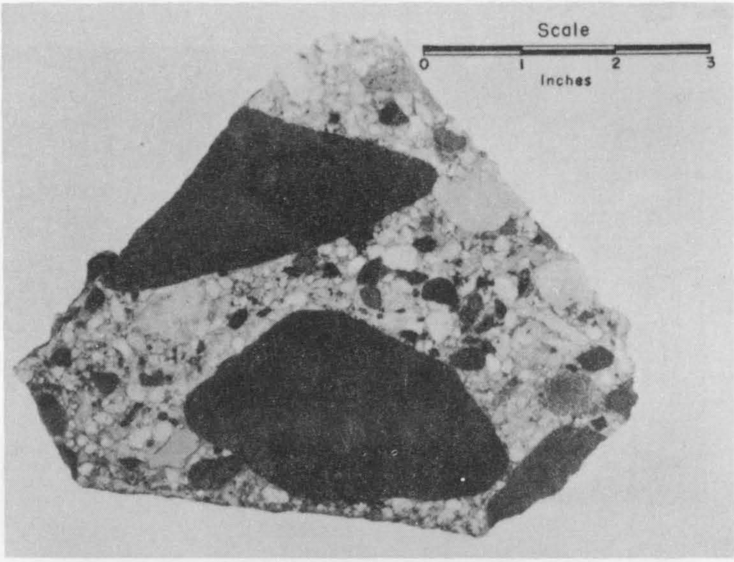

Figure 1:

Fossiliferous calcareous agglomerate from Dokuna Tuff. Large fragments are fine-grained basalt. Most foraminifera are large Lepidocyclina sp.

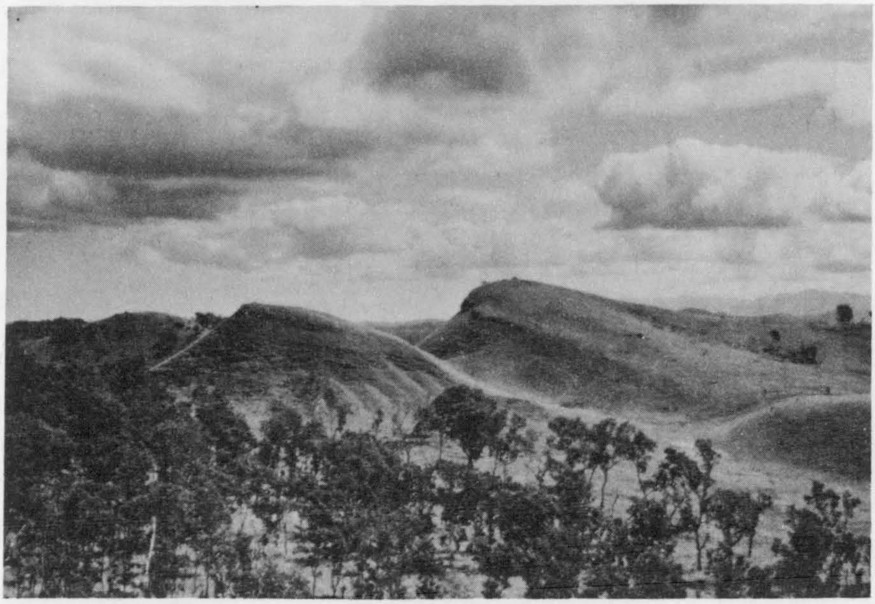

Figure 2:

Gently dipping Gidobada Limestone (maximum thickness 100 feet) unconformably overlying Port Moresby Beds, 1.7 miles east of Ginigolo.

OLIGOCENE

Sadowa Gabbro

The Sadowa Gabbro is named from 'Sadowa', a prominent hill within the Astrolabe Mineral Field (grid reference 532875, 8956160, Geboria 1:50,000 Sheet area). Because of the inhomogeneity of this igneous body, no single area within it can be regarded as typical. Sadowa has been chosen as a suitable reference locality because it is composed of relatively fresh and coarse-grained gabbro.

Basic igneous rocks included in the Sadowa Gabbro cover an area of at least 200 square miles extending from the Goldie River to the Kemp Welch River. The gabbro probably extends well beyond the area covered by the accompanying maps. Two distinct areas containing Sadowa Gabbro may be recognized: (1) The Astrolabe Mineral Field, in which the gabbro and sedimentary rocks of the Port Moresby Beds have a complex outcrop pattern. This is named the 'Astrolabe' area. Here the rock type ranges from olivine gabbro, through pyroxene-hornblende diorite, to granophyre. (2) A considerably larger and more uniform area south-east of the Astrolabe area, in which a far simpler relationship between the igneous and intruded sedimentary rocks is found. This is named the 'Gea' area.

The total vertical exposure of basic igneous rocks is about 2000 feet.

Contact Relationships and Internal Structure

Distinctive features of the contacts and internal structure of the Sadowa Gabbro are:

(1) The trend of the contacts is parallel to the regional strike of the Port Moresby Beds.

(2) Locally discordant contacts are evident in the Astrolabe area in the form of small equidimensional bodies which truncate the strike of the surrounding sedimentary rocks, e.g. north of the Dubuna mine. The strike of the gabbro contact may locally diverge by as much as 80° from that of the immediate sediments.

(3) Contacts on either side of a gabbro body may be parallel, e.g. north of the Merrie England mine and north of Sadowa.

(4) A sill-like body, up to 250 feet wide and 1 mile long, crops out immediately south-east of the Hector mine, and is connected to the main gabbro mass.

(5) Small tongues of fine-grained basic rock up to 1 foot wide and 10 feet long conformably intrude shale and mudstone of the Port Moresby Beds in Maiberi Creek, 1000 yards south-east of the Elvina mine.

(6) The attitude of the contacts ranges from almost horizontal to vertical. Steeply dipping contacts predominate in the Astrolabe area, as is shown by the contact/contour intersections on Plate 9. Gently dipping to horizontal contacts are present in the vicinity of the Moresby King mine, and half a mile west of the Sapphire King mine.

(7) The basic igneous rock is in contact with a variety of sedimentary rocks.

(8) No basic dykes have been found intruding rocks of the Port Moresby Beds.

(9) Low-grade thermal metamorphism of the Port Moresby Beds is restricted to a narrow irregular zone along the contact. The thermal metamorphism is discussed more fully on page

(10) Generally the gabbro is chilled against the sediments, but in rare instances coarse-grained gabbro is found at the margins.

(11) Xenoliths are not common, and all those observed were of sediments and greater than 3 feet across. Except for induration at their margins, the xenoliths show little evidence of reaction with the basic magma.

(12) A pink limestone containing foraminifera of Eocene age is preserved as a small inclusion in gabbro near the Musgrave River, north of Kodogere (fossil locality 19). This limestone is 6.3 miles from the nearest contact of the gabbro with the Port Moresby Beds.

(13) Well developed banding has been observed in the gabbro at only one locality, grid reference 9392400, 757700, Plate 9. Here, the banding is marked by alternating leucocratic and melanocratic bands half an inch thick, and trends parallel to the adjacent contact but dips towards it at 45°. Plate 2, figure 2 shows a similar banding observed in a cobble collected from the bed of a stream north of the Dubuna mine.

(14) Near some contacts, the feldspar laths and plates of opaque minerals are foliated, e.g. near Hospital Hill.

(15) At Eriama, in road cuttings near the site of the water treatment plant, a sharp contact is exposed between clotted leucocratic gabbro in which a crude steeply dipping banding is developed, and a finer, more melanocratic, variety.

(16) No large-scale magmatic layering was detected during field mapping.

(17) Rare breccias near the contacts contain angular blocks, 6 to 12 inches across, of coarse or fine-grained gabbro, in a matrix of fine-grained gabbro.

(18) Slight structural deformation since intrusion has formed small shear-zones, and zeolite-filled fractures and joints, near contacts.

Grainsize

Within the Astrolabe area, coarse-grained gabbro is most abundant. Finer, doleritic types are largely confined to the margin of the intrusion. In contrast, doleritic or basaltic rocks predominate in the Gea area (see Table 3). However, no vesicular or amygdaloidal rocks, or interbeds of pyroclastics, were found within the Gea mass, and it is assumed that the fine-grained basic rocks are intrusive.

Texture

The two most common textures in the gabbroic rocks are hypidiomorphic-granular to hypidiomorphic-ophitic, and clotted (glomeroporphyritic). The clotted rocks contain evenly scattered spherical clots of ferromagnesian minerals, up to half an inch in diameter. At some localities all the ferromagnesian minerals are confined to the clots.

The finer-grained rocks are more uniform in texture, although some slightly porphyritic varieties are found in small bodies to the north-east and east of Manugoro.

Mineralogy

The primary minerals (Joyce, 1965) present in the Sadowa Gabbro (excluding the granophyre differentiate on the Geboria 1:50,000 Sheet) are plagioclase, clinopyroxene, hornblende, olivine, orthopyroxene, quartz, magnetite, ilmenite, pyrite, apatite, and sphene. Secondary minerals include uralitic amphibole, red-brown hornblende, chlorite, bowlingite, serpentinous minerals, mica, calcite, kaolin, and prehnite.

Plagioclase is generally unaltered and faintly zoned. Its composition ranges from bytownite (An_{73}) to andesine (An_{34}), but labradorite is the most common.

Augite ranges from 40 to a few modal percent. The most common type is pale brown; colourless or greenish augite is less common. It is generally altered to uralitic amphibole.

Hornblende, apparently primary, was found in almost half of the 28 thin sections examined. Where present, particularly in the Astrolabe area, it is usually more abundant than pyroxene. It is green-brown, and quite distinct from the secondary pale green, red-brown, or dark green uralitic amphibole.

Olivine rarely exceeds 5 modal percent and is almost entirely altered to bowlingite or serpentinous minerals.

Orthopyroxene was detected in only three specimens, collected in the vicinity of Hospital Hill (Astrolabe area). In two of these it occurred sparsely, in discrete grains with pinkish to greenish pleochroism. In one specimen, the mineral was optically positive, apparently enstatite; and in the other, optically negative, apparently hypersthene. The third specimen contained very fine exsolution lamellae of orthopyroxene in several of the augite grains.

Quartz, up to 5 modal percent, was found in two specimens from the Astrolabe area (quarry on Rouna Road near Riverview homestead, and south of Sapphire King mine) as large anhedral grains, and as micrographic intergrowths with andesine.

A notable feature of some rocks is the presence of secondary mica, pleochroic in shades of golden brown or bright green.

Mineralogical Variation

The mineralogical and grainsize variations in gabbroic rocks within the Gea and Astrolabe areas are summarized in Table 3.

In the Gea area, there is little mineralogical variation. The typical mineral assemblage is labradorite (An_{60-65}), and augite, with or without minor olivine. Hornblende occurs in four specimens located near the margin of the gabbro. The content of mafic minerals ranges from 20 to 50 percent, but is commonly 40 percent.

TABLE 3

MINERALOGICAL VARIATION IN SADOWA GABBRO

(a) Mineralogical Variation in Sadowa Gabbro from Gea Area

Registered Number	Plagioclase	Augite	Ore	Orthopyroxene	Olivine	Amphibole	Mica (Secondary)	Quartz	Plagioclase *Composition	Grainsize
64071613	x	x	x		x				An_{72}	0.5-2mm
64071612	x	x	x		x				An_{61}	0.3-2mm
64071623	x	x	x		x					0.1-2mm
64071624	x	x	x		x					0.1mm
64071626	x	x	x		x				An_{62}	0.1-1mm
64071607	x	x	x							0.05mm
64071614	x	x	x							0.1-1mm
64071620	x	x	x							0.1-2mm
64071621	x	x	x						An_{65}	0.1-1mm
64071622	x	x	x							0.1-2mm
64071606	x	x	x		x	x			An_{61}	1.3mm
64071601	x	x	x			x			An_{62}	0.3mm
64071611	x	x	x			x			An_{62}	0.1-2mm
64071602	x	x	x		x	x	x		An_{54}	0.5-5mm

* Determined using Michel-Levy's method and the curve published in Kerr, 1959, Figure 13-26.

TABLE 3
(Cont.)

(b) Mineralogical Variation in Sadowa Gabbro from Astrolabe Area

Registered Number	Plagioclase	Augite	Ore	Orthopyroxene	Olivine	Amphibole	Mica dary)	Quartz	Plagioclase *Composition	Grain-size
64071615	x	x	x	x	x				An_{62}	0.5-4mm
64071608	x	x	x	x						0.5-4mm
64071616	x	x	x	x	x	x			An_{70}	0.5-2mm
64071625	x	x	x		x	x			An_{71}	0.1-3mm
64071609	x	x	x		x	x				1.4mm
64071619	x	x	x			x			An_{73}	0.3-1mm
64071605	x	x	x			x			An_{63}	0.1mm
64071610	x	x	x			x				0.5-1mm
64071618	x	x	x			x			An_{55}	0.1mm
64071627	x	x	x			x	x			0.3-1mm
64071603	x	x	x			x	x	x	An_{40}	1-4mm
64071604	x	x	x				x		An_{39}	0.5-4mm
64071628	x	x	x				x		An_{40}	0.3-3mm
64071617	x	x	x				x	x	An_{34}	0.5-3mm

* Determined using Michel-Levy's method and the curve published in Kerr, 1959, Figure 13-26.

In the Astrolabe area, a series of increasingly acid mineral assemblages can be recognized:

(1) Calcic labradorite-augite-olivine $\pm$ orthopyroxene.
(2) Calcic labradorite-augite-olivine-hornblende $\pm$ orthopyroxene.
(3) Sodic labradorite-augite-hornblende.
(4) Andesine-augite-mica $\pm$ hornblende $\pm$ quartz.
(5) Sodic andesine-augite-mica-quartz.

These mineral assemblages were recognized in thin section only. None of them could be distinguished in hand specimen, hence they are not indicated on the accompanying maps. The relationship between the assemblages cannot be elucidated at present because of the sparse sampling and complex outcrop pattern. From the limited data available, the regional pattern of differentiation appears to be irregular.

A body of granophyre, about 100 yards in diameter, intrudes calcareous sediments of the Port Moresby Beds, 1.3 miles south-west of Vaivai village at 529900, 8953700, Geboria 1:50,000 Sheet area. The rock is leucocratic and medium-grained, and consists of feldspar and quartz in micrographic intergrowths and as discrete grains, together with accessory serpentinous minerals, calcite, magnetite and apatite. The feldspars are orthoclase and twinned oligoclase. The granophyre is considered to be an acid differentiate of the gabbro.

Conclusions

The Sadowa Gabbro is part of a discordant basic igneous batholith which extends well beyond the area mapped. The batholith intrudes the Port Moresby Beds and encloses a xenolith of fossiliferous Eocene limestone. Its relationship to the Dokuna Tuff or Bootless Inlet Limestone (lower Miocene) is uncertain, but the batholith probably does not intrude these formations. The Sadowa Gabbro is considered to be Oligocene.

The mineralogy of the Sadowa Gabbro suggests that the parent magma may have been tholeiitic. However, the rock contains little orthopyroxene and no pigeonite, whereas basic rocks of tholeiitic parentage commonly contain both a lime-poor pyroxene - pigeonite or orthopyroxene - and a lime-rich clinopyroxene. Nevertheless, Benson (1944) has described tholeiitic dolerites from New Zealand that contain only clinopyroxene. He considered the absence of orthopyroxene to be the result of rapid crystallization. This conclusion is partly supported by Walker et al. (1952), and Hotz (1953), who have described chilled tholeiitic dolerites which contain little if any orthopyroxene or pigeonite. The absence of orthopyroxene from the fine-grained body in the Gea area may be explained by this hypothesis. In addition, some of the supposed magmatic complexity may be explained if the batholith is composed of a number of overlapping intrusions, each with its own cooling history.

Contact Metamorphism

Generally, the Port Moresby Beds show little if any metamorphism at their contacts with the Sadowa Gabbro, but locally a narrow aureole of calc-silicate hornfels is developed.

Within the Astrolabe area, calc-silicate hornfelses are well developed at several localities, namely: (1) near Eriama Creek, 0.4 to 0.5 miles west-south-west of the Sapphire mine; (2) at Eriama, immediately south of the water treatment plant; (3) at the crest of the prominent range of hills near the old Rigo road, 0.7 miles west of Vaivai village; and (4) on a north-westerly trending ridge, 0.3 miles north-west of Brown Hill. In the Gea area, contact metamorphic effects due to the Sadowa Gabbro are slight. Well preserved calc-silicate hornfelses were only found 2.5 miles west-south-west of Gobuia (Gea Sheet). Very low-grade hornfelses are more common and have been observed at several localities in both the Gea and Astrolabe areas.

Mineral assemblages (Joyce, 1965) observed in thin section include:

(1) Diopside-garnet-idocrase-wollastonite-calcite;
(2) Diopside-idocrase-brucite-diaspore;
(3) Diopside-idocrase-calcite-tremolite-diaspore-feldspar;
(4) Diopside-idocrase-calcite-epidote-plagioclase-wollastonite;
(5) Diopside-brucite-calcite;
(6) Diopside-calcite-chlorite-quartz.

The range is from upper albite-epidote hornfels facies to lower pyroxene hornfels facies, but most assemblages belong in the hornblende hornfels facies. Minerals indicative of pneumatolysis, e.g., scapolite or apatite, and 'skarn' metasomatism, e.g., magnetite, pyrite, or any other sulphides, are absent. Idocrase, which differs from grossularite garnet mainly in the presence of an hydroxyl component, is far more abundant than garnet. Its formation in preference to garnet is favoured by higher water pressure. Furthermore, the presence of tremolite, which also contains an hydroxyl component, indicates that at least moderate water pressures prevailed during metamorphism. Because no metasomatic elements were introduced, we prefer to regard this water as being present in the sediments prior to metamorphism.

LOWER MIOCENE

Dokuna Tuff and Bootless Inlet Limestone.

The Bootless Inlet Limestone represents a calcareous facies of the dominantly pyroclastic Dokuna Tuff; the two formations are contemporaneous.

Glaessner (1952) used the name 'Dokuna Tuff and Agglomerate' for rocks in the vicinity of Dokuna Village at the head of Bootless Inlet (1.8 miles west of the Geboria 1:50,000 Sheet area boundary). These pyroclastics were first separated from the Port Moresby Beds by Montgomery (1930), who considered that they rested conformably on the 'Upper Port Moresby Beds' and preceded the 'Bootless Inlet Limestone', although the latter was recognized as being the same age. The pyroclastics are named the Dokuna Tuff in this report.

The 'orbitoidal' limestone at Bootless Inlet was examined by Carne (1913), and identified as lower Miocene by Chapman (1914). The name 'Bootless Inlet Limestone' was first used by Stanley (1920a), who equated it with the Eriama Series in the vicinity of Mount Lawes. This correlation was based on the similarity of their structure and the apparent continuity of strike. Glaessner (1952) included this formation in the 'Dokuna Tuff and Agglomerate'. The name Bootless Inlet Limestone is here reinstated. The type area of the Bootless Inlet Limestone is 0.9 miles north-north-east of Bautama Mission, in the vicinity of grid reference 533000, 8950750 (Geboria 1:50,000 Sheet area).

The Dokuna Tuff crops out in a belt generally less than 300 yards wide, trending southwards along the old Rigo road from Vaivai village, thence along the disused Dubuna Tramway to a point 1 mile south of Maiberi village. Throughout this belt the unit is probably no thicker than 250 feet. Glaessner (1952) found a far greater development of the Dokuna Tuff near Port Moresby, and in that area it is probably more than 2000 feet thick. The tuff ranges from a fine-grained laminated apple-green vitric tuff or ashstone, through darker medium-grained crystal and lithic tuff, to coarse fossiliferous agglomerate. The agglomerate crops out as a small lens within dark crystal and lithic tuff, half a mile south-west of Maiberi village (fossil locality No. 23). About half of the rock consists of subrounded cobbles 2 to 4 inches long, of green vesicular basic volcanic detritus, which are set in a matrix of white brecciated limestone and smaller volcanic fragments from a half to three quarters of an inch across. Larger foraminifera are abundant in the matrix.

The Bootless Inlet Limestone crops out in an area parallel to and immediately south-west of the Dokuna Tuff. In its type locality the limestone crops out over one square mile with a thickness of 50 to 100 feet: elsewhere the outcrops are small and scattered. Along the old Dubuna Tramway the outcrops are very thin and disconnected and represent the last remnants of the formation. Blocks of limestone also crop out in the alluvium beside the tramway, but were too small to show on the map.

The Bootless Inlet Limestone is a richly fossiliferous calcarenite containing about 20 percent of green subangular basic volcanic detritus. The coarsest limestone is in the type area, where the average grainsize is 1 to 2 mm, with some grains 6 to 7 mm across. In places the volcanic fragments constitute more than 50 percent of the rock and it is a calcareous tuff. Minor tuff interbeds are found at some localities.

The presence of limestone in the Dokuna Tuff, and tuff in the Bootless Inlet Limestone, indicates that the formations grade into each other. In addition, the fossil assemblages in both are identical.

Belford (1965) studied the fossil assemblages, which indicate that both formations belong to the 'e' stage of the Dutch letter classification, i.e. lower Miocene. The fauna identified from three localities in the Bootless Inlet Limestone and one in the Dokuna Tuff is:

Bootless Inlet Limestone

Locality 20 — Foraminifera, algae.

Foraminifera:
- Lepidocyclina (Eulepidina) sp. (fragments)
- Heterostegina sp.
- Amphistegina sp.
- Globigerinidae (very rare)
- Indeterminable smaller Foraminifera

Locality 21 — Foraminifera, algae

Foraminifera:
- Lepidocyclina (Eulepidina) sp.
- Heterostegina borneënsis van der Vlerk
- Amphistegina sp.

Locality 22 — Foraminifera, algae, corals

Foraminifera:
- Lepidocyclina (Eulepidina) spp., including L. (E.) dilatata (Michelotti) and L.(E.) papuanensis Chapman
- Heterostegina borneënsis van der Vlerk
- Amphistegina sp.
- Carpenteria sp.
- Operculina sp.

Eocene:
- (Discocyclina sp. (derived)
- (Nummulites spp. including N. pengaronensis (Verbeek) (derived)

Dokuna Tuff

Locality 23 — Foraminifera, algae, corals

Foraminifera:
- Lepidocyclina (Eulepidina) spp., including L. (E.) dilata and L. (E.) papuanensis
- Heterostegina borneënsis
- Amphistegina sp.
- Carpenteria sp.

Oligocene:
- Nummulites fichteli Michelotti (derived)

Eocene:
- (Pellatispira sp. (derived)
- (Nummulites sp., probably N. pengaronensis (Verbeek) (derived)

Glaessner (1952) regarded the 'Dokuna Tuff and Agglomerate' as middle Oligocene, because he considered the Nummulites to be contemporaneous and not derived. The varieties of this genus identified by Belford (1965) are all Eocene species, except for N. fichteli which is Oligocene, but he concluded that they are all derived fossils. For this reason, both formations are dated by the foraminifera and are referred to the 'e' stage; but further palaeontological studies are required to equate the above fauna with that in samples collected from Glaessner's localities.

The palaeontological evidence indicates an unconformity between the Port Moresby Beds (Eocene) and these lower Miocene formations; Oligocene sedimentation is absent in this area. In a cutting along the disused Dubuna tramway, 1.4 miles north of the main Rigo road, unmetamorphosed Bootless Inlet Limestone is unconformably draped over a low ridge of Sadowa Gabbro. The distribution of the limestone and tuff suggests that sedimentation was confined to valleys and depressions in the pre-Miocene landsurface.

Because the Dokuna Tuff and Bootless Inlet Limestone are here regarded as belonging to the 'e' stage, it is possible that they may be correlated with the Boira Tuff, 10 miles west of Port Moresby, which is the same age.

UPPER LOWER MIOCENE

Gidobada Limestone

The Gidobada Limestone was named by G.A.V. Stanley (1947). His samples were studied by Glaessner (1947), who identified the foraminifera Miogypsina, and the corals Porites sp., Montastrea sp., and Cyphastrea sp., indicating a middle Miocene age. The limestone was assumed to be interbedded with gabbro, dolerite, and agglomerate which cropped out nearby. E.R. Stanley (1919a) recorded limestone containing the Palaeozoic corals Favosites or Chaetetes between Gidobada and Saroa. No outcrops of limestone were found in the area during this survey and it is possible that the limestone E.R. Stanley referred to is the Gidobada Limestone described here.

Three samples collected by A.K.M. Edwards from what he called the 'Kwikila Limestone' near Gidobada were examined by Crespin (1951), who recognized Miogypsina sp. and placed the limestone in the lower middle Miocene ('f' stage). At that time the limestone was regarded as the basal portion of the Kwikila Agglomerate unconformably overlying the surrounding gabbro, but it is now recognized as the Gidobada Limestone.

The Gidobada Limestone was found at two localities, one of which (No. 24) is about 250 yards south of the Gea 1:50,000 Sheet area and therefore is not shown on the accompanying maps.

Locality 25 (Type locality)

Location: 2.1 miles west-south-west of Kwikila District Office immediately north of main road.
Grid Reference: 570800, 8915050, Gea 1:50,000 Sheet area.
2741700, 798750, Kapa Kapa 1:63360 Sheet area.
Lithology: Strongly outcropping, grey-weathering, cream to buff fossiliferous limestone.
Area of outcrop: Less than half square mile.
Thickness: 100 feet.

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Stratigraphic Relationships: Horizontal limestone unconformably overlies Sadowa Gabbro and is unconformably overlain by Kwikila Agglomerate.

Fossil Content: Foraminifera identified by Crespin (1951). Tabulate and rugose corals, fragments of pelecypods, gastropods, and bryozoa.

Age: Upper lower Miocene ('f' stage).

Locality 24 (not shown on maps)

Location: 1.7 miles east of Ginigolo village in headwaters of Moagere Creek (Pl.4, fig.1).

Grid Reference: 2734450, 796350, Kapa Kapa 1:63,360 Sheet area.

Lithology: As for locality 25.

Area of outcrop: Less than half square mile.

Thickness: 100 feet.

Stratigraphic Relationships: Small basin (dips 10° to 20°) unconformably overlying Port Moresby Beds.

Fossil Content: Similar to Locality 25. The following foraminifera were identified by D. Belford (pers. comm.).

Lepidocyclina (Nephrolepidena) verrucosa Scheffen
L (N.) angulosa Provale
L (N.) verbeeki Newton & Holland
Cycloclypeus sp. cf. C. indopacificus Tan.
Amphistegina sp.
Operculina sp.

Age: Upper lower Miocene, Burdigalian, ('f' stage).

The Gidobada Limestone overlies the Port Moresby Beds (Eocene) and the Sadowa Gabbro with a marked angular unconformity. At locality 25 the limestone crops out 450 feet below Sadowa Gabbro on the crest of Dagonagolo Hill (0.8 miles to the north-west), and east of locality 24, hills consisting of calcareous sediments of the Port Moresby Beds rise 600 feet above the base of the Gidobada Limestone. This suggests that the Gidobada Limestone originally formed an epineritic reef adjacent to a steeply sloping shoreline.

MIDDLE OR UPPER MIOCENE

Siro Conglomerate

At Hombrom Bluff, a sequence is exposed of unconsolidated fluviatile conglomerate with minor interbeds of impure fine-grained sandstone and siltstone, which is separated by unconformities from the Sadowa Gabbro below and the Astrolabe Agglomerate above. The sequence was named 'Siro Beds' by Glaessner (1952), who correlated it with rocks of similar lithology near Siro village west of Port Moresby. The unit is here named the Siro Conglomerate.

Most outcrops of conglomerate are covered by scree, shed by the overlying Astrolabe Agglomerate, but it can be traced for 8 miles along the northern bank of the Laloki River from the 12-mile to Rouna Falls. East of Rouna Falls, the conglomerate does not crop out, but it is present in drillholes at the site of the No. 2 underground power station (Carter & Brouxhon, 1963). At its widest part, near Hombrom Bluff, the formation is 1.5 miles across and 1000 feet thick. The best exposures are in road cuttings and steep creek banks in the area around Hombrom Bluff, where the conglomerate dips at 30° to 40° to the north-east, and at the base of the Rouna Falls, where it is almost horizontal.

The coarse detritus in the Siro Conglomerate is well rounded and commonly pebble size. Cobbles are scattered through the formation, and at Rouna Falls the topmost bed contains boulders of basic igneous rock up to 3 feet across. A similar coarse bed crops out near the top of the sequence close to Hombrom Bluff. The pebbles are composed of fine to medium-grained basic igneous rocks, quartz, schist, slate, quartzite, and chert. All beds are polymictic, but some contain an abundance of volcanic pebbles and others almost none at all. The arenaceous matrix is of similar composition to the coarse detritus. Drill cores from Rouna Falls show that the amount of volcanic detritus in the conglomerate increases towards the top of the formation. Sandstone interbeds are uncommon: they are about 3 feet thick and have the same composition as the conglomerate.

The Sadowa Gabbro crops out on either side of the Siro Conglomerate - on the northern flank of Hombrom Bluff, and on the southern side of the Laloki River gorge. This suggests that the conglomerate is a fluvatile valley fill. The quartz and metamorphic fragments in the conglomerate were probably derived from the Owen Stanley Series to the north and north-east, and the increase in volcanic detritus towards the top of the unit indicates the onset of vulcanism which gave rise to the overlying Astrolabe Agglomerate.

The only fossil found in the conglomerate is an unidentified non-marine gastropod from a sandstone interbed, described by Glaessner (1952). He considers that the lack of fresh volcanic detritus in the conglomerate and the moderately high dips indicate that it is only a little younger than the Dokuna and Boira Tuffs. We think that the Siro Conglomerate was not deformed by the lower Miocene tectonic activity, and that it is middle or upper Miocene.

PLIOCENE

Kwikila Agglomerate

The Kwikila Agglomerate crops out over 5 square miles in an arcuate belt concave to the south-east, in the south-eastern corner of the Gea 1:50,000 Sheet area; Kwikila township is located on the inner edge of the belt.

Stanley (1947) first referred to the rocks of this formation and grouped them with the Gidobada Limestone and part of the underlying Sadowa Gabbro in the Miocene 'Gidobada Series'. Edwards & Best (1952) considered the Gidobada Limestone to be at the base of the agglomerate, which was equated with the Astrolabe Agglomerate. They also reported a pyroclastic vent south of Dogonagolo Hill, but this is now regarded as an outlier of the Kwikila Agglomerate capping a hill of gabbro.

The Kwikila Agglomerate contains a greater variety of rock types than the contemporaneous and more extensive Astrolabe Agglomerate. Agglomerate is the most common; it consists of subrounded rock fragments, ranging from 1 inch to 2 feet across, in a sandy tuffaceous matrix. Most fragments are pebble or cobble size and composed of tuff containing fragments of euhedral pyroxene; other fragments are porphyritic augite basalt, (comprising about 5 percent of the agglomerate), and hornblende or pyroxene andesite with a variety of textures. In many places, boulders of basalt in the soil are the only indication that agglomerate underlies the area. Fresh outcrops containing a typical assemblage of cobbles and boulders can be seen in a small quarry 400 yards north of the Kwikila/Gobaragere road, 1.25 miles north-east of Kwikila. Thin tuff beds containing rare cobbles of volcanics are interbedded with the agglomerate throughout the formation, but tuffaceous sandstone and conglomerate beds are confined to the base of the formation.

The beds along the convex edge of the belt of Kwikila Agglomerate dip radially inwards at up to 20°; on the inner edge, at Kwikila and at the small quarry mentioned above, they are horizontal. The outlier of agglomerate south-south-east of Dogonagolo Hill is also flat-lying. The Kwikila Agglomerate unconformably overlies the Sadowa Gabbro and undeformed Gidobada Limestone. This implies that the agglomerate is preserved in the attitude in which it was deposited. The maximum thickness of the agglomerate is about 250 feet.

The characteristics of the agglomerate are typical of subaerial deposition close to a volcano. The arcuate outcrop suggests that the centre may be concealed beneath the Ararabu Conglomerate, but this is unlikely because of the inward dips. No volcanic centres have been found in the Kwikila area, and it has not been possible to determine the source of the Kwikila Agglomerate.

Astrolabe Agglomerate

The rocks capping the prominent escarpments at Hombrom Bluff and Wari-arata were examined by Maitland (1893) and Stanley (1911), and named the 'Astrolabe volcanic series' by Carne (1913). The term Astrolabe Agglomerate was used by Glaessner (1952). In recent years this rock unit has been discussed in numerous reports concerned with dam and power station sites on the Laloki River (see references).

The Astrolabe Agglomerate crops out over 150 square miles and occupies the whole of the Sogeri Plateau and the Astrolabe Range. Outliers of agglomerate north-east of the plateau indicate that it originally covered about 300 square miles. The agglomerate is folded in a broad syncline plunging gently north-west for 20 miles, with dips of about 5° on either flank.

The agglomerate unconformably overlies the Port Moresby Beds, Sadowa Gabbro, and Siro Conglomerate. In diamond drilling to test the No. 2 underground power station site at Rouna Falls on the Laloki River, two holes 200 feet apart along strike (R19 and R28) showed a difference of 60 feet in the reduced level of the contact between the Astrolabe Agglomerate and the Siro Conglomerate (Carter & Brouxhon, 1963). The thickness of the formation ranges from 400 to 800 feet, with the minimum thickness exposed in the escarpment 2½ miles north of Rouna Falls. The range in thickness indicates that the agglomerate was deposited on a land-surface with a relief of at least 200 feet.

The Astrolabe Agglomerate is a coarsely stratified dark grey volcanic agglomerate with a relatively uniform lithology, and minor intercalated lenses of tuff. The agglomerate contains angular to subrounded fragments of vesicular, massive, or flow-banded basalt, and a little andesite in a tuffaceous matrix which commonly constitutes 30 to 40 percent of the rock. Most blocks in the agglomerate range from 3 to 12 inches across, but a few are from 3 to 5 feet wide. Nearly all the blocks are touching. Poorly developed beds 4 to 15 feet thick can be seen in some outcrops. Large-scale current-bedding, graded bedding, and load casts are absent or very poorly developed.

The tuff lenses are commonly about 6 inches thick, but some are up to 8 feet thick, and most lenses are less than 50 feet long. Small-scale current-bedding and some graded bedding are found in the tuff. Fossil coniferous wood has been collected from the tuff and agglomerate (Shirley, 1899). No lava flows were observed, although Davies (1960b) reported the occurrence of an augite basalt flow in a creek immediately east of Eilogo plantation.

The origin of the Astrolabe Agglomerate is problematical. It has a large areal extent, is moderately thick, and has a crude bedding: but the absence of bombs, lapilli, and scoria rule against an airfall volcanic origin; and the lack of graded bedding in the coarse beds, large-scale current bedding, and load casts suggest that it is not a sedimentary deposit. The poor sorting, the rounding of some boulders, the lenticular nature of tuff beds, the lack of flow rocks, and the absence of volcanic centres must also be considered.

During the eruption of Bezymianny volcano, U.S.S.R., in 1956, an agglomerate flow 30 to 35 m thick was deposited over 30 square km in valleys as a result of a 'nuée ardente' type of explosion (Bogoiavlenskaia, 1962). This agglomerate showed no trace of stratification, but some boulders were rounded, and small tuff eruptions commonly preceded the nuées ardentes. It is probably that the Astrolabe Agglomerate originated from a similar type of eruption, but some of the tuff beds may be lacustrine deposits.

PLEISTOCENE

Ararabu Conglomerate

Flat-lying, poorly consolidated conglomerate and siltstone unconformably overlie the Kwikila Agglomerate and Sadowa Gabbro between Kwikila and the Kemp Welch River. River gravels near Kwikila were first noted by Stanley (1947), who considered them to be Recent alluvium deposited by the Kemp Welch River. The gravels are now recognized as older than the Kemp Welch deposits, and have been named the Ararabu Conglomerate from Ararabu Creek which flows southwards over the gravels to Kwikila Creek, midway between Kwikila and the Kemp Welch River.

Because the conglomerate is poorly consolidated it does not crop out well, and the best exposures are to be found in road cuttings near the Kwikila District Office, and along the road to the Kokebagu plantation, 2.75 miles from Kwikila. At Kwikila the beds are horizontal, but near Kokebagu plantation they dip at a shallow angle to the north-north-east.

The conglomerate was deposited in a basin in the Kwikila Agglomerate. It extends an unknown distance beyond the Gea Sheet area south of Kwikila, and to the east it is overlain by Recent alluvium. Pebbles in the gravel of porphyritic augite basalt and hornblende andesite derived from the underlying Kwikila Agglomerate indicate an erosional unconformity between the two formations. In a small quarry 0.3 miles east of the Kemp Welch River Bridge on the Kwikila Road, the conglomerate lies unconformably on the Sadowa Gabbro, and gabbro is also exposed in the bed of Kwikila Creek 1.5 miles west-north-west of the Kemp Welch River Bridge. The Ararabu Conglomerate has a maximum thickness of 250 feet in the Gea Sheet area.

The conglomerate is composed of well rounded pebbles and small cobbles with some boulders up to 12 inches across, in a matrix of sand and silt which constitutes about 40 percent of the rock. Larger subrounded boulders of chert derived from the conglomerate are found on the hills south-west of Saroakei village. Rock types in the conglomerate are green, grey, and red chert, gabbro, and volcanics derived from the Kwikila Agglomerate. Yellow-brown siltstone in beds up to 3 feet thick crops out in the road cutting 2.5 miles south-south-east of Kwikila (Pl. 4, fig. 1; grid reference 577360, 713425, Gea 1:50,000 Sheet area). The siltstone contains abundant plant fossils, but none have been identified.

The detritus in the Ararabu Conglomerate is derived mostly from the Port Moresby Beds, the Kwikila Agglomerate, and the Sadowa Gabbro, all of which crop out adjacent to the conglomerate. This material was deposited in a small lake overlying part of the Kwikila Agglomerate.

RECENT

Recent alluvium has been deposited by all major streams in the area. Alluvial plains up to 2 miles wide have developed at the mouths of the larger creeks, e.g. near Dagoda village, but the width and depth of the deposits decreases rapidly inland. The largest area of Recent fluviatile sediments has been deposited by the Kemp Welch River north of Saroakei.

A zone of scree up to 2 miles wide forms some of the foothills of the Astrolabe Range. This scree, which includes blocks up to 50 feet long, has been shed from the escarpment of Astrolabe Agglomerate and almost completely masks the underlying bedrock.

On the Sogeri Plateau, between the Laloki River and Varo Creek, lateritic soils have developed, but are not indicated on the accompanying maps. The lateritic horizon ranges from 3 to 15 feet thick, with an average of about 7 feet (Ward, 1949a). The economic significance of these laterites is discussed on page .

STRUCTURE

The rocks in the Port Moresby/Kemp Welch River area have been deformed by at least six short periods of tectonic activity of decreasing intensity (Table 4). In the first two periods the area was tightly folded, but succeeding tectonic activity was limited to gentle folding and uplift over restricted areas. All structures were controlled by the tectonic grain of the country, which trends north-west.

The Cretaceous limestone cropping out near Bootless Inlet is generally strongly sheared north to north-west. It is unconformably overlain by unsheared Eocene sediments of the Port Moresby Beds, indicating that the limestone was deformed during the Palaeocene.

Whereas in the Port Moresby area Glaessner (1952) outlined several major structures related to Oligocene folding by delineating Cretaceous, Eocene, and Oligocene rocks, this has been impossible in the area described here because both Oligocene and Cretaceous rocks are mostly absent, and the Port Moresby Beds contain no distinct markers. The Port Moresby Beds mostly dip steeply to the north-east, suggesting that the major structures are tight isoclinal folds, slightly overturned to the south-west. The rocks are extensively fractured but not cleaved.

Small parallel folds are common throughout the Port Moresby Beds and are well exposed in the coastal cliffs and rock platforms at Osborne Point on the eastern side of Bootless Inlet, and near the wharf at Kapa Kapa. Small folds and contortions were also observed in a number of creek exposures. The strike of the axial planes is generally north-west, parallel to the regional trend, but the plunge and dip of the axial planes is different from the inferred major structures. Similar contortions in thin-bedded calcilutite near Port Moresby were interpreted by Montgomery (1930) as slump structures, thus accounting for their complexity and the divergence from the regional strike. Davies (1961a) reported small-scale slump structures in drill core from the Laloki Mine. Breccias in the lutite facies of the Port Moresby Beds are most probably the result of slump movements, but no unquestionable small-scale slump folds were observed by us in the field. On the other hand, several features suggest that the small folds observed throughout the Port Moresby Beds are of tectonic origin: for instance, the folds 'die out' into both overlying and underlying strata, and the crests of folds are not truncated by overlying strata. The style of folding suggests flexural slip, rather than flowage, under low vertical load.

The area between the Laloki River and Rabuka village is complex, with a wide divergence of strike and numerous basic intrusions. The predominant trend is north-east in the vicinity of Brown Hill, the headwaters of Erioma Creek, and the Federal Flag mine. Glasson (1954) considered that this divergence from the regional trend is due to a second period of folding about axes trending north-east, during the emplacement of the Sadowa Gabbro (Oligocene).

Glaessner (1952) recognized several strike faults in the Port Moresby area, of which two extend into the Geboria and Tupuseleia Sheet areas near Bogoro Inlet, but no evidence of them was found. The largest faults in the area, indicated mainly by topographical lineaments on the air-photographs, strike north and are transcurrent: strike faults are of minor importance. No faults were found to intersect rocks younger than Sadowa Gabbro, but the fault-bounded swamp east of the Kemp Welch River indicates that minor fault movements have continued up to recent times.

The Dokuna Tuff and Bootless Inlet Limestone occupy depressions in the pre-Miocene landsurface. The tuff was deformed by local tectonic movements in the Lower Miocene which produced steeply dipping beds striking parallel to the boundaries of the depositional areas. The Bootless Inlet Limestone nearby, of the same age, is almost undeformed.

Subsequent tectonic activity was restricted to relatively gentle and local vertical movements. Moderate dips in the Siro Conglomerate were produced by local faulting in the Upper Miocene (?), but some of this formation is undeformed; for example, at Rouna Falls. Differential uplift in the Upper Pliocene folded the Astrolabe Agglomerate into a broad shallow-plunging syncline with a maximum dip of 5° on the flanks. The vertical joints striking north-east and north-west in the agglomerate were probably produced at this time.

GEOCHEMICAL SAMPLING

Introduction

Geochemical sampling in the Port Moresby/Kemp Welch area was initiated by Mather (1964), by an orientation survey in December 1963. Sixty-seven samples were collected in this survey. They included stream sediments, detrital magnetite, rocks, mineralized rock, and gossans, which were later analysed on an emission spectrograph to determine the quantity and range of trace elements present. Sampling and analytical programmes determined from the orientation survey were implemented in the 1964 field season.

Programme

The geochemical programme involved collection of the following types of samples:

(1) Stream sediments: In and around the known mineralized area, about 10 stream sediments were collected per square mile (Pl.9). Outside this area, samples were collected wherever a stream was crossed during geological mapping, which resulted in a density of about one sample per square mile (Pls 10 to 13). In order to locate anomalous copper and zinc values related to possible mineralization all samples were analysed for total

TABLE 4

GEOLOGICAL HISTORY

PERIOD		EVENT	SEDIMENTARY ENVIRONMENT
RECENT		Rise in sea level, growth of coral reef, deposition of alluvium.	
PLEISTOCENE		Tectonic activity - uplift, minor faulting.	
		Deposition of Ararabu Conglomerate	Freshwater, lacustrine and/or fluviatile.
PLIOCENE		Erosion	
		Tectonic activity - uplift with slight warping	
		Explosive volcanic activity resulting in a large accumulation of basic pyroclastics - Astrolabe Agglomerate. Less extensive activity of different character - Kwikila Agglomerate.	Freshwater - lacustrine close to volcanic source, and subaerial-volcanic.
MIOCENE	UPPER TO MIDDLE	Tectonic activity - uplift, local faulting.	
		Deposition of Siro Conglomerate	Fluviatile, valley-fill
	LOWER	Local development of reef limestone- Gidobada Limestone.	Epineritic, adjacent to steep shoreline.
		Tectonic activity - folding.	
		Local pyroclastic sedimentation, grading laterally into foraminiferal limestone - Dokuna Tuff and Bootless Inlet Limestone.	Neritic.
OLIGOCENE		Tectonic activity - widespread folding and intrusion of Sadowa Gabbro with possible associated basic vulcanicity.	
EOCENE		Deposition of calcareous and non-calcareous lutite and growth of local reefs - Port Moresby Beds.	Mainly bathyal with pelagic foraminifera. Local neritic reefs.
PALAEOCENE		Tectonic activity - folding, shearing.	
UPPER CRETACEOUS		Deposition of Bogoro Limestone.	Bathyal with pelagic foraminifera.

copper, zinc, and nickel, and most for total cobalt. Cold extractable copper was determined in all samples, and zinc in some, to detect weakly-bonded copper which may indicate sulphide mineralization.

(2) Magnetite: Because traces of magnetite occur in some of the copper deposits of the Astrolabe Mineral Field, and in the basic igneous rocks, this mineral could prove a useful 'pathfinder' to undiscovered copper mineralization, particularly if the basic rocks were the source of the copper. It was reasoned that a high concentration of copper and zinc in the lattice of magnetite derived from gabbro may reflect higher than average concentrations of these elements in the parent magma, if equilibrium had existed. Magnetic samples were collected from streams, basic igneous rocks, and oxidized sulphide ore. They were analysed for copper, zinc, nickel and cobalt. These samples are referred to as 'magnetite', even though mineragraphic examination has shown that many of the grains are intergrowths of magnetite and ilmenite.

(3) Rocks: Representative samples of rocks were collected to determine the primary distribution pattern of copper, zinc, nickel and cobalt in the area. Although free sulphide content is important, it was not possible to include its determination in the analytical programme.

(4) Gossans: Gossan and any other rocks that were associated with the mineralization were analysed for copper, zinc, nickel, cobalt and arsenic.

Sampling Techniques

Most of the streams sampled were flowing. Sediment from the centre of the stream channel was wet-sieved at the site through an 80 B.S.S. mesh nylon sieve into a small gold-panning dish. The suspended material was allowed to settle, the water decanted, and the wet minus 80-mesh fraction was placed in a polythene bag, which was rolled or folded and inserted in a 'Kraft' paper geochemical sample packet. At base camp the packets were opened, and the clay suspension in the sample was allowed to settle in the polythene bag for a long time before the excess water was decanted. By this method, as much of the fine clay-sized fraction as possible was retained in the sample. The polythene bags were then sealed, and the samples were kept moist until they were analysed.

An attempt was made to collect magnetic material at all sediment sampling sites using a large 'Eclipse' hand magnet; the samples were stored in 'Kraft' paper sample packers. However, it soon became evident that magnetite was present only in streams draining areas containing outcrops of Sadowa Gabbro, Astrolabe Agglomerate, or Kwikila Agglomerate. In streams draining the Port Moresby Beds little, if any, magnetite could be collected.

Laboratory Techniques

Cold extractable copper and zinc were determined in the wet sediment samples using ammonium citrate/hydroxylamine hydrochloride as the extractant, and biquinoline as the calorimetric reagent. Magnetite was then separated from the wet sediment by adding distilled water and stirring with a large hand magnet. The remaining clay and silt was flocculated with a few drops of 0.1 M aluminium sulphate, the supernatant water decanted, and the sample dried in an oven at 105 ^{o}C. Aqua regia extractable Cu, Zn, Ni, and Co were determined on this magnetite-free sediment using an atomic absorption spectrophotometer.

All magnetite samples were crushed to a fine powder in a mechanical mortar and pestle, then mixed with water and the magnetite removed with a hand magnet. Some of the crushed rock was analysed for its total trace element content.

All samples of magnetite, rocks, and gossans were analysed for Cu, Zn, Ni, and Co using an atomic absorption spectrophotometer. Spectrographic analyses of residues remaining after aqua regia extraction show negligible quantities of these elements. Some samples of stream sediments, magnetite, and gossans were analysed for arsenic using a modified 'Gutzeit' method.

pH Measurements

An 'Electronic Instruments' portable pH meter was used to determine the pH of the water of representative streams throughout the area. From 25 measurements the range of pH was 7.1 to 7.9, with an average of 7.6

Statistical Analysis of Geochemical Results

Tennant & White (1959), and de Grys (1964), have determined that trace-element distribution patterns in soils and drainage basins are lognormal. Their method has been used to analyse the distribution of copper and zinc in 806 stream sediments collected from the Port Moresby/Kemp Welch area, and the result is shown in Figure 3. In this figure parts per million of copper and zinc are plotted against frequency on logarithmic probability paper. A similar graph showing the distribution of copper and zinc in magnetite is plotted in Figure 4. All contaminated samples were omitted from the calculations.

According to Tennant & White (1959), anomalous and background distributions are distinguished by changes in the slope of the line. In Figure 3, anomalous values are regarded as those above the marked change in slope at 180 ppm Cu and 120 ppm Zn, and it is evident that at least two distributions of copper and zinc are present in the stream sediments. The plots for copper and zinc are almost parallel, which indicates that a similar set of conditions probably controls the distribution of both elements.

RESULTS OF STREAM SEDIMENT SAMPLING

The location of all stream sediment samples is shown on Plates 9 to 13. The analyses of these samples are listed in Appendix I, and only the anomalous values are plotted on the Plates.

Cold Extractable Copper

Over 90 percent of the samples contained less than 0.5 ppm citrate-soluble copper. The highest value was 104 ppm from contaminated samples collected downstream from the Laloki and Sapphire mines. The threshold value is regarded as 5 ppm.

A province containing high citrate-soluble but normal total copper values occurs in the Tupuseleia Sheet area within the Port Moresby Beds. The reverse relation holds in anomalous areas in the Astrolabe Mineral Field except in contaminated samples. In most areas outside the Astrolabe Mineral Field no explanation is apparent for cold extractable copper anomalies, and it is doubtful if the anomalies are significant.

Cold-extraction methods have been used with success in tropical terrains by Webb & Tooms (1959), and Govett (1960). Nevertheless, the present results cast doubt on the suitability of the method in the Astrolabe area. Here the inconsistent results may be related to the manner in which copper is fixed in the sediment; for instance, in the contaminated samples the high values are probably caused by minute traces of copper carbonate, from which the copper would be easily extracted.

Total Copper

The cumulative percentage distribution of total copper in 806 stream sediment samples is shown in Figure 3. The mean value is 85 ppm and the threshold value is taken as 180 ppm. Excluding contaminated samples, 30 analyses contain between 180 ppm and 720 ppm copper.

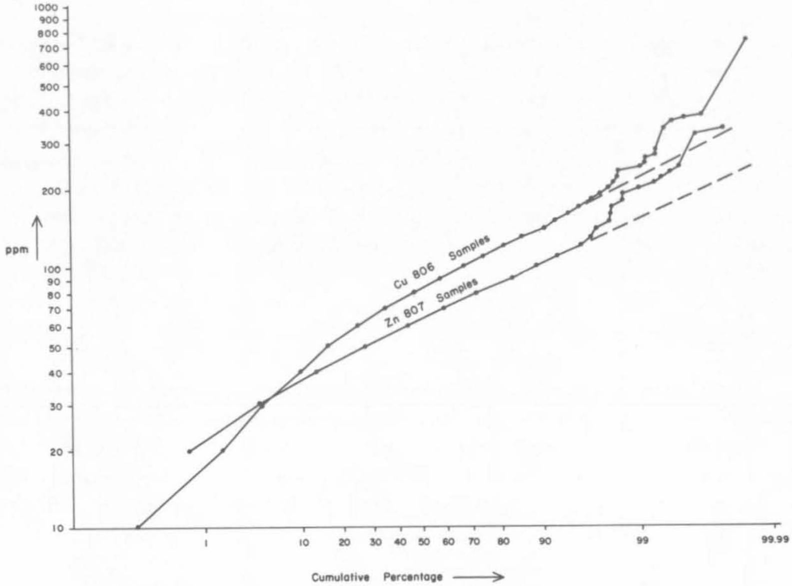

Fig. 3. Cumulative percentage distribution of total copper and zinc in stream sediments.

Two areas in the Astrolabe Mineral Field show significantly high total copper values.

(1) In the vicinity of the Astrolabe prospect samples 1336, 1337, and 1340 are anomalous. There are no major dumps at this prospect and no copper minerals are reported to have been found. The anomalous copper in sample 1340, 750 feet upstream from the Astrolabe prospect, may be derived from a relatively large body of poorly outcropping gossan (see Pl.9). Zinc is anomalous in the three samples. Sample 1336 is more than 1000 feet downstream from the prospect, and possibly indicates that the anomalous sediment trains may be this long at least.

(2) South-east and south of the Mount Diamond mine, two westerly flowing tributaries of Maiberi Creek contain anomalous samples 1289, 1290, 1292, 1270, 1271, and 1272. Sample 1292, with 736 ppm total copper, gives the highest value of any uncontaminated

sample collected in the survey. Small boulders of gossan occur in the creek bed at the sample site. Similarly, gossanous sediments crop out near the sampling sites in the southernmost tributary, and account for the anomalies which range from 202 to 261 ppm.

In addition to these main anomalous areas, several small copper anomalies (samples 720, 721, 734) occur in an area of Sadowa Gabbro near the Kemp Welch River, 3 to 4 miles north of Gobaragere plantation. Anomalous zinc values are found in the same area, but not associated with the anomalous copper values. The area of combined high copper and zinc values is at least 20 square miles. The smallness of the anomalies and the large area over which they are distributed suggests that they reflect slight changes in composition in the basic rocks, but they deserve investigation.

Zinc

The cumulative percentage distribution of total zinc in 807 stream sediment samples is shown in Figure 3. The mean value is 65 ppm and the threshold value is taken as 120 ppm. Thirty-five samples exceed the threshold and range up to 334 ppm. Almost all the zinc anomalies are associated with copper anomalies; for example, sample 1292 (south-east of Mount Diamond mine). The only exception is in the gabbro area north of Gobaragere plantation discussed above. The results from samples collected in the creek draining the Astrolabe prospect suggest that zinc may have a longer dispersion 'train' than copper. Anomalous values for copper and zinc are virtually absent from the gabbro areas in the Astrolabe Mineral Field.

Nickel and Cobalt

No anomalous values for nickel and cobalt are shown on the accompanying maps because spectrochemical analyses indicate that the amounts of these elements in the copper orebodies is not significant. Nickel values range from 1 to 262 ppm but are generally 30 to 80 ppm, and the average of 820 analyses is 53 ppm. The highest value is in sample 889 collected from area north of Gobaragere plantation. The cobalt content of stream sediment samples ranges from 4 to 175 ppm, but is generally from 20 to 50 ppm.

Arsenic

Some samples were analysed for arsenic. They range from 3 to 50 ppm, but the majority are 3 to 5 ppm.

RESULTS OF MAGNETITE SAMPLING

The location of all magnetic concentrates collected from streams is shown on the geochemical maps. The samples marked with their copper content are anomalous, and all analyses are listed in Appendix 2. Magnetic concentrates separated from ores, mine dumps, and basic igneous rocks are not shown on the maps, but their grid references are included with the results in Appendices 3 and 4.

Copper and Zinc

The cumulative percentage distribution of copper and zinc in 462 magnetic concentrates from streams is shown in Figure 4. The mean value for copper is 48 ppm, and for zinc 500 ppm. A marked change in the copper distribution occurs at 120 ppm, but there is no corresponding change in the zinc distribution. It is concluded that all values exceeding 120 ppm indicate the presence of minute inclusions of copper minerals in the magnetite and are derived from sulphide orebodies whereas all other magnetites are derived from the Sadowa Gabbro. This may account for the marked change in the distribution of copper relative to zinc. The normal distribution for both copper and zinc is probably a function of magmatic differentiation.

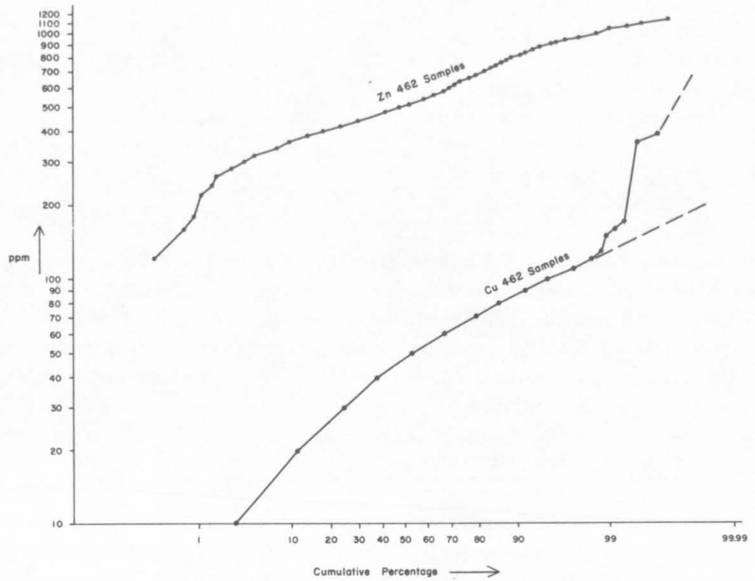

Fig. 4. Cumulative percentage distribution of copper and zinc in magnetic concentrates from streams.

Magnetite occurs mainly in streams draining basic intrusive or volcanic rocks; little or no magnetite could be collected in streams draining the Port Moresby Beds. Of the samples containing more than 120 ppm copper, only samples 1405 and 1407 from south of the Dubuna mine are thought to be uncontaminated, and deserve to be investigated (cf., Appendix 3).

Of the magnetite concentrates from stream sediment, only 1.8 percent contain greater than 120 ppm copper, whereas 20 percent of the 45 magnetic concentrates analysed from basic rocks exceed this value (Appendix 4). This discrepancy may be due to (1) non-representative sampling of the basic rocks, (2) copper lost from the lattice of the magnetite during transport, or (3) a slight difference in the purity of the concentrates. The magnetite in basic rocks contains from 4 to 1145 ppm copper. Most values are in the range 4 to 160 ppm, but this range contains two apparent groups, from 4 to 30 ppm, and 30 to 160 ppm. Zinc ranges from 66 to 1750 ppm but is commonly between 150 and 400 ppm.

TRACE ELEMENT ANALYSES OF BASIC ROCKS

The results of 25 trace element analyses of basic rocks from the Sadowa Gabbro are listed in Appendix 4, and summarized here.

Copper	Range:	6-389 ppm (Two groups; 6-22 ppm, and 68-389 ppm)
	Average:	98 ppm
Zinc	Range:	2-87 ppm
	Average:	53 ppm
Nickel	Range:	1-50 ppm
	Average:	14 ppm
Cobalt	Range:	5-35 ppm
	Average:	22 ppm

No conclusions can be drawn from these analyses without a petrographic study of each rock analysed. A comparison with analyses by Wager & Mitchell (1951) of differentiates from the Skaergaard intrusion indicates that the average copper content is similar to that in the olivine gabbro to olivine-free gabbro group in the Skaergaard intrusion. However, the values for nickel and cobalt are less than in the gabbro groups at Skaergaard, and nearer the values of the more acid differentiates.

TRACE ELEMENT ANALYSES OF SEDIMENTARY ROCKS

The results of trace element analyses of 19 sedimentary rocks from the Port Moresby/Kwikila area are listed in Appendix 5. The analyses of 16 samples of the Port Moresby Beds contain an average of 21 ppm Cu, 39 ppm Zn, and 26 ppm Ni. These values are only a little less than in a sample of lutite collected in diamond drill hole SC 4 one foot below the orebody at the Laloki mine which contained 38 ppm Cu, 41 ppm Zn, and 54 ppm Zn.

ECONOMIC GEOLOGY

COPPER

History of Mining

Copper mineralization was discovered in the Port Moresby area by J. MacDonald several years before the proclamation of the Astrolabe field late in 1906, and in the four years after the proclamation leases were taken over most of the prominent gossans. Although more than twenty lease areas in the field have been prospected, only three mines have produced more than 10,000 tons of ore. Copper has been the main metal product of the field, but gold and silver were recovered from concentrates from the larger mines. There has been no significant mining operation on the field since 1942.

On the 21st December 1906, an area of 1000 square miles was proclaimed the 'Astrolabe Copper Field'. Two reward claims of 160 acres each, the Hector and the Astrolabe (now known as Federal Flag), were granted and applications for four prospecting leases were submitted. By 1909, the Dubuna, Elvina, Federal Flag, Hector, Laloki, Mount Diamond, Paree, and Sapphire Creek lodes had been discovered and partly developed. Extensive testing and proving at the Laloki mine was carried out by the British New Guinea Development Coy. Small parcels of rich oxidized copper ore were expected, mainly from the Hector and Federal Flag mines. The Dubuna mine began production of rich oxidized ore in 1910, and was the source of most of the ore exported up to June 1912. About the same time, both the Dubuna and Laloki mines were taken over by the Great Fitzroy Mines Limited. G.C. Klug (1912) recommended an expenditure of £56,000 to develop these leases in order to ship 2000 to 3000 tons of ore per month for treatment in Australia. It is understood that the first ore shipped caught fire on the voyage.

Erle Huntley in 1917 recommended an expenditure of £130,000 to build an aerial ropeway and railway to transport ore from the Laloki and Dubuna mines to Bootless Inlet for smelting and conversion.

In 1919, the Astrolabe Copper Field was enlarged to 2040 square miles to include copper mineralization found several years previously at Mount Louis near Rigo, and renamed the Astrolabe Mineral Field. Samples of iron ore for use as pigment, and 10 tons of copper ore, were exported from Mount Louis in 1920, but although prospecting continued intermittently, no further ore was produced.

New Guinea Copper Mines Limited took over the Laloki and Dubuna mines in 1920, with the intention of shipping ore to Port Kembla for smelting. However, spontaneous combustion of ore in the ships' holds made it necessary to resume the project proposed by Huntley. The aerial ropeway, railway line, and smelter were completed in 1923 but smelting problems were immediately encountered and full production did not commence till 1925. Because of fire in the Laloki and, later, in the Dubuna mines open-cut mining commenced, and new smelting problems were introduced. These problems were not satisfactorily overcome, and the low price of copper at the time caused New Guinea Copper Mines Limited to cease operations in the latter half of 1926. This company had extracted 32,000 tons of ore from the Laloki mine since 1920.

With the closing of the Laloki and Dubuna mines activity on the field came to a halt. Except for a little interest shown in the area as a gold field in the early 1930's there was no major activity until 1936, when Mandated Alluvials N.L. acquired the Sapphire and Moresby King mines. A smelter was erected at Sapphire Creek, and between 1938 and 1940, 21,007 tons of oxide and sulphide ores were treated, yielding 6989 oz of gold, 17,552 oz of silver, and 268.7 tons of copper.

George A. More inspected the Laloki mine in 1940, to examine the possibility of smelting ore from this mine when reserves at the Moresby King and Sapphire mines were exhausted. A loan of £10,000 was obtained from the Commonwealth Government and the company began to instal a sintering plant, and reopen the underground workings at the Laloki mine. R. Pitman Hooper (1914) and N.H. Fisher (1941) reported on the Laloki, Moresby King, and Sapphire mines. However, because of the Japanese invasion, the company was forced to suspend operations in January 1942 before the new mining and smelting plant was ready for use.

From 1938 to January 1942, 16,953 tons of oxide and 10,438 tons of sulphide ore were mined, which yielded 1498.5 tons of matte, containing 8842 oz of gold, 22,880 oz of silver, and 361.2 tons of copper.

After the Second World War, Mandated Alluvials attempted to rehabilitate the mines by reconstructing the mining and smelting plant, together with roads and bridges. All the areas of interest within 5 miles of the Laloki mine were acquired in 1948, and at the request of the company the Bureau of Mineral Resources conducted a geophysical survey of the prospects in 1949-1950 (Tate, 1951). Because of an offer of free inspection of the leases, the Zinc Corporation Ltd made a thorough examination of all mines and prospects (King, 1950). K.R. Glasson (1954) reported to Mandated Alluvials on the prospects of the field, and R.N. Spratt (1957) mapped the geology of the Laloki - Dubuna area for Consolidated Zinc Pty Ltd.

As a result of these investigations, diamond drilling at the Laloki mine was undertaken in 1960 by the Administration and Enterprise Exploration Co. Pty Ltd (for Consolidated Zinc Pty Ltd). The limits of the orebody were outlined but no additional ore reserves were found.

Drilling by the Administration at the Hector mine in 1957, the Dubuna mine in 1963-64, and the Ventura prospect in 1964, failed to reveal any economic mineralization.

Production

Available records indicate that between 80,000 and 85,000 tons of copper ore were produced from the Astrolabe Mineral Field, in the period 1907 to 1965. Only three mines have contributed significantly to this total; Laloki (40,000 tons), Dubuna (20,000 tons), and Sapphire-Moresby King (17,000 tons).

General Features of Copper Mineralization

Geological Setting

All important copper mineralization in the Astrolabe Mineral Field occurs in shale and siltstone belonging to the lutite facies of the Port Moresby Beds. Slump breccia and minor tuff are commonly present in the sedimentary sequence adjacent to the orebodies, e.g., Laloki and Dubuna mines. Because of the structural complexity and poor outcrop it was not possible to determine whether or not the ore occurred in a specific stratigraphic horizon throughout the field.

In most cases the orebodies are in the sediments close to the contact with the Sadowa Gabbro, generally in areas where roof pendants are abundant. The gabbro/sediment contacts range from horizontal (Moresby King mine) to almost vertical (Sapphire King mine), and the gabbro nearby is commonly coarse-grained and shows a range in composition indicating, perhaps, strong differentiation. No copper mines occur in the gabbro, nor have any of the known orebodies been traced horizontally or vertically into gabbro. King (1950) considered that the lode at the Victoria Hampton prospect would extend into gabbro, but this conclusion can only be proved by additional drilling or shaft-sinking. The only known occurrence of copper sulphide in the Sadowa Gabbro is a specimen collected 2 miles north-east of Mount Lawes and examined in 1955 by W.B. Dallwitz and W.M.B. Roberts, which was determined as a prehnite-bearing hornblendite containing chalcopyrite.

Only minor amounts of copper mineralization are found in the chert facies of the Port Moresby Beds. Copper minerals have been found at only two localities in the Tupuseleia/

Ginigolo area: at Mount Louis near Gidobada, and half a mile north-west of Girabu (Gea 1:50,000 Sheet). At both places the mineralization is confined to shale xenoliths in gabbro. Pyrite is the only sulphide mineral with wide distribution in this facies; it occurs as nodules in calcilutite, and probably originated during sedimentation or diagenesis. Small gossans with pyritic boxworks crop out east of Mirigeda mission in the transition zone between the lutite and chert facies.

Physical Features

Copper orebodies throughout the Astrolabe Mineral Field are approximately lenticular. This is best seen at the Laloki and Sapphire-Moresby King mines, where the shape of the lodes is known from extensive exploration. The original sulphide outcrop at the Laloki mine was about 30 feet long and 20 feet wide. The orebody increased in size with depth so that at the 137-foot level it was 450 feet long and 90 feet wide (Fisher, 1941). Below this level the lode gradually diminished and finally disappeared in pyritic shale at about 160 feet. At the Sapphire-Moresby King mines, the lode has an irregular shallow dip, and ranges from 1 to 30 feet thick, in a series of connected lenses.

Structural Features

On the whole, the strike and dip of lodes in the field is about the same as the surrounding sediments. Diamond drilling at the Laloki mine revealed a grey and red banded lutite which consistently occurred within 10 feet of the footwall. At the Dubuna mine a narrow zone of gossan outcrops trends almost at right angles to the predominant strike of the surrounding lutites and shale, but at depth the lode conforms approximately with the sediments. As King (1950) has stressed, the distribution of apparent gossanous outcrops at the surface, because of iron migration, does not necessarily correspond with the distribution of the underlying sulphide bodies.

Post-ore folding and faulting is evident in many of the mines. Diamond drilling at the Laloki mine has shown that the orebody, as well as being lenticular, is synclinal, with a northerly dip at the southern end and a southerly dip at the northern end. Stanley (1911) notes a similar structure in the deeper level of the Dubuna No. 2 lode.

Faults with small displacements intersect the Laloki, Sapphire-Moresby King, and Elvina lodes. Small shears are evident in some of the adits at the Mount Diamond mine, but their relationship to the orebody is unknown.

The ore in the opencut at the Laloki mine is brecciated: angular blocks of sulphides up to 1 inch across are separated by narrow zones of finely ground sulphides. In addition, Fisher (1941) noted that the wallrock to the lode was intensely sheared, folded, and fractured. Diamond drilling has shown that this fracture zone occurs right around the orebody.

At all mines and prospects there appears to be little or no evidence of structural control of ore distribution.

Wallrock Composition

At all mines the wallrocks are unaltered. Drill cores from the Laloki mine show that although the wallrocks are fractured, they are not altered, and are similar to sediments away from the mineralized area. A narrow zone containing talc and a coarse mica (possibly

4383/66.—4

phlogopite) adjacent to the north-eastern gossan at the Hector mine is probably a contact metamorphic zone related to gabbro which crops out in a shaft immediately to the east of the gossan.

Mineralogy

Most ores from the field oxidize rapidly, so only a few samples of fresh sulphide ore could be collected from mine dumps and diamond drill cores. From these samples the mineralogy of the ores from major copper mines in the area has been determined (Table 5, after Pontifex, 1965). All the major orebodies have the same mineral assemblage: pyrite-marcasite-chalcopyrite-sphalerite, with minor galena, arsenopyrite, specularite, and gold. Gangue minerals in their order of abundance are chalcedony, calcite, chlorite, barytes, and talc. The ratio of sulphide to gangue is normally about 5:1.

Specimens of ore containing magnetite were found only at the Laloki mine, from diamond drill hole SC4, between 274 feet and 285 feet. However, a small amount of free magnetite was found at the Hector mine, and magnetic concentrates were separated with a hand magnet from dumps at the Laloki, Dubuna, and Hector mines. King (1950) reports that some magnetite occurs in specimens from the Mount Cook mine. Thus it may be concluded that magnetite is associated with the ore in some mines.

Textural Features of the Ores

The paragenesis of the sulphide mineralization as determined by Pontifex (1965) from the textures of the available ore specimens is shown in Table 6. The textural evidence indicates two distinct phases of mineralization separated by a period of tectonic activity when the orebodies were brecciated and folded.

During the first phase of mineralization all the major ore minerals were deposited by colloidal precipitation. Textural features representing this phase are well developed in ore from the Laloki mine, as follows:

(1) Spheroidal pyrite (see Pl.5, fig.2);
(2) Colloform, amorphous grains of admixed sphalerite and chalcopyrite. These consist of sphalerite with scalloped boundaries which contain abundant irregularly distributed veinlets and blebs of chalcopyrite (centre band Pl.7, fig.2);
(3) Scalloped banding and roughly concentric structures of pyrite and marcasite;
(4) Fine intercalated colloform bands of pyrite, marcasite, galena, sphalerite, and arsenopyrite;
(5) Cryptocrystalline silica (chalcedony), commonly showing Liesegang rings, as a filling between ore minerals.

Some of the iron sulphides have crystallized, probably as a result of a slight increase in temperature or pressure, before being deformed and recrystallized by the tectonic activity. However, the presence of brecciated spheres of pyrite in some specimens indicates that not all the iron sulpxides crystallized at this time.

During the tectonic activity in the Oligocene, accompanied by the intrusion of the Sadowa Gabbro, the following textures developed:

TABLE 5

ORE MINERALS (SHOWING APPROXIMATE PROPORTIONS) AND GANGUE MINERALS IDENTIFIED IN SECTIONS FROM MINES AND PROSPECTS
(after PONTIFEX, 1965)

Mine or Prospect	PROPORTIONS OF ORE MINERALS: Major approx. > 50%	Subordinate approx. > 10% < 50%	Minor and accessory approx. < 10%	Gangue Minerals
Dubuna	Pyrite Marcasite	Sphalerite	Chalcopyrite Galena Specularite	Calcite
Elvina	Pyrite Marcasite	Chalcopyrite Sphalerite Hematite	Galena ?Cubanite Hydrated iron oxides	Chalcedony Calcite
Sapphire	Pyrite	Chalcopyrite	Sphalerite Hydrated iron oxide	Clinochorite
Mount Diamond	Pyrite		Chalcopyrite Sphalerite ?Enargite	Chalcedony
Laloki	Pyrite Marcasite Chalcopyrite	Sphalerite	Galena Gold	Calcite Barytes Chalcedony
DDH SC4 Laloki. Between 274 feet and 285 feet	Magnetite Pyrite Chalcopyrite			Talc
Moresby King	Pyrite Marcasite Arsenopyrite	Chalcopyrite	Sphalerite Specularite Hydrated iron oxides	Quartz Chlorite
Paree	Pyrite Marcasite		Chalcopyrite Specularite	Calcite
Ventura	Pyrite		Chalcopyrite Covellite	Chalcedony

(1) Crystalline aggregates of chalcopyrite surrounded and rimmed by sphalerite and galena formed by unmixing of the amorphous sphalerite-galena-chalcopyrite colloform aggregates. Near barytes in the gangue (Laloki ore), sphalerite and galena appear to have completely diffused from the originally mixed grains to form borders around cores of chalcopyrite, and are themselves surrounded by a zone of partial unmixing as shown in Pl. 7, fig. 2.

(2) Euhedral pyrite retaining relic spheroidal structures;

(3) Strings and granular chains of euhedral pyrite along boundaries between calcite and barytes gangue (e.g., Pl. 6, fig. 1) and veining earlier formed minerals (see Pl.7, fig. 1);

(4) Pyrite and chalcopyrite which contain inclusions in zones conformable to the outer margins of the host mineral;

(5) Shattered iron sulphides 'cemented' by calcite, barytes, chalcopyrite, and sphalerite, all of which may be surrounded and veined by a later generation of pyrite;

(6) Small-scale folding of the original colloform banding (e.g., Pl. 4, fig 2);

(7) Fine-grained pyrite in recrystallised equigranular aggregates;

(8) Twinning of chalcopyrite.

During the second phase of mineralization magnetite was introduced probably by metasomatic solutions related to the Sadowa Gabbro (Pontifex, 1965). At this time corrosion of the chalcopyrite formed voids in which talc and magnetite were deposited, and brecciated pyrite was 'cemented' by magnetite. A diagnostic characteristic of this magnetite is the absence of intergrown ilmenite, whereas ilmenite is common in magnetite in the basic rocks of the area.

A little brecciation occurred after the textures of the second phase formed.

Chemistry of the Ores

An examination of all available assays shows that the primary ores from the major mines and prospects are similar. The copper content ranges from 1 to 5 percent; gold is commonly about 3 dwt/tons; and silver is normally about 10 dwt/tons but ranges up to 1 ounce/ton. A table of analyses in Carne (1913), indicates that zinc ranges from 1 to 3 percent, and lead from 0.2 to 0.9 percent. In addition, iron ranges from 30 to 50 percent (generally about 40 percent), and silica from 1 to 13 percent. An exception to this constancy is the ore in a narrow zone in the upper levels of diamond drill hole SC 3 at the Laloki mine, which assayed 10.9 percent copper and 4 percent zinc.

Table 7 lists the results of spectrochemical analyses of ore samples from selected mines and prospects. These results show that nickel, vanadium, titanium, and arsenic are almost absent, and that cobalt, tin, and molybdenum occur in trace amounts.

Ore Gensis

The following features of the copper mineralization in the Astrolabe Mineral Field suggest a syngenetic origin for the ore.

(1) All major orebodies are confined to the lutite facies in the Port Moresby Beds (Eocene), which consists of black shale, grey siltstone, and minor calcilutite.

PLATE 4

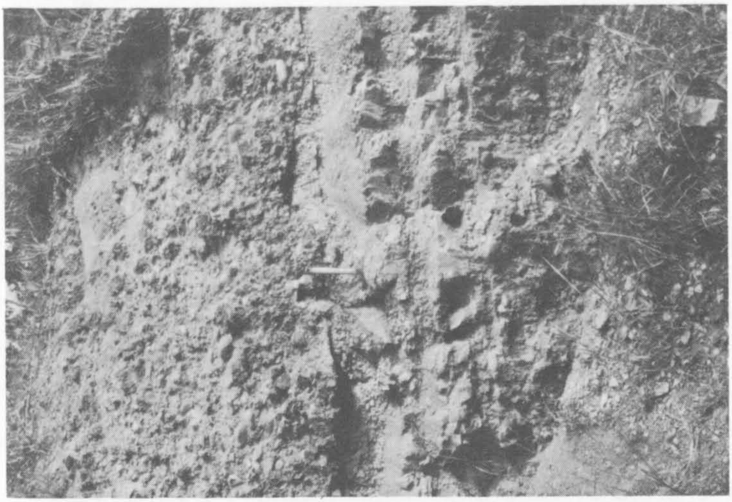

Figure 1:

Ararabu Conglomerate in road cutting 2.5 miles south-south-east of Kwikila. Hammer indicates top of siltstone bed containing plant fossils.

Figure 2:

Banding and folding in sulphide ore. Chalcopyrite (ch), sphalerite (sp), fine grained subhedral and spheroidal pyrite bands (py), barytes gangue (ba). Pl.5, fig. 2; Pl. 6, fig. 1; and Pl. 8, fig. 1 are from areas in the main fold. Laloki mine. X4.

PLATE 5

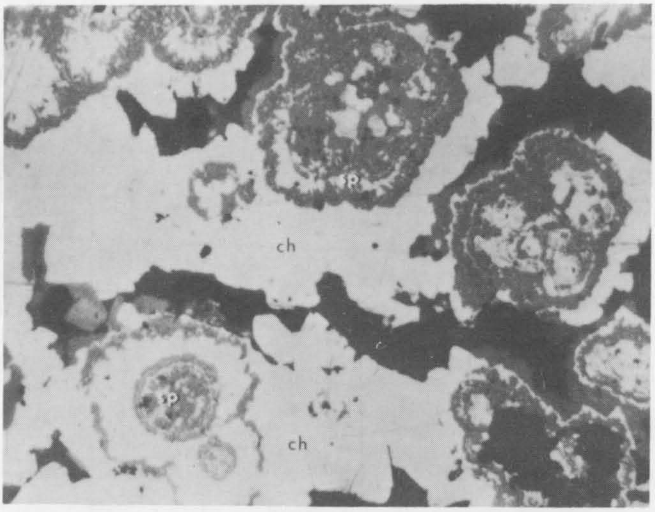

Figure 1:

Textures indicating diffusion of sphalerite (sp) from chalcopyrite (ch) formed during the crystallization of chalcopyrite subsequent to its colloidal precipitation with sphalerite. Laloki mine. X675.

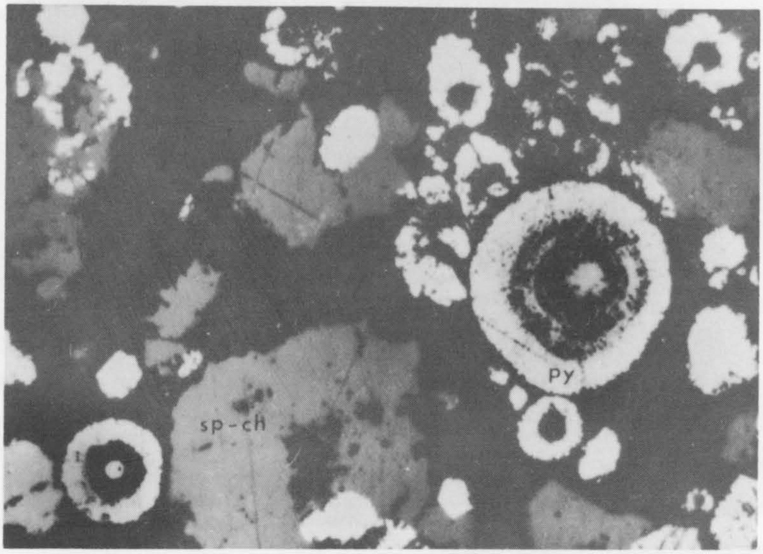

Figure 2:

Spheroidal pyrite (py) and grains of admixed sphalerite and chalcopyrite (sp-ch) in barytes gangue. Laloki mine. X675.

PLATE 6

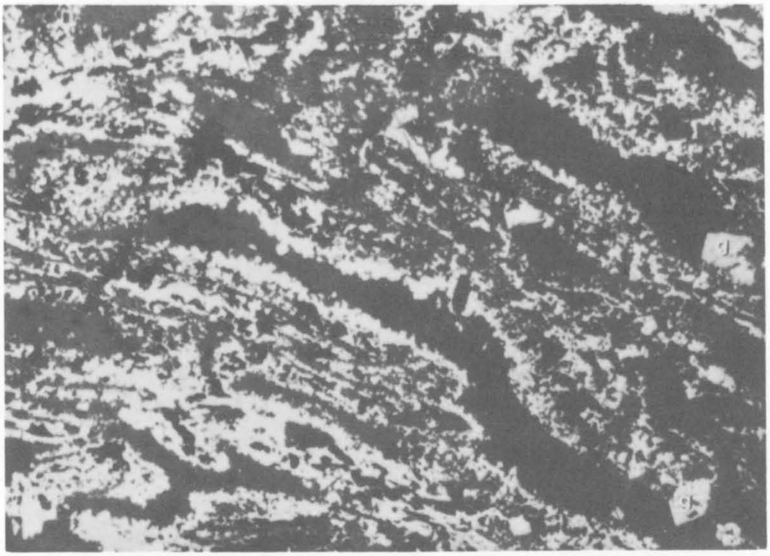

Figure 1:

Bands of granular marcasite in calcite gangue; free euhedral galena (g) in gangue. Dubuna mine. X106.

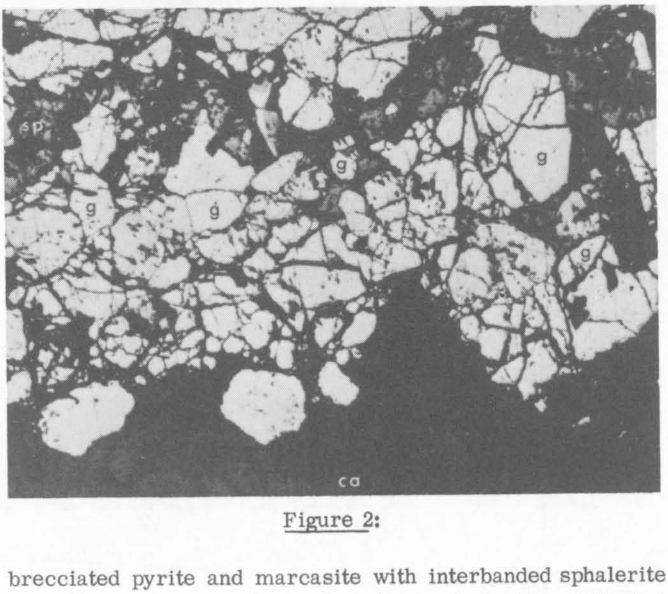

Figure 2:

Bands of brecciated pyrite and marcasite with interbanded sphalerite (sp) and galena (g). The banding is conformable to the contact with calcite (ca) gangue. Elvina mine. X42.

PLATE 7

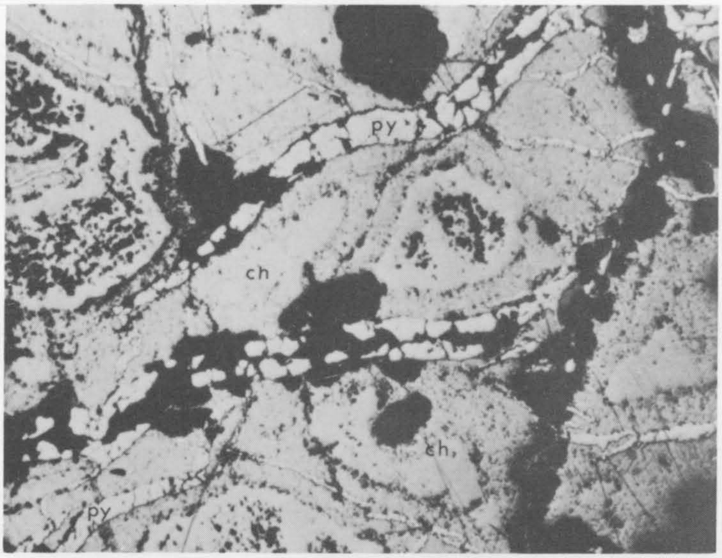

Figure 1:

Zoned chalcopyrite (ch) masses veined by a later generation of granular pyrite (py). Sapphire mine. X106.

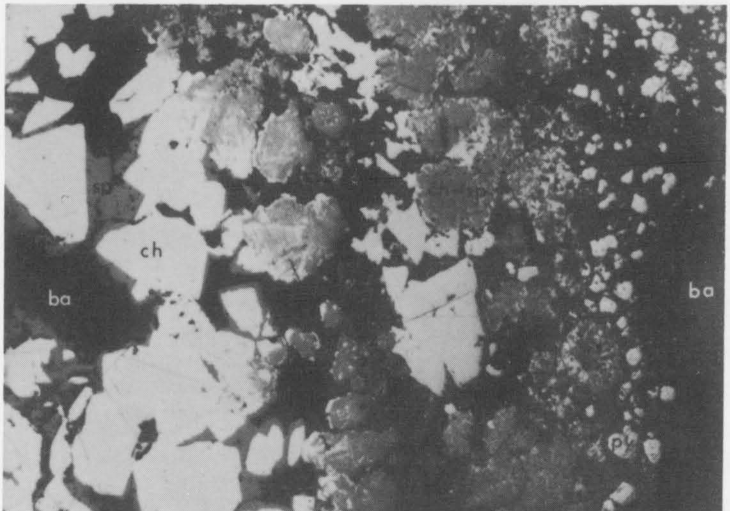

Figure 2:

Banding in Laloki ore. Left hand band consists of chalcopyrite (ch) with surrounding sphalerite (sp) rims. The centre band is a zone in which sphalerite is partly segregated from chalcopyrite (ch-sp). The white-grey grains along the right hand margin are euhedral and spheroidal pyrite (py). Dark coloured gangue is barytes (ba). Laloki mine. X106.

TABLE 6.

DIAGRAMMATIC REPRESENTATION OF THE PARAGENESIS OF SULPHIDE ORES IN THE ASTROLABE MINERAL FIELD

TIME	EOCENE		OLIGOCENE	RECENT
	Mineralization Phase I.		Mineralization Phase II.	Formation of Secondary Minerals
Pyrite	————		————	
Marcasite	————		————	
Chalcopyrite	————		———	
Sphalerite	————		———	
Galena	————		———	
Arsenopyrite	————		———	
Gold	————	HIATUS	- - - - - - - - ?	
Chalcedony	———		?———	
Calcite	———		?———	
Barytes	?———		?———	
Specularite	?———		?———	
Magnetite			———?	
Talc			———?	
Chlorite	- - - - - - -		?- - - - - - - - ?	
Rutile			- - - - - - - -?	
Covellite				- - ———— continuing
Hydrated FeO				- - ———— continuing
	Simultaneous colleidal precipitation and incipient crystallization.		Severe tectonic activity causing brecciation and folding with concurrent recrystallization of Phase I minerals. Introduction of gabbro.	Minor tectonic activity causing moderate brecciation.

TABLE 7

SPECTROCHEMICAL ANALYSES OF COPPER ORES*

Origin of Samples (Mine or Prospect)	Zn	Ni	Co	Cu	V	Mo	Sn	Pb	Ag	Bi	As	Mg	Ca	Al	Fe	Mn	In	Ge	Cd	Sb
Dubuna	$>1\%$	-5	7	$\frac{1}{2}\%$	-5	20	100	700	P	-	-	L	M	L	H	M	P	P	-	-
Elvina	1000	7	300	$\frac{1}{2}\%$	-5	20	20	20	-	-	-	L	-	L	H	L	P	-	-	-
Elvina	1500	5	500	$>\frac{1}{2}\%$	-5	60	5	50	P	-	-	L	M	L	H	M	P	-	-	-
Sapphire	4000	5	400	$>\frac{1}{2}\%$	-5	10	100	-10	P	P	P	M	L	L	H	M	P	-	-	-
Mount Diamond	50	-	15	700	-5	2	-	-10	P	-	-	L	-	L	L	L	-	-	-	-
Mount Diamond	$>1\%$	-	30	5000	-5	15	200	50	P	-	-	M	-	L	H	M	P	-	-	-
Laloki	$>1\%$	-	70	$>\frac{1}{2}\%$	30	150	70	2000	P	P	P	L	-	L	H	L	P	P	P	P
Laloki	$>1\%$	-	15	$>\frac{1}{2}\%$	7	300	100	1500	P	P	-	L	-	L	H	L	P	-	-	-
Moresby King	3000	5	100	$>\frac{1}{2}\%$	-5	10	20	-10	P	P	P	M	L	M	H	M	P	-	-	-
Moresby King	4000	-5	100	$>\frac{1}{2}\%$	-5	10	20	-10	P	P	P	L	L	L	H	M	P	-	-	-
Pari	700	-	50	$\frac{1}{2}\%$	-5	10	-	50	P	-	-	L	M	L	H	M	P	-	-	-

* By A.D. Haldane, BMR.

P - Present
L - low amount present
M - medium amount present
H - high amount present
-5 - less than 5 ppm
\- - sought but not detected

All values in ppm except where shown as %

Ti is low in all specimens: Na, B and P are absent.

(2) The orebodies are about conformable with the bedding of the enclosing sedimentary rocks.

(3) There appears to be no structural control to the mineralization. Fracturing and shearing at the margins of the orebodies is considered to have occurred during post-ore deformation as a result of a difference in competence between the orebodies and the surrounding sedimentary rocks.

(4) None of the known orebodies have been traced into the gabbro, and no massive sulphide bodies occur in the gabbro.

(5) The wallrock adjacent to the sulphide lodes is not altered, and no metasomatic minerals were introduced by the Sadowa Gabbro into contact metamorphosed calcilutites.

(6) The degree of deformation of the ores, indicated by their structure and texture, seems to be considerably more than the deformation indicated by structures in the gabbro.

(7) The primary ore textures suggest simultaneous colloidal precipitation of all major ore minerals, which implies a low temperature of deposition.

(8) Secondary ore textures have resulted from unmixing and recrystallization caused by tectonic activity, and possibly by a mild rise in temperature during the intrusion of the gabbro.

(9) At the Laloki mine, the orebody grades into a halo of pyritic shale.

(10) Pyrite nodules in calcilutite of the Port Moresby Beds indicate that iron sulphide has been deposited simultaneously with the sediments.

(11) The ores have a fairly constant mineralogy and chemistry.

(12) Minerals normally associated with orebodies in or adjacent to basic igneous rocks (e.g. Sudbury, Canada), such as cobalt, nickel, silver, pyrrhotite, and ilmenite, are lacking.

Individual Mines and Prospects

(*Indicates mine with recorded production).

Astrolabe (Dubuna North)

This prospect is situated 1.5 miles north of the Dubuna mine, at the foot of a prominent ridge trending 350°. The workings are completely overgrown by rainforest, and the nearest road ends at the Dubuna mine.

There is no record of production from this lease, and the period when it was developed is not known. Several costeans, two collapsed adits, and a shaft can still be located, but no sign of copper or even a substantial gossan can be seen. Fresh mudstone and shale crop out in creeks adjacent to the workings.

A. & E.

The A. & E. workings were not located, and the only reference to them is given by King (1950), who states: 'The A. & E. is situated on a watershed between the Goldie and Brown Rivers and is reached by walking across country, eastwards from the old Brown River track.

'On a spur of one of the highest gabbro hills there are a few small, shallow pits (all less than 2 feet in diameter and depth) put down on weak north-south vertical fractures in gabbro. Along these fractures there is some iron staining over a width of up to an inch. Four or five of these fractures occur in the 600 feet east-west extent of the ridge.'

*Dubuna

The Dubuna mine is 19 miles by road south-east of Port Moresby, and is the second largest copper producer in the Astrolabe Mineral Field. The history of the mine is outlined on pages to .

The production statistics for this mine indicate that 4936 tons of ore were shipped from 1910 to 1916, but detailed figures are not available. In 1924, reserves at the mine were estimated to be 40,000 tons. Prior to underground fires in 1925, it is estimated that 11,588 tons (Hooper, 1941), or 15,000 (King, 1950) were removed. It is concluded that the total production of ore was about 20,000 tons, and that underground reserves are about 25,000 tons.

As the result of a request for diamond drilling by Mr. J.C. Kennett in 1962, a combined geological and self-potential geophysical survey was made of the mine. This was followed by the drilling of 11 diamond drill holes totalling 904 feet by the Papua-New Guinea Administration, but no new economic mineralization was revealed.

The orebodies at the Dubuna mine are located at the centre of a belt of grey to greenish grey calcilutite, shale, and sedimentary breccia which dip west at 45^{o} to 80^{o}. The belt, 3000 feet wide and trending north-north-west, is bounded to the east and west by dolerite (Sadowa Gabbro). In the face of the opencut, intensely contorted shale strikes 360^{o} and dips steeply west. The axes of minor folds in this area are parallel to the regional strike. Dolerite crops out in the southern side of the opencut, and has been intersected in a drillhole at the base of the open cut and in another 500 feet to the north-west.

All mine plans and records have been lost or destroyed, and the dumps from the opencut mining now cover most of the early workings described by Carne (1913). According to Carne there are two main lodes:

No. 1 lode: strike 320^{o}, dip south-west at a low angle; prospected to a depth of at least 170 feet. This lode contained three main lenses, of which the largest was 100 feet long, with an average width of 14 feet and a maximum of 30 feet.

No. 2 lode: strike 300^{o}, dip 75^{o} north-east; prospected to a depth of at least 150 feet. Stanley (1911) noted that the orebody had a southerly dip in the deeper levels.

The main evidence seen today for mineralization in the mine area is two gossans trending north-north-west. The northern gossan is 30 to 35 feet wide and 400 feet long.

The southern gossan, near the open cut, is about 500 feet long and 60 feet wide near its northern end. In addition, discontinuous small outcrops of gossan trending 225° can be traced for 200 feet from a small shaft near the old camp site. This direction cuts across the strike of the surrounding sediments, but the larger gossans are concordant. However, the failure of diamond drilling to intersect any significant sulphide bodies beneath the gossans suggests that the outcrops do not indicate the true attitude, shape, and size of the underlying mineralization. Small lenses of sulphide mineralization up to 6 feet long and conformable to the bedding of the contorted shale are preserved in the open cut.

Most of the ore produced from the upper 50 feet of both lodes was enriched: the average assays until 1912 ranged from 21 to 24 percent copper and 4 to 4.4 dwt gold per ton. One of the few analyses of sulphide ore is given by Carne (1913), who sampled ore from the 122-foot level in the No. 2 lode over a width of 7 feet. The assay showed:

	Percent
Cu	3.82
Fe	37.94
Zn	2.70
Pb	0.22
S	32.04
SiO_2	10.11
$CaCO_3$	absent
Au	2.2 dwt/ton
Ag	8.2 dwt/ton

This probably approximates the chemical composition of the fresh sulphide ore.

The poor results of the diamond drilling; the lack of detailed mine plans; the limited amount of sulphide ore visible in the open cut; the small reserves; and the possible low grade of the remaining sulphide ore are factors which suggest that any further testing of this mine is unwarranted.

Eldorado

The Eldorado prospect has not been precisely located, but it probably corresponds with some workings found by King (1950) 2.5 miles north of Mount Lawes, consisting of two shallow pits in an area of gossan 400 feet long. The gossan crops out as scattered boulders in a raft of sediment 600 feet long, surrounded by gabbro. Stanley (1917) did not visit the Eldorado, but reported that a shaft had been sunk after the lease was granted in 1915. He also mentioned that a small shaft and tunnel had been dug on the Lubulor Lease, 3 miles north-north-east of Mount Lawes. This lease was not visited by Stanley and is not mentioned by King.

In the present survey, no workings were found corresponding with those in the above reports.

Elvina (Elvina West)

The Elvina mine is 1.5 miles east of the Dubuna mine, on the steep westerly bank of a western tributary of Maiberi Creek. A partly overgrown and collapsed mule track along Maiberi Creek connects with the Mount Diamond mine. The surrounding area is covered with dense rainforest.

A mining lease covering this area was granted in 1909. Most of the mine development took place prior to 1912, when the mine was examined and mapped by Carne. Plans showing what were probably the last efforts at prospecting the lode were prepared by Stanley (1918). These plans show over 1000 feet of drives and crosscuts on three connected levels, 60 to 70 feet apart. Crosscuts on the No. 1 level (an adit) revealed a steeply dipping sulphide orebody ranging from 21 to 30 feet wide over a length of at least 150 feet. The intermediate level intersected 35 feet of ore, and the deepest, No. 2 level intersected a faulted orebody of similar dimensions. An assay of ore from the upper levels of the winze connecting the three levels indicates 3.1 percent Cu, 36.26 percent Fe, 3.02 percent Zn, and 0.25 percent Pb(Carne, 1913). The No. 1 level is still accessible, but contains about 2 feet of water and the portal is partly collapsed.

Two steeply dipping lenses of fresh sulphide ore, 200 feet apart, are interbedded with black and grey shale, mudstone, and sedimentary breccia in the creek below the mine. The northern lens, about 3 feet wide, consists mainly of massive pyrite and assays 4.47 percent copper (Carne, 1913). The southern lode is a zone of sedimentary breccia 20 feet wide containing patches of massive sulphide.

Stanley (1917) estimated reserves at the mine as 5280 tons of ore assaying 2.5 to 3 percent copper. This estimate was made prior to the development of the lower, No. 2 level, and probable reserves of ore between the three levels are about 10,000 tons.

There is no recorded production from this mine.

Elvina South

The overgrown mule track leading from the Mount Diamond mine to the Elvina mine passes the collapsed portal of an adit 50 feet up the west bank of Maiberi Creek, at a point 0.75 miles north-east of the Mount Diamond mine. The portal is probably the entrance to the Elvina South mine.

The prospecting lease of 20 acres was applied for in 1909, and Carne (1913) reported that an underlay shaft had been driven into what was apparently the footwall of a gossan. Stanley (1917) stated that no ore was in sight and the lease was not being worked.

The steep banks of Maiberi Creek are covered with dense rainforest and outcrop in the area is poor. Large boulders of limonite stained and cemented breccia, up to 10 feet across, lie in the bed of Maiberi Creek, and boulders of iron-rich gossan are present over about 5000 square yards on both sides of the creek.

*Federal Flag (Astrolabe)

The workings on the Federal Flag lease (known as the Astrolabe until 1917) are about 300 yards south of the Rouna road, and 1200 yards east-south-east of the first crossing of Sapphire Creek on the track to the Laloki mine.

Until 1909, this lease was worked as an alluvial copper prospect, and produced 91 tons of ore containing 40 percent copper. Between 1912 and 1917, mining from several adits and a shaft produced 324 tons of ore averaging 33.2 percent copper, 4.6 dwt of gold, and 2.8 ounces of silver. All mine workings are now inaccessible.

Boulders of gossan and collapsed shafts and adits down the ridge adjacent to the workings indicate that other orebodies were mined in this area. The country rock consists of contorted shale and mudstone, generally striking 090°.

Gordon

This prospect was not found, but in the Annual Report for Papua 1906-1907, the Gordon mine is reported to lie 0.75 miles south-east of the Hector mine. The mine had three shafts 20 to 30 feet deep, and a tunnel 30 feet long passing through 8 feet of greyish ore containing a small percentage of copper and silver. Carne (1913), gave the following description of the site: 'Large cliff-masses, consisting principally of lime silicates, show stains of copper carbonate on joint faces, with a few leanly distributed particles of copper sulphide in one spot'. The site is probably very close to a gabbro contact.

*Hector

The orebody at the Hector mine was one of the first discovered in the Astrolabe Mineral Field, probably because of its proximity to Port Moresby and the Laloki River. It lies immediately south of the Rouna road, 12½ miles from Port Moresby, at the junction with the old Rigo road. The main development took place from 1907 to 1908, when 153.5 tons of ore containing 25 percent copper was produced. At the time of Carne's visit in 1912 the mine was idle. A small amount of ore was mined in 1916-1917,, bringing the total production to 275.5 tons.

Most of the ore was obtained from a small opencut and underlay shaft adjacent to the old Rigo road. The lode here strikes between 330° and 340° and dips north-east at 50°. The ore was oxidized and enriched, although low-grade sulphide ore is reported from the bottom of the underlay shaft. The orebody ranged from 2 to 8 feet wide, and was tested for a length of 90 feet to a depth of 30 feet.

Two narrow gossans in limonitic shale which trend almost parallel to the main lode, but 500 feet to the east, have been tested by two small shafts and several costeans. The gossans are 300 feet long and 150 feet apart. A contorted thin bed of limonitic shale 800 feet to the south-east contains magnetite, quartz, manganese oxides, and malachite.

The Administration in 1956 drilled four holes on the north-eastern side of the main workings, but failed to intersect any extensions of the orebody downdip. Gabbro was encountered in one hole at a depth of less than 200 feet. In addition, gabbro crops out on the western side of the opencut and in a shaft beside the northernmost gossan. The proximity of the gabbro, the failure of the diamond drilling, and the size of the orebodies, indicate that ore reserves are small.

Hercules

The Hercules mine comprises several shafts and trenches excavated in cupriferous gossan on the crest and side of a hill, 600 yards south-east of Maiberi village. The only report on this prospect is by Carne (1913), who found a collapsed shaft 30 feet deep, and a shallow costean across a gabbro-sediment contact which revealed copper carbonate at the contact. There is no record of any production.

Three small gossans trend 101^{o} across a small roof pendant of sediment in gabbro. Shafts in the two northern gossans have exposed copper carbonates, but shafts are now collapsed.

Boulders of gossan beside two shafts in the southern gossan are magnetic and contain a high proportion of manganese.

Katea

This lease was not located during the survey, but is near the junction of the Hiwick and Goldie Rivers and contains a small gossanous outcrop.

Koiari

A prospecting lease with this name, and located immediately north-east of the Dubuna lease, was applied for in 1914. There is no record of any development on the lease and no workings could be found.

*Laloki

The Laloki mine was the most productive in the Astrolabe Mineral Field. It is located on Simson Creek, a tributary of Sapphire Creek, 1.3 miles south of its junction with the Laloki River. A well-graded, but disused, track connects the mine to the main Port Moresby road. The first lease over the area of the Laloki mine was pegged in September 1907, and prospected by the British New Guinea Development Company. The ensuing history of this mine is outlined on pages to . The production of ore from the Laloki mine has been as follows (Hooper, 1941):

Prior to New Guinea Copper Mines Ltd	2060 tons
New Guinea Copper Mines Ltd (1917-1925)	32,638 "
Mandated Alluvials N.L. to 31/7/41	5790 "
Total	40,488 "

The copper and gold lode at the Laloki mine is interbedded with steeply dipping black shale in a succession of calcareous to non-calcareous grey, green, and red lutite, and sedimentary breccia. The footwall of the lode is everywhere within 10 feet of a bed of grey and red-banded lutite - a face recognized from diamond drill cores by C.L. Knight (Enterprise Exploration) - which indicates the constant stratigraphic position of the ore. The sedimentary rocks are in contact with gabbro 1000 feet north of the opencut, and gabbro was detected in diamond drill holes 250 feet and 275 feet below the footwall of the lode.

The shape and size of the orebody are illustrated by a block diagram prepared by Fisher (1941). The main massive sulphide body is 450 feet long, with a maximum horizontal width of 90 feet, and a vertical depth of 160 feet. Diamond drilling has shown that the lode grades outwards from massive sulphide to pyritic pug, then pyritic shale. In both plan and section the lode has a lenticular but slightly irregular shape: the strike ranges from easterly at the western end of the mine, to northerly at the eastern end; the dip above the 137-foot level is 45^{o} to the north and north-west, but below this Davies (1961a) considers that it flattens to almost horizontal, then rises, and dips about 15^{o} south at its northern margin. Small faults displace the lode, and the wallrock near the contacts is reported by Fisher (1941) to show signs of intense shearing, folding, and fracturing.

The ore consists of massive sulphide with very little silica or lime. The ore minerals in their order of abundance are pyrite, marcasite, chalcopyrite, sphalerite, magnetite, galena, hematite, and gold. However, unlike the other ore minerals, magnetite is not distributed throughout the orebody. The textural features of the ore are discussed on pages to . The average assay of ore from the 137-foot level is quoted by Hooper (1941) as 4.67 percent Cu, 2.8 dwt Au/ton, 10.8 dwt Ag/ton, 51.98 percent FeO, 4.8 percent SiO_2 and 39.97 percent S. The grade increases slightly with depth.

The limits of the lode were defined by 13 diamond drill holes totalling 5572 feet, drilled between 1959 and 1961 by the Papua-New Guinea Administration and Enterprise Exploration Co. Pty Ltd. No further work has been done since then. These limits are only a little greater than those indicated by Fisher (1941) who calculated reserves of 265,000 tons of ore assaying 4.57 percent Cu and 4.14 dwt Au/ton.

The lack of nearby treatment facilities, the relatively small amount of ore available, and the cost involved in redevelopment, make it uneconomical to reopen the Laloki mine, unless larger reserves are proved elsewhere in the vicinity.

Lu Lu

The precise location of this prospect is not known, but it is outside the area mapped. The only production was prior to 1912, and bags of ore averaging 24.4 percent copper were mined. Carne (1913) states: 'This lode occurs close to the foot of Mount Lawes, between it and the Laloki River, at the jail farm.... Its apparent strike is N. 8°E., vertical. Width, 3 to 4 feet, so far as can be seen. A shaft was sunk about 20 feet from the original outcrop to a depth of 33 feet, revealing oxidised copper ores, oxide or iron and quartz.'

Merrie England

A trench and collapsed adit on the west bank of Sapphire Creek, 1000 yards south of the Sapphire mine, constitute the Merrie England mine. A lease of 30 acres was granted in 1907, and forfeited in 1911.

Carne (1913) gives this account of the prospect: 'A few shallow openings were made in a gossary outcrop carrying stains of copper carbonate. It is recorded that 2.5 tons of ore were exported, but the return of value is not given.'

Mount Cook

The Mount Cook mine is located on the south-west slopes of Mount Cook, 1.6 miles north of the Ventura prospect. Mining commenced on two leases, each of 10 acres, in 1915, but ceased after E.R. Stanley inspected the prospect later that year.

Stanley (1915) reported a shaft from which there were two drives: the first failed to locate an ironstone body intersected by the shaft; the second, 50 feet lower and 96 feet long, intersected an ironstone body containing 4 to 7 percent copper. Work on the lease ceased when further development failed to reveal any additional ore. Only three small excavations, two in gabbro, and one in black shale and tuffaceous sandstone, all without a trace of copper minerals, can be found today.

Mount Diamond

The Mount Diamond mine is located on the north-western side of Maiberi Creek, about 1 mile south-east of the Dubuna mine. In dry conditions a four-wheel-drive vehicle can be driven to within 0.6 miles of the workings, along a mule track which branches off the old railway road to Dubuna and leads to Chapman's farm.

The mine workings comprise three shafts and three adits on the hillslope north-west of Maiberi Creek, and seven adits along a tributary stream about 200 feet west of the shafts. Most of the development took place between 1907 and 1913, but production figures were not kept.

The hill-slope around the mine has been stripped of soil to expose grey and dark grey lutites with a moderate dip to the south-south-west, and a thin cover of rubbly gossan near the workings. No outcrops of gossan occur, and the distribution of the rubble cannot be related with certainty to the attitude and extent of the underlying sulphide mineralization. Gabbro crops out extensively about a quarter of a mile north and a quarter of a mile south-west of the mine, and a small outcrop was found 500 feet south of the mine. Near the adits along the tributary stream the sediments dip steeply. At the entrance to several adits steeply dipping intersecting shear planes are developed, and the trace of the intersection of these shears is commonly parallel to the adits.

The most comprehensive plan of the main workings is by Carne (1913), and of the higher workings near the tributary stream by Thomas (1962). Most of the workings are now inaccessible.

Carne's plans indicate that the footwall and hangingwall are parallel and that the main lode strikes 077° and dips 42° north-west. The sulphide orebody in the main and No. 2 adits was 30 feet thick, and Carne shows the length to be more than 90 feet. The main shaft intersected the orebody at 80 feet, but the extent of the lode below this is not known. The higher adits in the tributary encountered several lenses of ore about 20 feet wide, but these are probably not connected to the main orebody 150 feet to the south-east.

Assays listed by Thomas (1962) indicate that the ore is similar to that at the Laloki mine. Ore from the main adit assayed 4.3 percent Cu, 0.9 percent Zn, 1.1 dwt Au, and 0.3 oz Ag over a width of 40 feet, and from the No. 2 adit 2.9 percent Cu, 1.1 percent Zn, 0.5 dwt Au, and 0.2 oz Ag. Samples from the north and south walls of the main tunnel between 118 feet and 159 feet contained:

north side; 4.8 percent Cu, 3 dwt Au, 0.5 oz Ag
south side; 4.5 percent Cu, 2.5 dwt Au, 0.5 oz Ag

King (1950) estimated the ore reserves to be 2000 tons; on the other hand, Glasson (1954) calculated approximately 30,000 tons of ore per vertical 100 feet. The reasons for the large difference in their figures is not obvious from their reports. Using the dimensions of the lode given by Carne (1913), and assuming seven cubic feet to one short ton, the ore reserves are about 400 tons per vertical foot. On this basis the ore reserves are a minimum of 24,000 tons. Drilling to determine the full extent of the main lode down dip may increase these reserves.

Mount Louis

This prospect is 0.4 miles east-north-east of Gidobada village (Gea 1:50,000 Sheet) and 350 yards by walking track north of the main Kwikila road: it is almost 30 miles away from any other copper mine. The prospect was not developed until 1918, although its existence was known before this. After a limited amount of exploration the lease was forfeited about 1920. Most of the workings are overgrown or collapsed, and the only information available is in a report by Stanley (1919).

Three small adits and three small shafts were dug in scattered outcrops of hematite-rich gossan trending north-west for 650 yards. The gossans are generally less than 20 feet long, and completely surrounded by gabbro. Exposures in the adits show that the mineralization occurs in xenoliths of shale in the gabbro. According to Stanley (1919), the orebodies range from 4 to 16 feet wide and assay between 0.33 and 2.91 percent copper. Secondary sulphides exposed in one shaft over a width of 4 feet assayed 10.2 percent copper. The gabbro is not mineralized. Ore reserves at this prospect are very small.

Pari (Paree)

The Pari prospect is about a quarter of a mile west-south-west of the Mount Diamond mine, not far from Chapman's farm. The workings are in gossanous shale and mudstone, which crop out on a steep-sided spur covered by dense vegetation. A large body of gabbro crops out 300 yards south of the prospect and probably underlies the workings at a fairly shallow depth. This prospect was developed from 1909 to 1911, but there is no recorded production. The workings comprise two adits driven eastwards into the spur at levels about 50 feet apart, one shaft (now collapsed), and five pits. According to Carne (1913) the bottom adit penetrated weathered ironstained grey shales with a steep dip south-west, and encountered ore at 201 feet. A winze was sunk in sulphides for 12 feet, and the adit continued for 19 feet in barren rock. The ore assayed 1.2 percent Cu and 3.3 dwt Au (Thomas, 1962). No ore was encountered in the upper adit, 160 feet long (Thomas, 1962), in weakly iron-stained shale dipping steeply to the north.

Several malachite-stained gossans about 4 feet high, 10 feet long, and 2 feet wide crop out between the workings, and trend east with a steep northerly dip. Trenches and pits higher up the slope east of the shaft were probably dug to test for any possible extensions of the gossans, but all are barren.

The sulphide mineralization is restricted to a zone about 400 feet long and 100 feet wide, trending east. No structural control to the lode could be found, although in many places the lode is at an angle to the bedding in the sediments.

It is concluded that any mining at this prospect would be uneconomical.

Ruby

The Ruby prospect is 1200 yards north of the Dubuna mine, on the lower slopes of a steep ridge trending north-west. No account of the prospecting remains.

Large boulders of gossan containing angular fragments of ironstained sedimentary rock cover an elliptical area 50 by 250 feet trending 310°. Eight shafts, up to 30 feet deep, and several pits were sunk in and around the area of gossan. All the shafts pass into grey shale and mudstone, a little stained by iron and manganese, which suggests that the orebodies have been eroded from this area.

*Sapphire King (Tobo and Tobo United)

The Sapphire King mine is 400 yards south-west of the Laloki mine, on the south-west bank of Sapphire Creek. Two creek crossings on the road from the Laloki mine are impassable.

Staniforth-Smith (1907) reported that 'black oxides' and sulphides were encountered in two tunnels on this lease. The mine was not being worked in 1912 when inspected by Carne; he reports that ore in a lens in the main tunnel contained 2 percent copper, with a little gold and silver.

Between 1938 and 1940 Mandated Alluvials N.L. mined 2252 tons of ore containing 1.2 percent copper, 5.3 dwt gold, and 0.96 oz silver. Operations ceased before the ore had been completely mined, when a landslide closed the main adit. Only the lower adit, at creek level, is now accessible.

*Sapphire and Moresby King

The Sapphire and Moresby King mines lie 17 miles east of Port Moresby, 2000 feet south of the main Rouna road on the upper slopes of a prominent ridge, and are connected to the main road by a steep track.

The first lease over the Sapphire area was taken out in 1909. The area was prospected until 1936 when Mandated Alluvials N.L. acquired the mine and built a smelter near Sapphire Creek. When operations ceased in January 1942 about 17,000 tons of ore - mostly oxidized - had been mined, yielding about 5460 oz gold, and 240 tons copper. The oxidized ore averaged about 10 dwt of gold/ton and 1 to 2 percent copper, and the sulphide ore averaged about 3 dwt of gold/ton and 4 percent copper.

The geology of the mines has been summarized by Fisher (1941). They are in the northern half of a block of mudstone and shale 3500 feet by 2000 feet, surrounded by gabbro. The Moresby King and Sapphire mines are assumed to be in the same lode, but this has not been established conclusively. The lode has a length of 900 feet north-west, and a breadth of 700 feet, and forms most of the hill around the mines. In general the lode is nearly horizontal, but in places it dips moderately to the south-east and north-west. On an average the lode is 1 to 6 feet thick, with some sudden bulges up to 30 feet thick. In part the assay values appear to be related to the thickness of the ore, but this is not a consistent relationship.

The lode is about conformable with the bedding in the sediments, but the relationship is not clear because of shearing in the sediments along the contact. Fisher (1941) reports that the ore is brecciated near the margin of the lode, and the boundary is displaced by small post-ore faults.

In 1936 and 1937, churn drilling to the north-west of the eastern Sapphire workings intersected only small amounts of sulphides (Hooper, 1941). In 1941, when the mine was still open, Fisher estimated reserves at 9000 tons of ore averaging slightly better than 10 dwt gold/ton. The size of the lode is well established and there is very little chance of increasing these reserves.

Ventura

The Ventura prospect is 1.5 miles north-west of Hombrom Bluff, and 0.3 miles south of the Hiwick River. It can be reached by a rough vehicle track which branches off the Rouna road 1 mile towards Rouna from the old Rigo road turnoff.

In 1913, Carne described the prospect, then known as the 'Empire', as 'superficial openings disclosing no values'. Only a shaft 36 feet deep on the crest of a hill remains today.

Two areas are covered by gossan. In the first, iron-rich magnetic gossan boulders cover a diamond-shaped area, 400 by 800 feet, which rises to a small hill at the south-eastern end. The second area, adjacent to the south-eastern end of the first, is roughly rectangular, and extends north-east for 1200 feet, with an average width of 200 feet. It contains gossanous and ironstained lutite in addition to outcrops and boulders of hematitic gossan. Barren sediment extends north in two arms from the high hill at the north-eastern end of this second area.

In May 1964, the Department of Lands, Surveys, and Mines completed drilling four diamond drill holes for C.R.A. Exploration Pty Ltd, in the first area of gossan. The holes were vertical, along a line trending north-west across the long dimension of the area. The three more northerly holes passed into gabbro at a very shallow depth without encountering mineralized rock or sediments. The fourth hole, drilled beside the shallow shaft, intersected 40 feet of gossan, 5 feet of sedimentary rocks, and 5 feet of massive pyritic ore after a gap of 15 feet in which no core was recovered. From 65 feet to 200 feet, the hole passed through unmineralized mudstone and shale, then entered altered gabbro. The hole was completed at 268 feet in altered gabbro.

From the results of the diamond drilling, it is clear that only the low hill at the south-eastern end of the first area is composed of gossan, and that boulders of gossan are scattered widely.

Victoria Hampton (Anaconda)

This prospect, on the northern side of the Hiwick River 1.75 miles north of Hombrom Bluff and 1.7 miles south-east of Mount Cook, can be reached by a walking track along the Hiwick River from the Ventura prospect. The mine, known as the Anaconda until 1911, is in a small roof pendant of gossan and sedimentary rocks surrounded by gabbro.

The lease was inspected by Stanley (1911), who found two shafts in a narrow gossan trending east-west which he traced for over 1000 feet. The western, or No. 1 shaft, now only a few feet deep, is located on the northern bank of a meander in Yolo Creek, a tributary of the Hiwick River. Of it Stanley wrote: 'The shaft in the creek has been sunk through 8 feet of gossan containing carbonates, and then to a depth of 33 feet through unaltered sulphides of iron and copper'. The lode was possibly 15 feet wide. An average sample of ore stacked beside the shaft assayed 0.9 percent copper, 0.6 dwt gold, and 0.1 oz silver per ton (Carne, 1913).

The No. 2 shaft, 500 feet to the east, was 102 feet deep. Unaltered sulphide containing chalcopyrite with traces of bornite and quartz was intersected at 60 feet. The shaft was full of water when inspected by Carne in 1912. A sample of ore stacked near the shaft yielded 2.83 percent copper, 12 grains gold, and 2 dwt silver per ton.

Thomas (1962) described the area as follows: 'Gossanous and semi-gossanous material can be traced eastwards from the shaft in discontinuous lenses, only a foot or two wide for about 500 feet. The gossanous shales are highly contorted in places and contain weak malachite stains. About 40 or 50 feet south of this line of mineralization and at a higher elevation is a series of isolated gossan boulders which may represent a second, parallel line of mineralization.

'About 500 feet north-east of the last gossan exposures is a low hillock with rubbly outcrops of green and brown shales and massive, purple shales or marls with irregular calcite veinlets. Among rubbly outcrops are fragments of massive hematite-magnetite.'

Miscellaneous Copper and Gossan Occurrences

(Trace element analyses of some of these gossans are to be found in Appendix 6).

Geboria 1:50,000 Sheet area

(a) Grid Reference: 531625, 8959575; 2300 yards south-east of Hector mine.

Small boulders of gossan are scattered over about 4000 square yards on the western slopes of a low hill on the northern banks of Eriama Creek. On the crest of the hill, there are copper carbonate stains in a boulder of medium to coarse-grained gabbro. A slightly inclined adit has been driven into the hill 50 yards south-west of the crest.

(b) Grid Reference: 534750, 8957720; 600 yards north-east of the Merrie England mine.

A costean 20 feet long, 4 feet wide, and 3 feet deep has been excavated to investigate copper staining in shaley sediments adjacent to a mass of red-brown calcilutite.

(c) Grid Reference: 533075, 8959450; Hospital Hill.

Green copper carbonate was found in cracks and joints in grey and grey-green calcareous shale at the bottom of a shallow pit.

(d) Grid Reference: 536800, 8952700; 200 yards south-east of the Elvina South prospect.

A shallow trench 6 feet long has been excavated in low outcrops of gossan and iron-stained sediment. About 200 feet north of this trench there is a small pit below a large outcrop of iron-stained laminated lutite, which has a little copper staining along cracks and bedding planes.

(e) Grid Reference: 530580, 8961250; 500 yards south-east of the Hector mine.

A discontinuous band of gossan and ferruginous sediment extends 500 feet north-west. The gossan has been tested by a shallow pit at the north-western end.

(f) Grid Reference: 530425, 8950175; half a mile west of Bautema mission.

A small opencut (10 feet by 20 feet) has been excavated in a gossanous mass adjacent to Cretaceous limestone. The gossan contains small amounts of green copper carbonate.

(g) Grid Reference: 530550, 8954800; 1200 yards south-west of Vaivai village.

Copper carbonate occurs in dump material beside an adit in metamorphosed limestone adjacent to a gabbro contact.

(h) Grid Reference: 531100, 890675; 500 yards south-south-west of the Hector mine.

Calcilutite at this point is stained by green copper carbonate.

(i) Grid Reference: 534600, 8956400; 500 yards south-east of Brown Hill.

Gossan boulders, up to 2 feet in diameter, are scattered over more than 6000 square yards. A small outcrop of gossan in thin-bedded lutite was found on a ridge 400 feet east of this area.

(j) Grid Reference: 533950, 8958100; 1200 yards south-east of the Sapphire mine.

Several boulders of gossan up to 10 feet across crop out at this point.

(k) Grid Reference: 533600, 8955175; 1300 yards south-east of Sadowa Hill.

A block of poorly outcropping gossan 10 feet wide extends over 200 feet and trends east-north-east.

(l) Grid Reference: 534300, 8954850; 600 yards north-east of the Ruby prospect.

Copper stains occur in gabbro, 50 feet west of a small area of scattered gossan boulders.

(m) Grid Reference: 535025, 8954100; 700 yards north-north-east of the Dubuna mine.

Grid Reference: 536075, 895975; 250 yards west of the Federal Flag mine.

At both of these localities, limonitic sediments crop out over more than 8000 square yards.

(n) Grid Reference: 535000, 8952775; 700 yards south-south-east of the Dubuna mine.

Gossan, and limonitic brecciated sediment, crop out in the creek bed, together with numerous boulders of gossan.

(o) Grid Reference: 536175, 8952325; 200 yards east of the Mount Diamond mine.

On the ridge above Maiberi Creek, there are two small areas of poorly outcropping gossan and limonitic sediments. Several very shallow pits in the eastern area do not reveal any copper staining or mineralization.

(p) Grid Reference: 536350, 8951740; 700 yards south-east of the Mount Diamond mine.

Grid Reference: 535675, 8952625; 600 yards north-west of the Mount Diamond mine.

Small outcrops of gossan and limonitic sediments occur at these localities.

Tupusuleia 1:50,000 Sheet area

(a) Grid Reference: 534450, 8948900;
536100, 8949050;
534900, 8947925.

Gossan boulders, and siliceous sediments containing small lenses of limonite and pyrite boxworks, crop out over small areas at each of these localities.

Gea 1:50,000 Sheet area

(a) Grid Reference: 561550, 8924350.

A xenolith of grey and brown shale less than 30 feet across contains small amounts of copper staining.

(b) Grid Reference: 559150, 8926425.

Rubbly outcrop of gossan covers an area 40 feet by 10 feet. Several other small areas of gossan, and sediment containing small lenses of limonite and pyrite boxwork, crop out nearby. Small gossan bodies were noted on the ridge half a mile south of this area.

Geophysical Exploration

In 1949 and 1950, the Bureau of Mineral Resources carried out a geophysical survey of all major copper mines and prospects in the Astrolabe Mineral Field (Oldham, 1950; Tate, 1951). All mines were surveyed by magnetic and self-potential methods; equipotential-line and potential-drop-ratio methods were tested at the Laloki mine, but were relatively unsuccessful because of the dense vegetation cover and the variation in near-surface conductivity. Electromagnetic methods were not used but were recommended for any future survey. Magnetic methods were the most successful.

The gabbro was found to be weakly to moderately magnetic in all the areas tested, and its contacts were indicated by steep magnetic gradients and irregularities in the magnetic pattern. These irregularities made it difficult to interpret the magnetic data at most mines because almost all of them are close to gabbro contacts. The magnetic effect of the lodes at the Laloki and Federal Flag mines was masked by magnetic boulders of agglomerate nearby.

The most promising results were obtained at the Laloki, Mount Diamond, and Dubuna mines. At the Laloki mine, a strong magnetic anomaly was found 100 feet north-north-east of the main airshaft, which diamond drilling later proved to be the north-western limit of the main orebody.

Strong well-defined magnetic and self-potential anomalies were obtained over the known orebody at Mount Diamond. Tate (1951) concluded that the anomalies could be produced by an orebody striking east over a length of 500 feet and dipping 20° north for 100 feet. Three vertical diamond drill holes along the axis of the anomaly were recommended but never drilled.

At the Dubuna mine a magnetic anomaly 1500 feet long was recorded, trending south from 200 feet west of the main airshaft to near 'Nabi's Gully'. No mineralization or gossan is evident along this line. Costeaning at right angles to the axis of the anomaly was recommended, but never carried out.

At the Sapphire-Moresby King, Federal Flag, Hector, Pari, and Elvina mines only weak anomalies were obtained in the vicinity of known orebodies and gossans.

MANGANESE

The occurrence of manganese in the Rigo district was first reported in 1886. Little interest was shown until 1938, when the high grade of the ore was realized. After the successful sale of the first shipment in 1939, Mr A.C. English obtained the leases and he, and later Mr L.J. English, maintained a small but almost continuous production of ore until 1962. In this period, about 2200 tons of manganese ore, with an average grade of 85 percent MnO_2, was mined mainly from the Pandora and Doavagi mines about $1\frac{1}{2}$ miles north-east of Rigo, and exported to Australia for the manufacture of batteries.

The manganese mineralization in the Port Moresby/Rigo area has been described by Richardson (1949), and Edwards & Best (1952). Manganese oxides are found in an area of 20 square miles around Rigo as small lenses, pockets, thin discontinuous beds, nodules, veinlets, or disseminations, in chert, calcilutite, or mudstone of the Port Moresby Beds. The greatest production has been from the Pandora mine, where the ore occurs mainly in two lenses, the largest of which is 80 feet long and 4 feet wide, and extends down, a dip of 30°, for at least 70 feet. The bedded and disseminated nature of some of the deposits suggests they are of sedimentary origin; other deposits have been reconcentrated by faulting, solution and weathering.

Costeans were excavated in two small outcrops of pyrolusite near Girabu during this survey (for locations see Gea 1:50,000 map, Pl. 13). Neither of the costeans revealed manganese of economic grade. In addition, small veinlets of pyrolusite were found in fractured yellow chert 1.5 miles south-east of Gaile, and massive manganese minerals were found in cupriferous gossan at the Hercules prospect.

There is every possibility of finding further occurrences of manganese oxides of a similar size to the Pandora lode, but these would not support large mining operations. However, such deposits would be admirable for the local inhabitants to prospect and mine on a co-operative basis, and this activity should be encouraged.

BAUXITE

An initial survey of the Sogeri Plateau for possible sources of bauxite was made by Ward (1949a), followed by J.E. Thompson (BMR) in 1959. Bauxite and bauxite clays from 3 to 5 feet thick were discovered over an area of less than 5 square miles in the vicinity of Karakatana village, now flooded by Sirunumu Dam. The bauxite is derived from the Astrolabe Agglomerate and forms a superficial soil horizon, overlain in part by laterite up to 1 foot thick.

Analyses of five samples from this area are as follows:

Moisture in air-dry sample at 110°C	SiO_2	Available Al_2O_3	Fe_2O_3	TiO_2	Loss on ignition at 1000°C	Total
%	%	%	%	%	%	%
2.70	22.03	20.07	42.07	1.13	14.11	99.41
10.70	38.3	30.73	14.87	1.94	13.63	99.20
6.74	34.72	27.85	21.19	1.84	14.14	99.74
7.76	31.47	28.43	24.20	1.42	14.48	100.00
2.26	7.90	41.72	24.74	1.88	23.17	99.41

(Results are calculated on a moisture free basis)

BEACH SANDS

Beach sands south-east of Kapa Kapa were sampled by M.C. Konecki (BMR) in 1956 to determine their economic potential. The samples showed that over 99 percent of the heavy minerals were magnetite-ilmenite intergrowths, pyroxene, and amphibole, derived from the weathering of basic igneous rocks. Only traces of zircon, topaz, apatite, rutile, and anatase were found.

LIMESTONE

The suitability of limestones and other rocks in the Port Moresby area for cement manufacture had been discussed by Noakes (1949), Ward (1949b), and Edwards (1950). Most of the rocks examined proved unsuitable; only the Bogoro Limestone at Bootless Inlet was found (by Edwards) to have the correct composition, but reserves are limited to about one million tons.

Chip samples were collected from the outcrop of Gidobada Limestone 2.1 miles west-south-west of Kwikila, and crushed to yield a bulk sample. This sample contained:

$CaCO_3$	91.9%
Fe	0.6%
MgO	0.8%
Insolubles	2.1%

Analyst: J.C. Wise, Department of Lands, Surveys and Mines, Port Moresby.

Reserves at this site are about 20 million tons. However, the analysis shows that the limestone is low in clay and iron and these would have to be added before the crushed limestone could be used to manufacture cement. Possible sources of clay and iron have been suggested by Edwards (1950), but the cost of transporting the materials to a suitable manufacturing site would probably prove prohibitive. Limestone similar in age, and possibly composition, crops out at Ginigolo and to the west of Port Moresby (Glaessner, 1952), and between Kapa Kapa and Hula.

WATER

All the rivers and larger creeks in the area are permanent and generally contain enough water to satisfy the present demand. However, some villages, principally those on the coast adjacent to the mouths of the larger streams, lack drinking water. At Barakau mission this problem was solved by piping water from a bore sunk in the alluvium of a small creek 1.4 miles away to the south-south-east. This method could be used to provide fresh water to other villages in a similar environment.

ROAD AND BUILDING MATERIALS

Almost all types of rock in the area have been used to build roads. Weathered gabbro has been used most, and is obtained from small quarries on the southern side of the Rouna road between 14 and 17 miles from Port Moresby. Around Kwikila, the Sadowa Gabbro, Kwikila Agglomerate, and Ararabu Conglomerate have been quarried for road-surfacing materials. Calcilutite and limestone from a quarry on the Rouna road, 9 miles from Port Moresby (immediately west of the boundary of the Geboria Sheet area), is crushed and used to prepare bitumen aggregate used on urban roads in Port Moresby. No more suitable rock is available close to Port Moresby. The massive, matrix-poor beds in the Astrolabe Agglomerate may yield a good aggregate, but the gabbro near Port Moresby is deeply weathered, and fresh rock is unobtainable.

Suitable aggregate for the erection of the wall of Sirunumu Dam was obtained by quarrying, crushing, and sizing basaltic agglomerate from the Astrolabe Agglomerate. Local supplies of quartz sand are unobtainable in the area.

CONCLUSIONS AND RECOMMENDATIONS

The inferred copper ore reserves in the Astrolabe Mineral Field are approximately 350,000 tons containing 4 percent copper and some gold; the Laloki Mine contains 265,000 tons of these reserves, with an average grade of 4.6 percent copper and 4.1 dwt/ton gold. Although the ore is high grade, efforts to devise a suitable treatment process have been unsuccessful to date. Inhibiting factors include rapid oxidation of ore on exposure, and fine grinding (up to 87 percent less than 200 mesh) needed to liberate the economic minerals. Other deterrents to reopening the mines are the combustible nature of the ore and heavy ground. However, if a suitable treatment process can be devised, the mines could be economically operated by a small syndicate.

Diamond drilling at the Mount Diamond mine

Minimum ore reserves at this mine are 24,000 tons, calculated on a known length of 90 feet, a width of 30 feet, and a depth of 60 feet. A geophysical survey of this mine in 1950 revealed strong magnetic and self-potential anomalies over the known orebody. According to Tate (1951), these anomalies could be explained by an orebody with a length of 500 feet. Assuming this to be correct, the ore reserves may be increased fivefold. In addition, the extent of the lode down-dip is not known.

The three diamond drill holes along the axis of the anomaly recommended by Tate were never drilled, and would provide a good basis on which to commence exploration.

Close stream sediment and soil sampling in the vicinity of the Astrolabe prospect.

Stream sediment samples collected in this area show anomalous concentrations of copper and zinc (p.). Some of the copper has probably been derived from the Astrolabe prospect, but an area of poorly outcropping gossan 250 feet long on the ridge to the north of the prospect is another possible source. The poor gossan is in a block of sediments with a known depth of 1000 feet, all of which is a potential host for mineralization. In addition, the mineralization may extend along strike from the gossan to the Astrolabe prospect.

Because the terrain is rugged and densely vegetated, stream sediment sampling, followed by soil sampling along ridges and contours, is recommended.

A closer investigation of stream sediment copper anomalies to the south and south-east of the Mount Diamond mine (p.)

It is probable that small undiscovered gossans crop out in this area. Close stream sediment sampling and a re-examination of known gossans is recommended. Soil sampling in the vicinity of all gossans may be required.

Investigations to examine a possible southern extension of mineralization at the Dubuna mine.

A magnetic anomaly found by Tate (1951) extends south from the known workings at the Dubuna mine for almost 1000 feet. Magnetite collected to the south of the Dubuna mine in 'Nabi's Gully' contained an anomalously high copper content (p.). More stream sediment and magnetite sampling should be undertaken in conjunction with a detailed ground examination of the area.

Regional geophysical investigations

Low-level aeromagnetic surveys appear to be the most suitable for geophysical exploration in the Astrolabe Mineral Field. Other types of geophysical surveys in which the instruments can be transported by helicopter could also prove effective, whereas ground surveys, because of the difficulties of access, would be inefficient.

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APPENDIX 1

ANALYSES OF STREAM SEDIMENT SAMPLES

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070002	20	22	15	55		0.5	3		533600	8958400
4	25	27	21	60		-0.5*	10		533100	8958800
5	36	27	21	53		-0.5	-2		534750	8949000
6	30	66	52	47		-0.5	3		535700	8949000
7	28	40	37	60		0.5	-2		533690	8958700
8	30	106	65	78		-0.5	7		536450	8948300
9	30	75	62	67		-0.5	7		536470	8948070
10	31	55	52	55		-0.5	6		534770	8948730
11	10	72	12	60		2.0	12		533820	8948250
14	10	-	23	37		3.0	2		535050	8945800
16	17	100	65	93	A	8.8	7		534230	8947970
17	17	45	45	55		1.0	2		535530	8946050
18	31	55	75	75		-0.5	4		535470	8946350
19	35	62	62	65		4.0	3		535920	8943830
20	22	12	18	45		0.5	6		540000	8958250
23	17	32	32	35		1.5	3		537500	8946050
24	n.d.	40	22	26		-0.5	-2		538200	8946250
26	n.d.	-	55	27		1.0	3		537300	8946350
28	n.d.	42	29	33		5.0	2		542200	8940100
31	n.d.	43	35	56	A	2.5	9		542150	8940100
32	n.d.	66	42	63		-0.5	-2		541000	8939300
33	n.d.	42	25	62		3.0	3		542900	8939250
34	n.d.	88	55	77	A	0.5	5		543000	8939350
35	n.d.	73	42	43		0.5	4		531900	8950000
36	n.d.	87	70	62		-0.5	3		532850	8948920
37	n.d.	155	97	77		11.3	5		532660	8948630
38	n.d.	60	35	37		-0.5	4		539300	8947050
40	n.d.	76	55	68		-0.5	8		539900	8947020
41	n.d.	45	35	36		-0.5	-2		539950	8947500
43	n.d.	42	25	32		-0.5	3		539650	8947900
47	-	50	-	50		-0.5	14		532550	8947750
48	-	85	68	60		1.3	-2		533670	8949700
50	-	55	42	51		-0.5	10		537850	8945000
53	-	84	72	47		-0.5	5		530370	8959775
56	-	60	42	39		-0.5	6		530220	8957330
59	-	42	29	32		1.5	-2		530220	8957330
61	-	37	35	31		-0.5	4		531180	8955480
64	-	42	35	41		-0.5	8		531180	8955180
67	-	40	42	46		-0.5	4		542500	8939220
70	-	42	42	65		-0.5	-2		541950	8939770
72	-	65	59	46		-0.5	3		535550	8950530
75	-	63	45	43		2.5	5		536700	8950250
76	-	63	55	41		1.0	-2		536750	8950100

Footnote: *-0.5 means less than 0.5
+A= anomalous content.

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070078	-	62	48	58		-0.5	-2		537550	8949900
80	-	77	43	45		0.5	3		537500	8949750
82	-	42	30	27		0.5	3		538450	8949350
85	-	48	32	52		-0.5	3		538550	8948700
86		31	25	22		2.0	-2		538400	8947850
88		55	50	54		2.0	6		538500	8947800
89		63	48	56		-0.5	6		537900	8944850
90		54	35	50		-0.5	6		538550	8944650
91		50	60	62	A	20.0	-2		539750	8944650
94		60	52	65	A	8.3	8		540150	8945100
96		36	34	33		0.5	4		538630	8945000
97		60	43	49		1.5	7		541550	8946350
99		57	81	52		-0.5	-2		541700	8946350
100		40	32	30		-0.5	6		537750	8945850
102		15	10	17		-0.5	-2		537650	8941980
103		14	12	27		-0.5	-2		537770	8941670
104		10	7	15		1.0	3		538780	8943200
105		58	43	56		1.0	3		539310	8941810
108		51	45	52		2.0	3		539880	8943290
109		58	34	45		2.5	-2		541120	8942500
112		46	34	49		-0.5	-2		540750	8941950
113		38	25	45		1.8	3		542400	8942550
116		27	17	27		0.5	-2		543450	8943000
118		50	47	61		2.0	-2		543420	8943000
120		59	61	55		0.8	-2		541800	8941900
122		48	32	42		4.7	-2		540700	8944170
124		154	67	54		-0.5	3		541200	8944150
126		79	50	53		1.3	-2		542200	8943780
128		70	40	49					541350	8943400
131		105	107	97		-0.5	6		550100	8935100
132		84	73	56		-0.5	3		549570	8935650
134		147	45	57		4.7	-2		548600	8935650
137		62	48	54		0.5	4		546000	8936000
138		158	42	60		7.5	3		549100	8936140
140		172	57	77		-0.5	4		550060	8938010
143		90	65	64		2.5	-2		549000	8936200
144		52	42	48		-0.5	3		544450	8935600
149		187	48	100	A	10.0	-2		545800	8940450
153	20	57	42	52		-0.5	4		548450	8927775
154	22	103	104	71		2.5	4		547425	8928200
155	26	60	50	80		-0.5	4		551325	8928775
158	17	42	30	39		-0.5	-2		551525	8929350
162	22	87	37	23		-0.5	-2		553100	8933225
164	26	121	57	37		-0.5	-2		552950	8933200
166	25	60	65	46		-0.5	-2		552475	8934700
168	27	70	67	50		-0.5	-2		551325	8935225

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070170	28	88	81	88		-0.5	-2		552025	8935475
172	30	72	65	83		-0.5	3		552200	8935375
175	17	31	17	24		-0.5	3		553000	8931400
177	24	40	47	60		0.8	-2		552075	8929725
179	12	21	12	26		-0.5	-2		552075	8931625
181	12	42	25	27		-0.5	-2		552425	8931775
183	15	32	25	28		-0.5	-2		554625	8927825
184	20	65	40	42		-0.5	-2		555275	8929650
187	12	28	20	25		-0.5	-2		555100	8930225
189	20	55	42	35		-0.5	4		554675	8930500
191	38	90	81	72		-0.5	6		562225	8929575
193	22	51	70	38		-0.5	-2		566550	8926600
194	30	65	137	39		-0.5	-2		566350	8928625
197	30	46	76	42		-0.5	-2		565750	8929050
199	24	40	64	36		-0.5	3		566425	8927875
202	12	64	37	45		4.5	5		546000	8940450
204	40	96	80	66		4.5	-2		544750	8939400
205	10	50	23	13		-0.2	-2		544850	8939000
208	44	121	100	78		3.0	5		544050	8936350
209	15	64	46	52		-0.5	4		538400	8943400
210	32	67	64	68		1.0	-2		538600	8943920
211	20	50	17	48	A	-0.5	3		546200	8942000
213	27	375	57	120		33.0	12		546400	8942000
215	26	60	55	57		1.0	-2		546700	8940350
216	15	50	37	14		4.0	-2		545450	8941300
218	20	31	32	22		-0.5	-2		545300	8941050
220	4	54	32	41					546500	8936500
221	30	102	55	80					546900	8936850
222	n.d.	n.d.	n.d.	n.d.	A	50.0			546000	8940450
223	12	31	17	22		-0.5	-2		544450	8938150
225	17	52	52	62		17.0	-2		544950	8938400
229	12	65	47	34					548550	8937500
231	25	98	90	37		-0.5	-2		548900	8938250
233	25	69	58	44		-0.5	4		548580	8939750
235	17	50	30	28					547100	8937900
236	25	121	55	74					547400	8937000
238	22	43	32	58		-0.5	-2		546750	8941400
240	32	72	70	68		-0.5	3		546700	8941500
242	15	55	45	44		2.5	4		546550	8942500
244	24	73	62	36		-0.5	-2		545050	8947000
246	30	106	78	92		-0.5	-2		543700	8938100
247	20	106	70	78		2.0	3		546200	8932550
248	22	85	85	67	A	20.0	7		546650	8933600
249	22	96	70	67		2.5	-2		545850	8933640
250	12	98	60	62		-0.5	-2		545200	8932500

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070251	34	70	70	75		-0.5	-2		548250	8929775
252	25	95	66	100		-0.5	-2		550200	8927100
253	18	82	35	130		-0.5	3		550850	8926000
254	22	58	65	62		-0.5	2		554350	8924625
255	22	75	62	85		-0.5	5		554850	8924300
265	36	87	72	44		-0.5	-2		563375	8931325
266	30	75	51	60		-0.5	-2		563750	8930325
269	26	87	58	50		-0.5	-2		563450	8929725
270	38	106	90	60		-0.5	-2		563400	8929175
272	36	113	102	52		-0.5	-2		563300	8928825
274	30	76	176	41		-0.5	-2		566725	8927925
275	38	79	72	66		-0.5	8		567850	8925225
276	35	80	52	82		-0.5	6		555125	8927450
277	22	119	50	46		-0.5	-2		556000	8928000
279	26	58	50	87		-0.5	-2		555850	8928175
282	32	74	52	80					571475	8925600
284	37	112	65	73		-0.5			571700	8926075
285	37	121	60	95		2.0			570325	8926000
286	55	130	75	200	A	2.0			571200	8927250
287	28	88	60	90	A	30.0			570000	8929475
289	28	100	112	38		4.0			532000	8959275
290	33	138	116	38		-0.5			531725	8958800
291	15	70	50	42		-0.5			530975	8957400
293	24	920	55	310	A	30.4			534325	8953250
295	30	300	75	107	A	30.0			534750	8953600
297	26	65	45	63		1.6			534450	8953925
299	20	60	50	40		1.0			534475	8954200
301	20	71	52	66		-0.5	-2		541650	8945820
303	22	77	65	65		-0.5	3		541650	8945970
305	30	77	60	78		-0.5	3		543950	8945670
309	17	119	56	47		-0.5	-2		554300	8914050
310	19	69	56	62		0.5	6		561150	8914300
311	25	76	70	58		-0.5	8		560450	8914900
312	19	51	45	51		-0.5	4		562300	8914050
313	25	82	70	67		-0.5	-2		559850	8916330
316	30	69	70	67		-0.5	4		561000	8917170
317	24	100	82	83		2.5	6		562850	8913700
318	26	106	80	117		2.0	4		556800	8916050
319	22	63	62	56		1.8	-2		562650	8913550
320	17	55	60	49		-0.5	4		561950	8913950
322	22	38	48	46		-0.5	3		563000	8915300
324	26	77	62	56		-0.5	3		563500	8915000
326	15	42	50	42		-0.5	-2		563150	8914100
327	13	48	45	54		-0.5	-2		563150	8914430
329	22	90	82	63		4.5	3		561200	8916200
330	25	87	65	53		-0.5	4		565930	8916750
332	19	57	62	74		-0.5	3		571800	8914450

Registered	Aqua regia soluble					Citrate soluble		As	Metric grid reference	
Number	Co	Cu	Ni	Zn	Remarks	Cu	Zn			
64070334	50	80	62	70		-0.5	-2		571200	8914300
336	35	70	60	57		-0.5	-2		571030	8914750
338	35	85	70	62		4.5	2		570500	8914750
340	38	88	85	54		-0.5	-2		569120	8914450
342	24	41	50	47		0.5	3		568250	8915600
346	32	84	82	81		2.5	3		567000	8915730
348	25	63	66	62		2.5	-2		566850	8915470
350	42	91	66	88		-0.5	-2		577750	8913220
351	35	70	96	57		-0.5	-2		565280	8925700
353	24	58	55	34		-0.5	-2		565250	8925875
355	60	116	122	77	A	7.2	3	3	560450	8923920
356	32	67	55	59		4.5	-2	5	558650	8924000
357	17	156	55	85		-0.5	5		561650	8920050
358	30	115	50	57		-0.5	-2		560850	8920400
359	30	108	58	64		0.5	-2		561850	8921275
360	38	78	72	62		-0.5	-2		561830	8921850
361	37	115	82	86		4.2	-2	5	559350	8923800
362	57	103	74	80		-0.5	-2	5	559350	8924350
363	32	83	58	120		-0.5	-2	5	559608	8924620
365	35	86	47	70		3.0	4	3	560150	8924575
367	50	122	94	73		-0.5	-2	3	560800	8924350
369	32	75	60	54		-0.5	-2		562950	8929775
371	32	85	64	62		0.9	-2		562225	8929950
373	42	88	72	51		0.5	-2		563840	8929975
375	48	131	87	60		0.8	-2		564310	8928920
377	35	80	66	45		0.5	-2		564525	8928170
379	24	61	55	45		0.8	-2		564275	8927600
381	45	106	88	59		0.8	-2		565470	8927170
383	47	129	66	80		-0.5	-2		568030	8926650
385	30	72	42	105		0.8	-2		567725	8929680
387	30	82	37	53		-0.5	-2		567528	8928370
389	32	79	40	42		0.5	-2		567700	8928500
391	28	86	42	47		-0.5	-2		568350	8927280
393	40	97	54	73		0.5	-2		568500	8927425
395	40	89	56	77		-0.5	-2		567900	8926150
398	27	62	40	50		0.8	-2		567100	8924200
400	50	82	82	82		-0.5	-2		564700	8924875
401	22	65	50	67		1.0	2		548000	8934350
402	24	75	52	64		1.0	2		548350	8932800
403	50	98	70	90		-0.5	2		576400	8919300
404	30	61	46	60		-0.5	-2		575450	8920000
405	32	77	70	64		2.5	3		573900	8919200
406	38	107	90	95		-0.5	4		574550	8920200
407	38	108	70	83		-0.5	-2		572800	8915200
408	48	74	64	72		-0.5	-2		575550	8916500
410	37	80	56	76		-0.5	-2		575550	8916500

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070411	35	87	56	70		-0.5	3		575300	8915550
413	37	83	60	72		-0.5	3		570550	8919350
415	38	87	64	60		-0.5	-2		570380	8920380
416	48	114	80	78		-0.5	-2		572000	8919550
417	37	78	60	57		-0.5	-2		571900	8919000
420	24	67	56	36		-0.5	-2		569900	8917900
423	42	95	66	67		-0.5	-2		567900	8919400
424	26	51	56	40		-0.5	-2		568300	8918700
427	37	100	82	50		-0.5	-2		568900	8917800
430	35	91	73	62		-0.5	-2		567300	8917650
431	37	89	76	67		-0.5	-2		567600	8916900
432	37	95	82	67		-0.5	-2		570500	8917600
434	24	95	70	51		-0.5	-2		570600	8917500
436	26	84	73	43		2.0	-2		565500	8917550
438	45	108	66	88		0.8	4		570200	8921300
439	45	79	58	62		0.5	-2		571400	8922500
440	62	104	78	180	A	3.0	-2		572800	8922100
441	70	113	82	150	A	-0.5	3		576400	8920450
442	32	92	56	51		1.5	-2		567100	8918900
443	35	104	56	90		2.7	3		566350	8919000
444	47	123	71	150	A	2.3	-2		567350	8918250
445	37	80	54	79		2.3	3		566670	8920730
448	37	82	56	51		1.5	-2		566550	8921100
450	45	93	54	100		2.7	-2		566680	8921100
451	26	74	50	54		-0.5	-2		566800	8913700
453	29	61	60	44		-0.5	-2		566800	8913950
455	45	106	71	62		-0.5	-2		568400	8913500
457	22	53	44	35		2.0	-2		568000	8913700
459	35	89	58	49		-0.5	-2		567950	8913520
461	39	80	58	69		2.0	4		566700	8916250
462	37	100	56	59		-0.5	3		569350	8914600
465	35	89	54	61		-0.5	-2		569500	8914750
468	42	89	56	76		1.5	-2		576650	8913870
470	32	115	52	91		1.5	-2		575400	8914000
471	30	56	37	66		1.5	4		575700	8914070
474	45	94	54	88		1.5	-2		574350	8914620
475	45	100	40	95		0.8	3		572450	8914650
476	40	108	54	59		-0.5	3		561070	8927600
479	30	75	45	65		1.5	3	3	560700	8922050
480	14	32	25	36		-0.5	-2	3	560550	8922150
481	25	95	56	65	A	5.3	-2	5	559070	8921800
482	35	103	64	74		1.2	-2	5	560680	8922420
483	30	75	52	51		1.5	-2	5	561170	8922670
485	40	89	58	62		3.0	3	5	561000	8923600
487	30	82	54	51		0.8	-2	3	561000	8923800

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070489	14	34	27	59		-0.5	-2	5	559000	8921500
490	14	35	27	52		-0.5	-2	3	557600	8922200
491	11	38	32	59		-0.5	-2	5	556600	8922370
492	29	96	62	88		1.5	-2	5	557400	8923460
494	34	107	62	88		-0.5	-2		556650	8925750
496	30	84	54	41		0.8	-2		565700	8925180
498	30	80	54	69		-0.5	-2		565825	8925340
500	30	57	21	42		-0.5	-2	3	560650	8923920
502	31	93	56	45		-0.5	-2		566650	8920200
504	27	97	58	54		-0.5	-2		566200	8920100
506	27	84	45	50		0.8	-2		562200	8920700
507	65	105	42	77		-0.5	-2		563750	8919300
508	29	82	52	50		-0.5	-2		563650	8919200
510	80	106	94	88		-0.5	3		563000	8919000
511	30	75	54	65		0.8	-2		563050	8918950
512	25	77	52	59		2.3	3		562100	8918900
515	37	80	54	82		-0.5	-2		562500	8918600
516	27	84	45	43		-0.5	-2		563850	8918200
517	37	95	54	55		-0.5	-2		565500	8920530
518	55	142	68	91		0.8	-2		569200	8920150
519	32	79	37	40		0.8	-2		562700	8923400
521	14	40	30	55		-0.5	-2		560450	8919200
522	47	110	54	67		-0.5	-2		561200	8930600
524	55	110	62	67		-0.5	-2		561100	8930450
526	39	125	58	62		-0.5	-2		562050	8930100
528	30	60	32	67		-0.5	-2		581300	8924550
530	37	87	54	67		0.8	-2		581250	8924600
532	47	155	148	71		-0.5	-2		582100	8924000
534	55	152	114	88		1.5	-2		580050	8920050
535	45	181	65	82	A	-0.5	-2		581700	8920450
536	55	158	85	100		2.0			581800	8919600
537	57	134	76	74		1.5	-2		581800	8915600
538	21	32	25	85		-0.5	-2		580400	8915800
539	21	47	27	42		-0.5	-2		541250	8943000
541	27	93	17	37		1.5	-2		541500	8943300
543	32	72	17	48		0.8	-2		542000	8943650
545	27	55	37	42		1.5	-2		543400	8943800
546	33	79	60	125		-0.5			533600	8963070
547	24	57	42	68		-0.5			534330	8963000
548	34	77	41	65		1.6			533970	8963500
549	33	76	55	72		0.8			533325	8963750
550	33	70	46	53		-0.5			532750	8964100
551	37	74	50	78		2.0			533100	8964100
552	36	90	52	72		-0.5			534850	8963650

Registered	Aqua regia soluble					Citrate soluble		As	Metric grid reference	
Number	Co	Cu	Ni	Zn	Remarks	Cu	Zn			
64070553	50	72	49	88		-0.5			535600	8963450
554	36	63	45	75		3.0			535000	8963770
555	36	59	45	65		-0.5			535125	8963950
556	34	75	50	65		-0.5			534725	8964200
557	48	143	90	72		1.0			533825	8964325
558	37	54	41	100		1.6			534000	8961700
560	36	54	35	82		-0.5			533700	8961250
561	14	34	23	66		0.6			534550	8961270
562	26	43	30	74		-0.5			534275	8961270
563	38	59	41	81		-0.5			533200	8962825
564	32	72	50	80		-0.5			532700	8962400
565	42	74	51	87		-0.5			531950	8962150
566	40	66	50	77		-0.5			532275	8962450
567	35	60	44	90		0.6			533600	8962130
568	57	271	88	144	A	5.0			533500	8964325
569	42	73	49	85		-0.5			533650	8962400
570	49	114	80	54		-0.5			529450	8964350
572	54	76	53	55		0.6			528880	8963175
573	65	105	81	60		0.6			529850	8963300
574	86	71	50	62		0.6			530700	8963000
575	33	66	46	60		-0.5			531200	8963030
576	32	74	29	97		-0.5			534350	8967600
577	26	48	33	90		-0.5			534440	8967375
579	41	132	93	55		-0.5			534425	8966950
580	34	120	84	65		1.6			534750	8966275
581	48	118	73	90		-0.5			535525	8964875
582	48	108	78	88		-0.5			535550	8965225
583	28	79	65	38		-0.5			534350	8965575
584	28	70	46	73		-0.5			534120	8964870
585	35	88	60	65		-0.5			533475	8964725
586	48	125	65	85		-0.5			532950	8964825
587	30	121	51	60		-0.5			532525	8964875
588	36	90	55	90		-0.5			531250	8964375
589	50	110	63	50		-0.5			531650	8964400
592	32	55	45	72		1.0			530350	8962450
593	34	55	49	62		-0.5			530180	8962400
594	25	133	59	138	A	1.0			528900	8962400
595	18	39	30	105		-0.5			524600	8964100
596	36	71	51	93		1.0			531400	8962250
599	36	67	50	85		-0.5			533450	8962525
600	56	130	35	90		-0.5			531300	8967900
601	37	89	54	42		-0.5			566910	8924300
603	47	140	78	150	A	-0.5			568550	8924300
605	42	103	54	74		-0.5			570250	8925550
606	24	133	58	180	A	-0.5			570325	8925275
607	44	87	50	52		-0.5		5	560670	8925450

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070609	62	129	47	62		1.5		5	559700	8926300
610	40	202	50	130	A	4.5		10	559500	8926500
612	27	98	52	37		-0.5			558300	8929660
614	32	98	78	34		1.5			557730	8930125
616	25	98	64	49		0.8			557760	8930300
618	23	108	45	36		1.5			557560	8930710
620	18	67	37	42		1.2			557510	8930870
622	27	82	50	n.d.		-0.5			558870	8930230
624	21	72	37	32		-0.5			558750	8929910
626	28	82	42	32		-0.5			559320	8929900
628	27	69	52	37		-0.5			559700	8928550
630	21	60	37	29		-0.5			559700	8928620
632	28	73	38	42		-0.5		5	558220	8928920
634	28	57	29	40		-0.5		5	558125	8927850
636	33	38	46	45		-0.5		3	557850	8925875
637	28	70	50	63		3.6		5	556970	8925930
638	19	63	38	44		1.0		5	558875	8926700
640	24	66	38	45		-0.5		3	559000	8926875
642	50	110	85	57	A	9.0			562325	8927000
643	26	67	42	33		-0.5			560800	8926100
646	15	63	29	22		-0.5			562225	8926000
647	19	63	29	33		-0.5		5	560870	8925525
649	26	79	42	37		-0.5			561025	8926825
651	30	97	54	52		-0.5			564550	8925700
653	28	99	55	50		-0.5			564600	8925525
655	24	82	38	43		-0.5			564450	8924100
657	28	82	34	35		4.0			564250	8925850
659	28	96	46	53	A	10.0			564450	8924650
661	55	118	80	55		4.0			564825	8924200
663	26	73	38	35		2.0		10	562400	8924975
665	28	90	46	52		-0.5			562825	8925950
667	33	116	65	57		-0.5			562350	8926100
669	37	98	55	65		1.6			562125	8926000
671	15	68	34	43		4.0			562650	8925500
673	24	63	46	43		2.0			562575	8924990
675	28	73	46	45		1.0			562350	8923825
677	31	59	24	75		-0.5			560650	8919825
678	76	150	60	112		1.0			570975	8927150
679	65	166	40	80		1.0			571750	8927475
681	44	125	57	70		-0.5			571800	8927600
683	40	79	55	63		-0.5			571125	8929350
685	40	90	31	68		-0.5			574150	8930000
687	36	100	65	35		-0.5			574550	8929700
689	50	157	105	50		1.0			574650	8929550
691	52	139	121	70		-0.5			575100	8928200
693	45	91	113	52		1.0				

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070697	44	100	98	75		-0.5			575625	8931000
699	48	139	114	55		1.0			576850	8930550
701	48	100	60	80		-0.5			570000	8928900
704	50	120	130	72		-0.5			572800	8930325
706	44	102	57	85		-0.5			572850	8930475
707	52	135	113	83		-0.5			573000	8929950
709	40	125	85	75		-0.5			576350	8930575
710	44	105	96	68		-0.5			577075	8929925
712	90	132	93	50		-0.5			576050	8930875
714	75	100	85	44		-0.5			576425	8930625
716		48	34	36		-0.5			581250	8927525
717	117	65	57	35		1.0			578725	8928525
719	105	176	84	59		-0.5			578275	8927375
720	113	200	84	58	A	-0.5			578675	8926375
721	87	195	75	86	A	-0.5			578000	8924525
723	93	80	55	60		-0.5			533250	8959550
724	81	17	12	50		-0.5			532500	8959300
725	50	92	100	50		-0.5			531825	8959000
726	65	120	80	52		-0.5			577775	8928350
728	150	95	60	80		-0.5			579150	8929250
729	104	117	75	60		-0.5			578600	8929500
731	150	144	80	50		-0.5			579250	8929500
732	93	65	45	50		-0.5			578725	8929825
734	115	195	70	86	A	-0.5			577875	8924750
736	45	42	18	40		1.0			534525	8954425
738	87	95	44	35		-0.5			534425	8954725
740	50	58	31	30		-0.5			534300	8954850
742	55	109	63	32		1.0			534350	8954975
744	57	36	18	30		-0.5			533550	8955475
747	100	83	50	62		-0.5			539925	8963700
748	105	68	44	70		-0.5			539050	8963850
749	109	35	51	70		-0.5			553525	8965025
751	72	83	49	63		-0.5			534975	8966300
752	65	87	49	54		-0.5			535000	8965825
753	78	132	70	74		-0.5			535000	8965050
754	44	78	70	43		-0.5			534950	8965050
755	80	126	60	52		-0.5			531400	8968150
756	65	117	60	60		-0.5			531775	8968100
757	82	114	53	45		-0.5			531650	8967650
758	60	106	53	52		-0.5			532200	8967750
760	69	124	45	83		-0.5			532775	8967800
762	79	119	44	80		-0.5			532300	8968200
763	50	165	88	65		1.0			532000	8967100
764	53	75	28	44		-0.5			530975	8966800

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070765	105	90	60	44		-0.5			529700	8966300
766	83	112	56	52		-0.5			528100	8966400
767	100	100	51	50		-0.5			528200	8966500
768	90	78	48	55		-0.5			528600	8965700
770	118	55	37	62		-0.5			542300	8963800
772	93	51	42	52		1.0			540500	8962300
773	87	47	35	50		-0.5			540000	8965100
774	79	53	30	43		1.0			539150	8965000
776	107	57	39	52		-0.5			539600	8964350
777	85	112	56	51		-0.5			536900	8965100
778	52	90	58	84		-0.5			537100	8965250
779	51	92	49	76		-0.5			537480	8965850
781	45	78	44	103		No sample			537550	8965875
783	52	99	60	87		-0.5			536800	8964600
784	44	102	42	77		3.0			525450	8970300
785	52	95	53	83		1.6			525400	8971000
786	60	73	50	92		-0.5			536500	8964600
787	92	68	56	66		0.6			526800	8970150
788	70	55	49	61		1.0			526600	8969800
789	25	58	46	60		2.0			525800	8969500
791	22	35	20	124		-0.5			524900	8971000
792	29	57	36	59		-0.5			524500	8971400
793	45	118	52	71		-0.5			521650	8969600
794	37	30	34	78		-0.5			523500	8968800
795	39	62	53	81		1.0			523600	8968600
796	46	100	46	82		1.0			524000	8968050
797	35	62	40	63		-0.5			536800	8964600
799	36	108	80	80		-0.5			562100	8918200
800	44	126	86	90		-0.5			562250	8918100
801	38	105	66	92		1.6			562700	8917700
802	36	80	61	83		-0.5			563300	8917300
803	69	165	118	100		2.0			578200	8920200
804	65	122	99	204	A	1.0			578200	8919900
805	53	91	84	96		1.0			574850	8917200
806	42	68	57	25		-0.5			574600	8917100
807	64	71	77	76		1.0			573600	8916900
808	42	105	60	86		1.0			573400	8916600
809	43	101	55	81		-0.5			573000	8916300
810	39	77	46	75		-0.5			572900	8915600
811	27	76	20	92		0.6			524875	8966280
812	34	82	34	102		1.0			524725	8966400
813	28	50	27	73		-0.5			524700	8966825
814	21	45	24	62		-0.5			524825	8967000
815	25	38	21	68		0.6			523950	8967000
816	60	70	26	57		1.6			523100	8967700
817	40	69	43	98		-0.5			533675	8962465

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070818	35	89	53	96		0.6			533730	8962630
819	41	85	51	100		-0.5			533175	8962390
820	36	82	34	96					533125	8962275
821	39	56	50	116		-0.5			532325	8962050
823	30	64	39	73					532675	8962525
824	33	74	41	82					533030	8963650
825	36	85	49	85					533125	8962430
843	32	115	113	124		-0.5			534050	8956400
845	26	147	63	96					533125	8955400
846	33	32	22	64		-0.5			532975	8955675
848	33	98	64	206	A	-0.5			534800	8955000
850	29	54	40	67		-0.5			529575	8956025
874	34	74	41	196	A	-0.5			532225	8959350
876	39	108	106	34		0.6			531550	8958800
877	25	34	28	47		-0.5			530680	8956925
878	30	64	49	49		-0.5			530600	8957900
879	24	71	50	42		-0.5			532000	8956000
881	32	137	76	91		1.6			534625	8954350
883	26	75	50	44		-0.5			534225	8954975
884	33	105	58	49		-0.5			534100	8955100
886	39	113	83	55		1.0			533300	8955425
888	20	53	48	105					559650	8919150
889	80	158	262	192	A	-0.5			575625	8922725
890	60	150	124	177	A	-0.5			576475	8923925
892	48	135	62	173	A				576500	8923775
894	48	69	68	90		-0.5			574650	8924375
896	47	106	53	55		-0.5			573500	8925925
898	37	66	72	82		-0.5			575125	8924650
900	52	77	62	147	A	-0.5			574600	8923500
914	25	37	31	78		-0.5			559475	8919775
951	54	129	21	100		-0.5			575450	8925025
953	52	159	88	81		-0.5			574625	8926850
955	50	152	90	79		-0.5			573675	8927300
957	20	20	29	48		-0.5			534150	8959975
959	36	109	51	90		-0.5			533600	8960080
960	36	110	63	69		-0.5			533350	8960225
961	45	145	90	83		-0.5			533150	8960350
962	40	100	60	89		-0.5			532825	8960310
963	27	122	64	44		-0.5			532450	8960750
965	36	112	52	69		-0.5			532250	8960725
966	26	121	55	63		1.0			531200	8959825
967	28	122	57	42		-0.5			531500	8959750
969	50	117	90	82		-0.5			533100	8959820
970	20	131	21	145	A	-0.5			534325	8959740
972	24	46	16	78		-0.5			534225	8959440
974	19	11	10	52		-0.5			534100	8959330

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64070976	46	36	56	112		-0.5			552425	8965125
978	40	54	27	65		-0.5			535975	8958975
1012	20	17	9	57		-0.5			535350	8956925
1015	30	90	41	62		-0.5			536250	8956350
1016	21	112	34	60		-0.5			536300	8956450
1018	28	100	44	69		-0.5			535525	8957025
1020	24	100	52	103		-0.5			535525	8957125
1022	116	25000	190	9350	A	90.0			535000	8958725
1023	46	23500	61	1650	A	54.0			535000	8958650
1024	13	178	65	120		4.0			535450	8959050
1025	26	143	48	78		-0.5			535425	8959125
1026	41	240	74	115	A	18.0			535400	8959200
1027	46	125	32	63		-0.5			535075	8959425
1028	24	126	60	99		-0.5			535000	8957225
1038	24	12	33	58		-0.5			537675	8956525
1051	49	45	17	58		-0.5			535850	8958800
1052	46	4880	61	1650	A	104.0			535350	8958700
1054	33	103	33	86		-0.5			535275	8958550
1056	49	109	31	64		-0.5			535350	8958400
1057	28	139	33	101		-0.5			535475	8958275
1059	30	79	36	78		-0.5			535450	8958000
1061	50	4160	60	3100	A	104.0			535375	8958000
1063	25	138	41	118		1.0			535225	8958025
1065	28	182	46	70	A	-0.5			535000	8957900
1067	32	79	33	101		-0.5			536450	8957600
1069	42	37	30	101		-0.5			536550	8956975
1070	30	68	36	90		-0.5			536200	8957150
1072	28	86	53	78		-0.5			536150	8957225
1075	32	130	67	101		-0.5			535950	8956525
1076	26	50	33	38		-0.5			534000	8959370
1078	31	35	11	56		-0.5			533375	8958750
1080	10	29	20	42		-0.5			533270	8958825
1082	39	28	10	63		-0.5			533125	8958940
1084	31	34	15	81		-0.5			532820	8958775
1086	30	29	11	70		-0.5			532720	8958800
1088	34	21	9	46		-0.5			532770	8959925
1090	27	61	43	66		-0.5			532350	8959850
1092	35	42	30	58		-0.5			532800	8958325
1094	36	120	71	56		1.0			532600	8959520
1096	20	72	47	16		-0.5			531825	8959550
1098	27	90	43	25		-0.5			531670	8959650
1100	32	75	49	59		-0.5			533999	8958725
1102	73	21	10	66		-0.5			533900	8958230
1103	79	96	82	216		-0.5			532950	8958180
1104	48	151	106	48		-0.5			532950	8957740

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Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64071105	25	44	14	85		-0.5			533260	8957530
1107	26	111	61	47		-0.5			533150	8957475
1109	31	112	59	41		-0.5			533300	8957050
1110	20	78	51	24		-0.5			533175	8956980
1112	36	89	68	35		-0.5			532900	8956780
1114	22	46	16	25		-0.5			532800	8956630
1116	40	85	64	52		-0.5			532700	8957000
1117	36	61	51	49		-0.5			532725	8957150
1118	32	57	55	52		-0.5			532850	8957420
1120	29	71	49	42		-0.5			533025	8957580
1122	28	95	26	78		-0.5			534200	8957050
1124	29	125	42	101		0.6			534350	8957025
1126	31	50	21	80		-0.5			534525	8957700
1128	26	70	41	87		4.0			534575	8957650
1129	23	19	7	44		-0.5			534500	8957500
1131	20	12	9	63		-0.5			534230	8957490
1132	24	43	16	80		-0.5			534250	8957680
1134	29	21	20	59		-0.5			534140	8957650
1136	25	25	10	57		-0.5			534750	8957650
1138	22	38	21	66		-0.5			534075	8958000
1140	31	99	47	77		1.0			534150	8958020
1142	28	38	20	82		-0.5			533775	8958670
1144	36	99	31	100		-0.5			533600	8958080
1146	30	79	36	59		0.6			534100	8958450
1148	30	113	50	70		-0.5			534175	8958350
1150	26	40	45	75		-0.5			534000	8957850
1151	15	500	22	73	A				535225	8957200
1152	32	132	65	91		0.6			534975	8957600
1153	25	144	66	96		0.6			535125	8957325
1155	22	25	16	46		0.5			535350	8957175
1156	30	66	47	90		0.6			536525	8956800
1158	30	112	57	79		-0.5			536525	8956750
1160	31	98	56	102		-0.5			536150	8956750
1162	24	30	17	70		-0.5			535650	8958650
1164	23	22	14	48		-0.5			536625	8958475
1166	24	43	40	85		-0.5			536250	8958600
1168	30	70	40	89		-0.5			536175	8958150
1170	19	100	36	81		-0.5			536350	8958175
1172	32	123	57	97		1.6			535075	8955400
1174	29	168	55	146		-0.5			535650	8957950
1176	34	135	82	115		0.6			535050	8954500
1177	38	140	83	68		-0.5			535050	8954600
1179	39	174	62	94		3.0			535025	8954750
1181	33	109	77	72		1.0			535175	8954850
1183	35	110	93	207	A	1.6			535100	8954900
1184	42	185	67	80	A	-0.5			534975	8953675

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64071186	46	188	66	81	A	0.6			535300	8953650
1188	46	132	83	116		-0.5			535250	8953575
1190	39	175	54	91					535150	8953525
1191	40	131	62	69		-0.5			535325	8953950
1193	30	62	31	71		1.0			535375	8954275
1195	29	113	37	69		-0.5		5	536100	8955175
1197	36	158	61	65		-0.5			535475	8954750
1199	30	80	56	76		-0.5			535425	8955575
1201	26	83	41	40		-0.5			531250	8957300
1203	31	70	40	55		-0.5			531425	8957360
1205	30	82	37	78		-0.5			531520	8957470
1207	15	51	24	21		-0.5			531340	8957800
1209	29	100	41	34		0.6			531540	8957720
1211	20	97	60	34		0.6			531450	8957750
1213	25	49	45	44		-0.5			531850	8957220
1215	32	55	39	55		-0.5			531870	8957320
1217	23	189	43	104	A	-0.5			531260	8957300
1219	26	88	42	55		-0.5			531375	8956975
1221	27	109	37	45		-0.5			521200	8956490
1223	26	90	15	41		-0.5			532125	8956425
1225	41	78	62	116		-0.5			530650	8957574
1226	20	59	47	22		1.0			531000	8957625
1228	30	93	71	51		0.6			532150	8958300
1230	62	82	61	68		-0.5			532190	8958200
1232	39	86	72	58		0.6			532200	8958180
1234	25	147	50	88		0.6			532080	8958000
1236	27	82	43	46					532250	8955930
1237	12	11	6	24		-0.5			532325	8956050
1239	15	19	14	31		-0.5			532300	8956100
1241	30	88	48	75		0.6			530950	8956000
1243	20	78	30	72		-0.5			531700	8956250
1245	35	117	50	68		-0.5			531700	8956350
1247	25	76	38	62					530600	8956050
1248	35	798	82	134	A	6.0		8	535830	8952225
1250	22	132	41	83		-0.5		3	536080	8952490
1252	22	174	60	26		-0.5		3	535925	8952675
1253	36	40	52	30		-0.5		3	535950	8952850
1256	33	74	33	42				3	535950	8953020
1257	35	126	72	103		-0.5		5	536080	8953075
1259	45	89	68	72		-0.5		3	536250	8953440
1261	29	97	30	94		-0.5		3	536175	8953575
1263	34	122	47	117				5	534775	8952000
1264	30	220	53	134	A	-0.5		5	535010	8952000
1266	46	217	54	135	A				535300	8952050
1267	35	73	41	83				5	535625	8951800

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64071268	30	132	40	78				5	535650	8951650
1269	25	215	61	114	A	-0.5		5	535900	8951600
1271	28	202	55	102	A	-0.5		3	534050	8951400
1272	30	261	48	102	A			5	536150	8951500
1273	18	150	51	113				5	536250	8951410
1274	40	168	50	92				5	536225	8951500
1275	20	105	49	96					536250	8950720
1276	33	106	54	91					536075	8950800
1277	41	119	50	90					562350	8922370
1278	21	129	38	112					562725	8921725
1279	34	112	61	56		0.6			562750	8921550
1281	29	82	48	53		-0.5			562300	8921350
1283	20	86	48	89		-0.5			556175	8919175
1284	19	62	42	62		-0.5			556625	8919450
1285	18	52	38	50		-0.5			556050	8919175
1286	18	82	49	73		-0.5			558100	8918200
1287	13	49	55	47		-0.5			556300	8919875
1288	23	164	47	90				10	536525	8951925
1289	21	240	61	113				5	535925	8951925
1290	24	n.d.	78	140	A	-0.5		3	536250	8951960
1292	35	136	57	334	A			3	536560	8952010
1293	29	180	61	102		-0.5		5	536600	8951920
1295	25	90	38	33					535060	8952840
1297	36	131	68	57		-0.5			535930	8952700
1298	24	87	39	33				3	537500	8952060
1299	13	60	16	51				3	537570	8952080
1300	31	67	93	79		-0.5		3	535910	8951830
1305	52	74	20	53					535000	8959450
1324	44	214	65	126	A	-0.5			535500	8955575
1325	26	80	38	83		-0.5			535725	8955400
1327	22	37	21	51		-0.5			535525	8955725
1329	22	68	60	78		-0.5			535400	8955925
1331	19	26	16	64		-0.5			535250	8955950
1333	40	159	105	130		2.0			534975	8955525
1334	20	77	32	75		-0.5			535075	8955650
1336	31	264	82	196		-0.5			534975	8955650
1337	26	335	69	316		-0.5			534900	8954850
1338	21	140	58	107					534825	8955700
1339	27	137	89	118		-0.5			534675	8955875
1340	26	360	85	200		-0.5			534675	8956000
1341	38	104	44	46		-0.5			533675	8955825
1343	32	140	60	51					533650	8955825
1344	38	39	16	36		-0.5			533425	8955950
1346	40	95	20	31		-0.5			533500	8956050
1348	32	122	41	32					533575	8956125

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64071349	32	113	51	74		-0.5			533750	8956300
1351	28	116	59	64					533675	8956300
1352	32	119	52	80		-0.5			546725	8936925
1353	45	204	69	77	A	1.0			546450	8936875
1354	32	84	46	44		0.6			538350	8957425
1356	35	66	36	58		0.5			528250	8957400
1358	44	90	56	65					529075	8955800
1359	26	79	55	80					529000	8956500
1360	50	132	80	76		3.0			528225	8953375
1362	43	119	74	75		-0.5			528300	8953550
1364	26	68	39	51					530775	8952925
1365	35	116	64	70		1.0			529950	8952075
1367	40	117	49	69		-0.5			533800	8953625
1369	21	55	25	33					533600	8953625
1370	34	63	42	34					533550	8953675
1371	26	90	40	36					533775	8954250
1372	44	170	72	110		-0.5			533525	8954700
1374	31	119	49	88					533750	8957250
1375	42	131	40	75		-0.5		3	536390	8954800
1377	24	48	17	49		-0.5		3	536350	8953790
1379	35	222	80	104	A	-0.5		5	536130	8952600
1381	45	168	80	118		-0.5		5	536550	8952640
1383	40	129	70	93		-0.5		3	536540	8952870
1385	25	58	21	43	A			50	536375	8952450
1386	28	225	52	45	A			5	535480	8952270
1387	33	216	52	39				3	535775	8952275
1388	25	264	55	152				5	535775	8952125
1389	29	128	56	107		-0.5		5	537040	8952080
1391	33	133	49	100				30	537290	8952160
1392	29	121	54	97		-0.5		5	537400	8952300
1394	25	104	41	85		-0.5		3	537400	8952200
1396	30	111	53	94		-0.5		3	537020	8952730
1398	30	94	55	107		-0.5		5	537260	8953000
1400	36	365	46	237	A	-0.5		8	537050	8953075
1401	29	36	30	30		-0.5		3	535600	8951500
1403	31	36	40	36		-0.5		5	535600	8951210
1406	31	173	58	104		-0.5			535080	8952790
1408	41	40	51	49		-0.5		3	535160	8951200
1410	23	135	52	111		-0.5			536950	8951725
1411	26	108	49	63		-0.5			537025	8951675
1412	30	160	88	106		-0.5			536950	8951250
1413	21	95	50	84		-0.5			537000	8951225
1414	11	40	18	36		-0.5			537125	8957175
1415	26	128	57	77		-0.5			537875	8950850
1416	25	91	57	93		-0.5			537625	8950900

Registered Number	Aqua regia soluble Co	Cu	Ni	Zn	Remarks	Citrate soluble Cu	Zn	As	Metric grid reference	
64071417	12	47	17	40		-0.5			537325	8951075
1418	47	100	142	80		-0.5			536975	8950025
1419	27	138	52	81		-0.5			537450	8950200
1420	40	100	60	54					532350	8953450
1421	40	93	55	57					532225	8953650
1422	25	98	49	38					532050	8954025
1424	37	105	61	53		-0.5			533475	8953275
1447	29	135	56	85		-0.5			533425	8954525
1449	36	92	63	79		-0.5			533275	8950625
1451	41	688	73	186	A	20.0			530250	8961525
1453	33	158	70	106		-0.5			530550	8961425
1454	31	139	69	111		1.6			530550	8961175
1455	33	99	51	64		0.6			530950	8961050
1456	21	90	30	229	A	-0.5			531025	8961050
1458	29	138	71	99		-0.5			531450	8960950
1459	23	100	62	96		1.0			530550	8960575
1460	38	116	69	78		-0.5			530650	8960250
1461	33	118	70	123		-0.5			530425	8960050
1462	51	140	117	111		0.6			530325	8960750
1463	41	122	69	67		0.6			530350	8960625
1464	44	147	98	102		1.0			530275	8960900
1465	23	87	59	36		1.6			530450	8960825
1466	39	55	42	53		-0.5			529775	8961050
1467	48	70	46	71		-0.5			529575	8960850
1469	36	250	63	115	A	0.6			529100	8960300
1470	44	118	76	63		3.0			529200	8960500
1488	44	118	82	55		3.0			530350	8958825
1489	25	112	87	81		2.0			530800	8959500
1490	38	86	81	66		2.0			530725	8959650
1491	37	113	76	76		2.0			530850	8959675
1492	33	147	74	68		1.0			530950	8958950
1493	39	140	91	49		1.6			530925	8958650
1494	20	65	47	48		1.0			530450	8958550
1495	47	135	60	105		0.6			530370	8959775
1496	46	199	91	85	A	-0.5			531975	8961025
1497	39	91	65	75		0.6			531475	8961200
1498	29	38	36	90		2.0			530325	8958300
1499	35	142	47	152	A	0.6			544450	8958325
1501	55	1350	79	406		21.6		25	536975	8952925
1502	26	114	47	106		0.5		3	537000	8953025
1507	39	109	69	82		0.6		5	537375	8953700
1508	26	73	32	71		1.0		3	536675	8954325
1510	27	122	48	115		-0.5		5	536550	8954600
1512	21	85	38	92		-0.5		5	536650	8954600
1514	30	152	45	86				3	536425	8954325
1516	34	162	62	145	A	-0.5		5	536550	8953800
1519	34	96	49	62		-0.5		3	536475	8953600
1520	29	112	74	96		2.0			531825	8951300

APPENDIX 2.

TRACE ELEMENT ANALYSES OF MAGNETIC MATERIAL FROM STREAMS IN PAPUA

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64070021	35	650	160	150	537500	8946050	
25	37	600	150	145	538200	8946250	
27	27	335	100	75	537300	8946350	
39	37	585	145	135	539300	8947050	
42	63	525	180	110	539950	8947500	
44	35	535	135	120	539650	8947900	
46	42	625	145	145	537900	8946250	
49	25	475	130	110	533670	8949700	
51	71	610	180	160	530370	8959470	
54	35	575	160	110	530100	8957750	
57	42	685	190	140	530100	8957750	
60	33	525	145	150	535200	8959490	
63	35	450	120	145	531180	8955480	
66	42	415	120	120	531180	8955180	
73	45	450	110	135	535550	8950530	
74	44	500	130	145	536700	8950250	
77	67	480	170	140	536750	8950100	
79	26	415	135	135	537550	8949900	
81	47	550	115	135	537500	8949750	
83	37	480	145	150	538450	8949350	
84	30	400	95	130	538550	8948700	
87	41	500	145	150	538400	8947850	
92	60	575	145	145	539750	8944650	
95	142	675	115	175	540150	8945100	A
98	87	525	140	150	541550	8946350	
111	70	435	170	165	541120	8942500	
115	33	540	130	125	542400	8942550	
117	36	450	165	135	543420	8943000	
119	42	575	160	130	543420	8943000	
121	40	620	160	145	541800	8941900	
123	71	470	140	165	540700	8944170	
125	130	420	215	200	541200	8944150	A
127	64	435	120	145	542200	8943780	
129	89	440	190	175	541350	8943400	
133	75	440	200	160	549570	8935650	
136	81	525	140	130	548600	8935650	
139	86	610	145	115	549100	8936140	
141	117	400	155	105	550060	8938010	
145	53	360	160	165	544450	8935600	
150	30	290	90	85	545800	8940450	
152	58	370	140	140	548450	8927775	
157	58	330	170	115	551325	8928775	

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64070159	60	330	170	190	551525	8929350	
160	36	490	110	145	553000	8931400	
161	90	420	195	175	553100	8933225	
163	126	345	200	165	552950	8933200	A
165	67	440	160	155	552475	8934700	
167	85	440	205	165	551325	8935225	
169	58	460	170	120	552025	8935475	
171	25	325	110	110	552200	8935375	
176	90	520	270	155	552075	8929725	
178	50	440	135	160	552075	8931625	
180	75	475	170	180	552425	8931775	
182	50	400	150	150	554625	8927825	
185	37	430	130	140	555275	8929650	
186	33	480	140	160	555100	8930225	
188	65	530	210	130	554675	8930500	
190	33	725	150	145	562225	8929575	
192	55	535	180	150	566550	8926600	
195	55	940	540	120	566350	8928625	
196	63	450	170	130	565750	8929050	
198	63	460	180	150	566425	8927875	
200	63	850	460	135	566725	8927925	
203	50	610	100	100	546000	8940450	
206	70	550	140	120	544350	8939000	
212	50	510	125	110	546200	8942000	
214	90	550	150	120	546400	8942000	
217	80	550	160	130	545450	8941300	
219	45	690	100	80	545300	8941050	
224	50	500	80	60	544450	8938150	
226	65	520	105	80	544950	8938400	
228	90	570	105	80	548550	8937500	
230	90	610	125	110	548900	8938250	
232	45	590	40	60	548580	8939750	
234	45	600	40	50	547100	8937900	
237	40	430	60	30	546750	8941400	
239	60	500	90	40	546700	8941500	
241	60	430	90	30	546550	8942500	
243	35	420	100	30	545050	8947000	
256	50	650	180	150	531225	8950900	
257	68	600	190	135	548325	8931100	
263	322	430	120	140	534325	8953250	
267	55	415	170	135	563750	8930325	
268	55	650	170	135	563450	8929725	
271	67	800	240	140	563400	8929175	
271	45	435	115	110	563300	8928825	
278	35	420	100	110	556000	8928000	
280	30	275	75	85	555850	8928175	
281	41	810	100	126	571475	8925600	

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64070288	62	810	141	130	570000	8929475	
292	37	700	121	128	530975	8957400	
294	350	725	98	140	534750	8953600	
298	90	480	112	122	534450	8953925	
300	100	645	210	190	534475	8954200	
302	60	510	150	40	541650	8945820	
304	35	500	60	35	541650	8945970	
306	50	710	90	40	543950	8945670	
314	50	1000	110	40	559850	8916330	
321	80	800	150	45	561950	8913950	
323	60	810	110	35	563000	8915300	
325	90	950	140	40	563500	8915000	
328	80	900	140	30	563150	8914430	
331	65	700	270	60	565930	8916750	
333	45	600	200	90	571800	8914450	
335	40	550	240	100	571200	8914300	
337	85	600	210	105	571030	8914750	
339	60	500	150	75	570500	8914750	
341	50	450	230	75	569120	8914450	
343	70	550	430	80	568250	8915600	
345	65	900	330	90	568130	8915450	
347	90	850	190	90	567000	8915730	
349	70	750	350	75	566850	8915470	
352	57	335	195	130	565280	8925700	
354	50	420	135	115	565250	8925875	
364	65	480	170	135	559600	8924620	
366	28	530	100	115	560150	8924575	
368	48	400	135	125	560800	8924350	
370	45	485	120	110	562950	8929775	
372	32	400	115	110	562225	8929950	
374	66	530	195	115	563840	8929975	
376	48	490	90	72	564310	8928920	
378	35	390	126	110	564525	8929170	
380	35	380	115	80	564275	8927600	
382	36	680	164	86	565470	5927170	
384	60	960	110	86	568030	8926650	
386	47	460	135	105	567725	8929680	
388	45	570	235	100	567525	8928370	
390	47	630	135	105	567700	8928500	
392	55	740	164	110	568350	8927280	
394	54	1140	135	86	568500	8927425	
396	53	770	115	75	567900	8926150	
399	25	540	95	107	567100	8924200	
412	120	600	450	110	574300	8915550	
414	60	850	302	60	570380	8920380	
422	70	400	90	120	569900	8917900	
425	50	400	80	80	568300	8918700	
428	50	450	90	80	568900	8917800	

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64070429	60	430	100	80	567300	8917650	
433	40	430	110	70	570500	8917600	
435	70	450	120	90	570600	8917500	
437	50	430	580	80	565500	8917550	
446	30	400	110	80	566670	8920730	
449	37	440	146	86	566550	8921100	
452	160	600	370	80	566800	8913700	A
454	50	500	370	70	566800	8913950	
456	80	550	600	90	568400	8913500	
458	60	650	400	80	568000	8913700	
460	70	520	600	80	567950	8913520	
463	80	650	180	90	569350	8914600	
466	70	570	350	100	569500	8914750	
469	58	560	155	130	576650	8913870	
472	55	640	170	135	575700	8914070	
477	42	420	124	86	561070	8927600	
478	55	550	115	95	560700	8922050	
484	62	530	150	105	561170	8922670	
486	43	500	100	80	561000	8923600	
488	42	420	120	75	561000	8923800	
493	36	490	176	110	557400	8923460	
495	55	490	146	105	566650	8925750	
497	60	480	164	112	565700	8925180	
499	57	390	152	110	565825	8925340	
501	25	410	132	86	566680	8921100	
503	21	510	75	80	566650	8920200	
505	66	800	210	120	566200	8920100	
509	100	460	90	72	563650	8919200	
513	77	880	176	125	562100	8918900	
514	60	620	126	91	562500	8918600	
520	25	485	92	102	562700	8923400	
523	360	560	130	105	561200	8930600	A
525	30	490	110	102	561100	8930450	A
527	53	530	130	102	562050	8930100	
529	12	580	85	62	581300	8924550	
531	32	530	130	62	581250	8924600	
533	69	1100	126	90	582100	8924000	
540	36	370	105	85	541250	8943000	
542	70	455	160	110	541500	8943300	
544	76	365	170	145	542000	8943650	
590	90	670	108	152	528850	8963175	
591	102	660	108	141	530700	8963000	
602	22	380	85	102	566910	8924300	
604	53	720	110	81	568550	8924300	
608	10	410	70	80	560670	8925450	
611	51	495	98	90	559500	5926500	
613	13	355	70	58	558300	8929660	
615	70	465	220	135	557730	8930125	

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64070617	61	495	167	115	557760	8930300	
619	60	380	167	105	557560	8930710	
621	16	495	110	110	557510	8930870	
623	12	300	80	81	558870	8930230	
625	42	455	175	120	558750	8929910	
627	22	495	98	115	559230	8929900	
629	17	340	105	73	559700	8928550	
631	24	420	118	90	559700	8928620	
633	34	425	125	95	558220	8925920	
639	20	375	78	68	558875	8926700	
641	34	405	145	122	559000	8926875	
644	30	470	140	110	562325	8926100	
645	34	690	140	105	562225	8926000	
648	24	380	112	90	560870	8925525	
650	41	690	200	120	561025	8926825	
652	34	540	150	125	564550	8925700	
654	38	575	138	110	564600	8925525	
656	36	390	130	80	564450	8924100	
658	18	410	85	80	564250	8925850	
660	24	490	104	95	564450	8924650	
662	25	415	118	95	564825	8924200	
664	24	500	98	95	562400	8924975	
666	42	460	150	125	562825	8925950	
668	30	455	150	105	562350	8926100	
670	30	505	125	105	562125	8926000	
672	21	430	110	90	562650	8925500	
674	23	370	104	95	562575	8924990	
676	25	420	100	95	562350	8923825	
680	65	540	121	152	571750	8927475	
682	44	450	100	150	571800	8927600	
684	41	890	102	118	571125	8929350	
686	46	356	92	120	574150	8930000	
688	41	460	78	138	574550	8929700	
690	74	460	121	145	574650	8929550	
692	46	330	92	128	575100	8928200	
696	62	410	100	128	575700	8930875	
698	70	410	138	120	575625	8931000	
700	55	410	112	130	576850	8930550	
702	55	1360	160	130	570000	8928900	
703	106	840	172	180	572800	8930325	
705	41	600	110	140	572850	8930475	
708	70	490	88	108	576350	8930575	
713	60	450	102	104	576050	8930875	
715	52	730	90	106	576425	8930625	
718	21	440	130	102	578725	8928525	
722	107	1160	130	144	578000	8924525	
727	49	375	156	126	577775	8928350	

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64070730	52	560	92	100	578600	8929500	
733	37	560	121	102	578725	8929825	
737	29	410	81	180	534525	8954425	
739	18	500	72	120	534525	8954725	
741	32	280	86	184	534300	8954850	
743	80	820	170	192	534350	8954975	
745	10	650	50	126	533550	8955475	
750	41	690	164	178	553525	8965025	
759	38	950	156	130	532200	8967750	
761	50	1160	98	124	532775	8967800	
769	31	750	60	74	540450	8963650	
771	31	810	64	72	542300	8963800	
775	55	565	100	78	539150	8965000	
780	40	151	86	88	537480	5965850	
782	40	540	86	80	537550	8965875	
790	65	432	132	138	525800	8969500	
798	92	324	156	118	536500	8964600	
826	35	440	64	120	523950	8967000	
827	41	324	64	98	524700	8966825	
844	80	394	240	110	534050	8956400	
847	8	550	35	100	532975	8955675	
849	12	1045	60	120	534800	8955000	
875	30	510	96	138	532225	8959350	
880	10	600	50	121	532000	8956000	
882	53	535	161	132	534625	8954350	
885	62	770	244	162	534100	8955100	
887	72	560	298	180	533800	8955425	
891	40	510	79	106	576475	8923925	
893	95	950	102	134	576500	8923775	
895	85	820	130	131	574650	8924375	
897	40	460	122	108	573500	8925925	
899	46	520	136	121	575125	8924650	
952	24	320	62	96	575450	8925025	
954	105	1200	138	131	574625	8926850	
956	105	800	130	120	573675	8927300	
958	18	145	71	111	534150	8959975	
964	68	850	500	241	532450	8960750	
968	96	500	298	220	531500	8959750	
971	24	515	60	120	534325	8959740	
973	10	230	64	111	534225	8959440	
975	0	217	22	72	534100	8959330	
(Mine977 Sample)	300	34	25	106	535725	8957425	
1013	15	1070	50	108	535350	8956925	
1014	84	740	93	121	536250	8956350	
1017	65	465	172	125	536300	8956450	
1019	65	1110	198	221	535525	8957025	
1021	20	525	50	92	535525	8957125	

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		As	Remarks
64071029	166	850	53	112	535000	8957225		A
1050	668	1220	58	120	535975	8958975		A
1053	143	880	63	121	535350	8958700		A
1055	171	800	60	122	535275	8958550		
1058	411	930	90	108	535475	8958275	5	
1060	206	830	124	130	535450	8958000	5	A
1062	2430	1780	99	128	535375	8958000	40	A
1064	71	680	124	128	535225	8958025		
1066	56	750	210	142	535000	8957900		
1068	92	605	118	125	536450	8957600		
1071	24	660	60	98	536200	8957150		
1073	24	650	59	102	536150	8957225		
1077	28	555	113	112	534000	8959370		
1079	22	570	68	139	533375	8958750		
1081	38	880	126	150	533270	8958825		
1083	16	750	38	130	533125	8958940		
1085	15	920	43	108	532820	8958775		
1087	20	870	60	110	532720	8958800		
1089	16	820	40	160	532770	8959925		
1091	27	800	71	108	532350	8959850		
1093	12	640	60	110	532800	8958325		
1095	44	550	139	176	532600	8959520		
1097	72	710	526	203	531825	8959550		
1099	76	680	500	240	531670	8959650		
1101	40	520	130	174	533999	8958725		
1106	13	630	40	96	533260	8957530		
1108	13	650	38	148	533150	8957475		
1111	88	490	303	210	533175	8956980		
1113	60	370	120	189	532900	8956780		
1115	43	470	101	189	532800	8956630		
1119	45	700	111	113	532850	8957420		
1121	43	480	100	162	533025	8957580		
1123	20	570	60	117	534200	8957050		
1125	65	520	51	105	534350	8957025		
1127	30	640	120	139	534525	8957700		
1130	26	560	123	145	534500	8457500		
1133	20	700	82	122	534250	8457680		
1135	12	730	24	94	534140	8957650		
1137	12	640	19	103	534750	8957650		
1139	16	520	40	99	534075	8958000		
1141	31	450	81	105	534150	8958020		
1143	16	570	39	103	533775	8958670		
1145	13	550	58	105	533600	8958080		
1147	31	480	93	110	534100	8958450		
1149	68	510	211	117	534175	8958350		
1154	28	520	80	99	535125	8957325		
1157	20	520	51	80	536525	8956800		

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64071159	11	750	31	78	536525	8956750	
1161	16	650	38	72	536150	8956750	
1163	10	590	22	97	535650	8958650	
1165	20	680	46	92	536625	8958475	
1167	28	330	70	97	536250	8958600	
1169	55	500	79	121	536175	8958150	
1171	25	500	78	112	536350	8958175	
1173	20	430	55	99	535975	8955400	
1175	24	500	51	99	535650	8957950	
1178	90	670	238	146	535050	8954600	
1180	51	780	232	151	535025	8954750	
1182	71	760	420	172	535175	8954850	
1185	82	540	102	112	534975	8953675	
1187	80	560	71	105	535300	8953650	
1189	51	640	113	103	535250	8953575	
1192	20	525	60	105	535325	8953950	
1194	24	570	98	132	535375	8954275	
1196	70	690	132	161	536100	8955175	
1198	44	525	152	108	535475	8954750	
1200	44	800	93	103	535425	8955575	
1202	15	580	53	112	531250	8957300	
1204	40	710	91	100	531425	8957360	
1206	38	840	141	139	531520	8957470	
1208	29	720	102	111	531340	8957580	
1210	76	700	370	118	531540	8957720	
1212	38	690	70	100	531450	8957750	
1216	43	730	78	105	531870	8957320	
1218	88	103	105	87	531260	8957300	
1220	50	720	105	100	531375	8956975	
1222	71	410	144	243	532120	8956490	
1224	44	490	77	162	532125	8956425	
1227	21	380	59	120	531000	8957625	
1229	44	440	155	128	532150	8958300	
1231	91	660	311	162	532190	8955200	
1233	59	810	228	141	532200	8958180	
1235	64	880	138	131	532080	8958000	
1238	10	590	25	120	532325	8956050	
1240	10	550	25	120	532300	8956100	
1242	43	370	133	218	530950	8956000	
1244	77	940	114	170	531700	8956250	
1246	48	470	118	220	531700	8956350	
1249	1082	720	70	100	535830	8952225	
1251	43	540	105	151	536080	8952490	
1254	27	240	82	120	535950	8952850	
1255	40	340	94	120	535950	8953020	
1258	79	830	167	128	536080	8953075	
1260	37	520	132	138	536250	8953440	

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		As	Remarks
64071262	22	460	30	105	536175	8943575		
1265	106	480	105	120	535010	8952000		
1270	48	500	86	120	535900	8951600		
1280	59	730	144	151	562750	8921550		
1282	63	740	133	151	562300	8921350		
1291	55	670	98	131	536250	8951960		
1294	51	650	93	140	536600	8951920		
1296	71	460	164	131	535930	8952700		
1302	24	530	59	208	535000	8959450		
1326	22	500	48	140	535725	8955400		
1328	16	400	52	120	535525	8955725		
1330	10	250	28	100	535400	8955925		
1332	12	390	28	100	535250	8955950		
1335	60	370	32	120	535075	8955650		
1342	47	360	74	232	533675	8955825		
1345	29	390	70	220	533425	8955950		
1347	50	470	80	258	533500	8956050		
1350	71	750	405	199	533750	8956300		
1355	64	880	138	160	528350	8957425		
1357	31	660	57	131	528250	8957400		
1361	64	650	75	131	528225	8953375		
1363	29	730	60	140	528300	8953550		
1366	88	570	86	128	529950	8952075		
1368	58	480	62	81	533800	8953625		
1373	75	480	120	92	533525	8954700		
1376	50	570	151	146	536390	8954800		
1378	23	490	108	126	536350	8953790		
1380	111	940	144	122	536130	8952600		
1382	72	910	142	140	536550	8952640		
1384	68	850	132	132	536540	8952870		
1390	48	770	98	120	537040	8952080		
1393	34	450	87	120	537400	8952300		
1395	21	340	62	102	537400	8952200		
1397	47	1000	87	120	537020	8952730		
1399	45	1070	91	124	537260	8953000		
1402	31	390	108	120	535600	8951500		
1404	20	275	71	120	535600	8951210		
1405	1355	890	98	98	535060	8952840	5	A
1407	382	470	132	98	535080	8952790	15	A
1409	47	178	102	78	535160	8951200		
1425	25	420	60	119	533475	8953275		
1446	55	370	98	95	533650	8954600		
1448	56	430	81	100	533425	8954525		
1450	52	360	72	140	533275	8950625		
1452	870	1470	83	172	530250	8961525	5	A
1457	63	930	76	124	531450	8960950		
1463	21	580	57	120	529575	8960850		
1471	23	530	58	120	529425	8960525		

Registered Number	Cu	Zn	Ni	Co	Metric grid reference		Remarks
64071504	48	420	80	140	537220	8953810	
1506	20	300	70	114	537330	8953830	
1509	23	400	60	115	536675	8954325	
1511	35	360	74	120	536550	8954600	
1513	34	350	71	120	536650	8954600	
1515	21	370	120	110	536425	8954325	
1517	40	430	60	102	536550	8953800	
1518	47	480	111	120	536475	8953600	
1521	60	440	120	111	536225	8951500	
1522	46	410	86	122	535925	8951925	
1523	41	342	88	118	536560	8952010	
1524	80	535	192	123	535060	8952840	
1525	96	610	192	152	537500	8952060	
1527	49	380	90	142	535000	8959450	
1528	53	450	95	142	530775	8952925	
1529	61	440	125	117	533600	8953625	
1530	57	850	158	130	533550	8953875	
1531	40	335	81	108	537000	8951225	
1532	70	710	130	134	537125	8957175	
1533	96	750	135	134	537875	8950850	
1534	58	530	100	121	537625	8950900	
1535	102	770	130	120	537325	8951075	
1536	102	900	120	121	537458	8950200	
1537	98	960	120	120	531450	8960950	
1538	96	740	376	163	529775	8961050	
1539	78	650	212	141	530350	8958825	
1540	91	1050	200	134	530850	8959675	
1541	94	900	116	121	530450	8958550	
1542	96	560	202	134	530370	8959375	
1545	101	600	362	146	533650	8955825	
1546	104	310	123	140	533575	8956125	
1547	94	560	342	148	533675	8956300	
1549	28	340	111	112	532350	8953450	
1550	58	530	126	105	532225	8953650	
1551	59	680	148	126	532050	8954025	
1552	53	580	41	78	524875	8966280	
1553	55	530	59	88	524725	8966400	
1554	62	420	120	120	524700	8966825	
1555	43	290	50	85	524825	8967000	
1556	31	320	46	88	523950	8967000	
1557	57	310	40	122	523100	8967700	
1558	151	530	120	122	533030	8963650	A
1559	119	500	102	160	533125	8962430	
1560	67	480	60	83	533125	8955400	
1561	81	990	143	122	535225	8957200	
1562	80	860	140	117	535150	8953525	
1563	118	680	222	126	532250	8955930	
1564	100	380	123	94	530600	8956050	
1565	62	330	110	88	535950	8953020	
1566	88	520	228	158	535650	8951650	

APPENDIX 3

TRACE ELEMENT ANALYSES OF MAGNETITE EXTRACTED FROM ORES AND MINE DUMPS

Registered Number	Metric Grid Reference		Cu	Zn	Ni	Co	As	Mine
64070259	534950	8953325	110	450	210	110	n.d.	Dubuna
260	530150	8961400	452	3000	190	115	40	Hector
262	534950	8953325	860	330	260	90	n.d.	Dubuna
977	535725	8957425	300	34	25	106	n.d.	Laloki

APPENDIX 4

TRACE ELEMENT ANALYSES* OF BASIC ROCKS AND SEPARATED MAGNETITE

Reg. No. e.g., 264/61 = Total rock (264) separated magnetite (261)

			Total Rock				Magnetite			
Reg. No.	Grid Reference		Cu	Zn	Ni	Co	Cu	Zn	Ni	Co
0264/61	533450	8960100	105	30	20	25				
0828	532980	8957080								
0829/30	533600	8957120	12	35	6	21	19	241	46	106
0832/31	534230	8957580	6	52	3	13	7	156	25	58
0833/34	533550	8956370	6	4	1	5	4	88	84	30
0835/36	535790	8954300	6	35	3	10	10	111	25	50
0837/38	524980	8967880	84	58	15	21	54	263	92	132
0839/40	535800	8954360	22	75	8	21	25	255	45	95
0841/42	535000	8954000	137	45	28	25	334	289	200	105
0865/66	559190	8926000	221	55	28	27				
0867/68	534610	8958500	10	68	7	32				
0869/70	534670	8958630	20	66	7	32				
0871	535740	8951670								
0873	560975	8924750								
0901/04	582250	8924200	6	46	3	21	14	103	200	52
0902/03	577800	8919950	138	82	10	25	172	220	760	75
0905/06	534200	8964000	68	84	15	21				
0907/08	533600	8964100	70	46	10	21	45	310	186	112
0910/09	533500	8964300	123	50	12	21	95	253	298	102
0912/11	532150	8966600	147	56	20	32	160	300	436	200
0913	560800	8926800								
0915	584275	8923950								
0916/17	561000	8925775					58	110	108	70
0918/50	564550	8925500					162	720	212	92
0919/20	562825	8924200					110	240	84	60
0921	563700	8924575								
0922/23	557125	8925900					180	299	76	58

4383/66.—8

			Total Rock				Magnetite			
Reg. No.	Grid Reference		Cu	Zn	Ni	Co	Cu	Zn	Ni	Co
0924/25	561075	8924100					112	620	94	60
0926/27	572925	8930525					73	900	226	112
0928/29	559225	8926550					19	360	40	100
0930/31	567525	8928370					32	930	50	64
0932/33	578950	8924875					81	870	240	90
0934/35	562575	8924990					105	540	311	140
0936/37	561825	8922875					266	580	308	130
0938/39	562300	8923625					85	700	100	119
0940/41	557900	8927000					20	195	80	106
0942/43	533650	8959650					7	191	38	88
0944/45	578300	8919550					66	560	95	185
0946/47	572950	8914200					103	66	88	166
0948/49	533700	8959425					78	560	95	180
1003	575350	8925650								
1004	570300	8913700								
1005	573900	8924175								
1006	568650	8915125								
1030	570700	8914950								
1032/31	575425	8923025	180	75	26	27	102	990	122	134
1034/33	569550	8915475	115	61	22	21	143	910	100	165
1036/35	531650	8959890								
1039/09	535225	8958225	246	87	10	35	1145	384	200	132
1040/10	535325	8958925	389	36	13	11	24	103	38	41
1041/01	573075	8926800	89	58	10	21	84	412	176	120
1042/07	532600	8960400	18	25	16	11	77	140	96	82
1043	569050	8914275								
1044/08	533750	8959530	213	56	50	32	70	246	122	88
1045	572350	8926150								
1046	568475	8916050								
1047	573750	8927000								
1048	570300	8913700	19	39	15	19	67	336	108	120
1049/02	575150	8922175					137	1750	81	89
1074/37	535575	8958825								
1301/03	534000	8958250					20	93	40	41
1304/06	535300	8957100					27	246	52	72
1307/08	533775	8957165					41	254	50	82
1309/10	532770	8958240					49	360	100	105
1311/12	533650	8957175					107	225	134	74
1314	533075	8957900								
1315/16	535450	8957100								
1317/13	532750	8957125					30	222	46	92
1318/19	535925	8957650					76	336	40	92
1321/20	535225	8957200					61	600	60	160

*Analyses in parts per million

APPENDIX 5

TRACE ELEMENT ANALYSES OF SEDIMENTARY ROCK SAMPLES

Registered Number	Metric Grid Reference		Cu	Zn	Ni	Co	Pb	Formation
64071709	539950	8963775	19	38	25	5	-25*	Port Moresby Beds
1710	536075	8953125	4	38	66	8	-25	" "
1711	552150	8923650	10	40	17	-3	-25	" "
1712	528700	8953825	10	117	28	3	-25	" "
1713	561700	8920600	25	41	25	-3	-25	" "
1715	553250	8920800	8	19	10	-3	-25	" "
1716	561700	8920600	15	40	28	3	-25	" "
1717	572500	8914700	40	61	17	9	-25	Kwikila Agglomerate
1718	530375	8054750	13	93	28	3	-25	Port Moresby Beds
1719	535725	8944975	11	16	6	-3	-25	" "
1720	535625	8957450	38	41	54	5	-25	" "
1721	543175	893600	8	4	4	-3	-25	" "
1722	530625	8950200	28	25	17	-3	-25	" "
1723	534625	8951200	78	27	20	6	-25	Dokuna Tuff
1724	540250	8936450	14	19	25	5	25	Port Moresby Beds
1725	559425	8914950	65	32	27	-3	-25	" "
1726	533075	8959325	6	3	14	5	37	" "
1727	536525	8954250	59	73	50	7	-25	" "
1728	532525	8950475	6	11	16	-3	-25	Bootless Inlet Limestone

*'-25' means 'less than 25 ppm'

APPENDIX 6

TRACE ELEMENT ANALYSES OF GOSSAN SAMPLES

Registered Number	Metric Grid Reference		Cu	Zn	Ni	Co	As	Pb	Remarks
64070851	534950	8947950	6400	130	42	46	333	n.d.	
0852	535000	8946500	92	40	25	15	10	"	
0853	536125	8949100	2500	400	104	60	25	"	
0854	536400	8947350	200	50	212	65	2000	"	
0855	539850	8946350	34	80	25	7	8	"	
0856	561450	8924400	1700	60	42	55	60	"	
0857	561450	8924400	29800	100	60	65	5	"	Visible copper carbonates

Registered Number	Metric Grid Reference		Cu	Zn	Ni	Co	As	Pb	Remarks
0858	561700	8919825	1000	25	20	15	n.d.	n.d.	
0859	561550	8920250	2550	250	108	90	n.d.	"	
0860	559050	8926350	9300	170	50	50	50	"	
0861	560000	8925750	1200	3040	70	57	10.	"	
0862	560300	8925525	67	55	70	22	n.d.	"	
0863	560600	8925500	1040	2800	34	105	1250	"	
0864	559300	8926300	n.d.	n.d.	n.d.	n.d.	2500	"	
1651	533225	8960550	800	740	46	40	375	"	
1652	559370	8926570	1465	680	23	31	3750	"	
1653	534460	8948840	735	114	43	17	250	"	
1654	534200	8959750	560	740	34	31	5	"	
1655	535050	8952400	8800	210	110	660	20	"	
1656	564300	8928900	1040	108	38	40	20	"	
1657	536025	8950950	100,000	850	241	1105	5	"	Chalcopyrite
1658	537070	8952820	2060	220	24	34	75	"	in specimen
1659	530400	8957660	930	48	26	12	30	"	
1660	536925	8952875	850	104	14	17	50	"	
1661	566900	8916750	2990	390	51	39	n.d.	"	
1662	566900	8916750	1240	320	40	26	10	"	
1663	536175	8951675	203	26	10	5	30	"	
1664	533910	8958050	n.d.	n.d.	n.d.	n.d.	1000	"	
1665	536700	8945675	38	16	21	8	10	"	
1666	530440	8954800	6300	1890	36	17	8	"	
1667	564325	8927925	2270	98	51	75	250	"	
1668	561625	8920310	1380	150	75	23	n.d.		
1669	561625	8920310	525	145	55	13	"	343	)From
1670	561625	8920310	2060	260	63	23	"	455	)bulldozed
1671	561625	8930310	2380	295	78	45	"	745	)costeans
1672	532075	8951500	210	59	66	14	"	-25*	
1673	560810	8924130	130	73	55	3	"	25	
1674	563225	8915670	10	11	20	-3	"	25	Manganiferous
1675	536860	8945770	288	25	15	9	"	-25	"
1676	560330	8924400	2100	46	42	15	"	-25	"

*'-25' means 'less than 25 ppm'

APPENDIX 7

DESCRIPTIONS OF ORE SPECIMENS

by

I.R. PONTIFEX

Dubina Mine, Reg. No. 64071701 (Pl.6, fig. 1)

Minerals identified: Major pyrite, marcasite; minor chalcopyrite, sphalerite, galena, hematite, calcite.

Hand-specimen: A massive ore consisting mainly of pyrite and marcasite; in some parts of the specimen these form undulating scalloped bands. Minor sphalerite and chalcopyrite. Calcite is the only gangue and calcite crystals crowd together in voids within the ore.

Polished section: Pyrite-marcasite 85%, sphalerite 10%, chalcopyrite 3%, galena 2%, hematite 1%.

Most of the iron sulphides are marcasite, but in some aggregates and grains this grades imperceptibly into pyrite. These minerals generally occur in irregular aggregates as small euhedral and subhedral grains, fairly uniform (average of 0.3mm across); they are generally not fractured.

Within the aggregates the iron sulphides occur in a variety of forms:

a. Adjacent to the calcite gangue layers of subhedral grains form folded scalloped bands up to 2mm wide and 7mm long. Some bands grade progressively from fine to relatively coarse-grained layers. The outer layers nearest the gangue are generally marcasite.

b. Granular chain-like bands of euhedral pyrite and marcasite grains enclose and partly enclose chalcopyrite, sphalerite, and galena. Some marcasite rims around chalcopyrite are intimately intergrown with sphalerite.

c. Granular strings of pyrite and marcasite intimately follow crystal planes in some lenses of calcite gangue.

d. Colloform-like bands of granular pyrite are commonly intergrown with poorly developed bands of sphalerite.

e. In some places, concentric spongy bands of granular pyrite form spheroids up to 2mm in diameter.

Pyrite and marcasite also occur as single euhedral and subhedral grains in the calcite gangue.

The other sulphides are randomly distributed.

Sphalerite forms irregular masses within pyrite aggregates, in the calcite gangue and intercalated with iron-sulphide bands. The masses have an average size of about 0.3mm and a maximum size of about 2mm. Some sphalerite encloses and intrudes pyrite, chalcopyrite, and galena; it is itself enclosed by pyrite and less frequently by galena and chalcopyrite.

Much of the sphalerite contains small amounts of chalcopyrite inclusions, irregular in shape and distribution. Some of the inclusions appear to be an emulsion-textured exsolution type, but most occur in anastomosing vein-like and fine graphic intergrowths in the host. Chalcopyrite also occurs as discrete grains in the gangue and in the pyrite matrix. In some places fine rods of chalcopyrite are oriented along the crystal planes of calcite.

Galena typically forms subhedral grains and allotriomorphic masses; these have an average size of 0.15mm and most commonly fill spaces within granular pyrite and enclose small pyrite grains. Some galena crystals are partly replaced and cut by veins of granular pyrite-marcasite. Galena forms composite grains with sphalerite and chalcopyrite and commonly encloses grains of both.

Calcite fills intergranular spaces, fractures, and other voids within the ore-mineral aggregate. The calcite carries single grains of the sulphide minerals and also minor amounts of specular hematite.

Elvina Mine, Reg. No. 64071702

Minerals identified: Pyrite, sphalerite, chalcopyrite, quartz.

Hand-specimen: A grey, extremely fine-grained siliceous rock which contains irregular patches and veins of finely granular pyrite.

Thin section: The matrix surrounding the opaque minerals consists of a micromosaic of cryptocrystalline quartz with accessory amounts (2%) of clay particles. Individual quartz grains have a spherulitic extinction under crossed nicols, suggesting that the siliceous material is chert. The chert grades away from the opaque mineral boundary zone into a dirty cryptocrystalline matrix of quartz.

Cavities within the ore mineral aggregate are lined and filled with cryptocrystalline quartz which has a minutely fibrous fan-shaped structure and a spherulitic extinction. These features are characteristic of chalcedony.

Polished section: Pyrite is the predominant ore mineral; it occurs in veins and breccia fragments which form irregular masses. In the veins the pyrite forms euhedral and subhedral grains, many of which are brecciated. Minor sphalerite and chalcopyrite grains occur in voids within the pyrite aggregates and also the veins. Marcasite was not recognized.

Elvina Mine, Reg. No. 64071703

Minerals identified: Major pyrite, marcasite, hematite. Minor chalcopyrite, sphalerite, galena, ?cubanite, calcite, goethite.

Hand-specimen: A massive brecciated ore containing pyrite, chalcopyrite, and minor sphalerite. Calcite occurs in stringers, veins, and patches between the ore minerals. Part of the specimen consists of multiple roughly conformable fine scalloped layers of intercalated pyrite, calcite, and sphalerite. These appear to be successive wave fronts conformable with the contact of sulphides and calcite gangue. Veins of calcite cut through ore minerals and also through patches of crystalline calcite.

Polished sections: 64071703A: On a macroscale this section shows fine interlayering of scalloped chains of granular pyrite, partly enclosing masses of chalcopyrite.

Pyrite is severely brecciated and pulverized; most of it is granular and typically it is intimately intergrown with marcasite. Interstices are filled with calcite, hematite, and chalcopyrite. Hematite occurs in a variety of forms: (a) as small spheroidal bodies in calcite, partly replaced by a rim of hydrated iron oxide; (b) as irregular masses, and less commonly spheroidal bodies, filling interstices in pyrite aggregates; (c) as narrow zones of inclusions in some pyrite, conformable with the external shape of the host grain, and surrounding subhedral pyrite grains in calcite; (d) as small curved shells in calcite, which may be remnants of spheres of hematite; (e) as rods and stringers along intercrystal contacts of calcite.

Granular rims of pyrite commonly surround hematite.

Chalcopyrite occurs in irregular spongy masses in the pyrite aggregates; commonly it forms a reticulated intergrowth with pyrite, which suggests that chalcopyrite is invading and replacing pyrite. Some of these zones have differentiated into poorly defined bands of different concentrations of the two minerals. Single grains of chalcopyrite occur in the calcite gangue. Chalcopyrite grains are moderately fractured, but not as severely as pyrite. Some consist of a skeletal framework, which suggests that the original crystal has been extensively leached.

Small blebs (0.005mm) of chalcopyrite and a pink-brown mineral occur in some coarse-grained pyrite. The pink-brown mineral is most probably cubanite.

No sphalerite is present.

64071703B: Most of this section consists of fine-grained pyrite in rather spongy aggregates. Individual grains are commonly subhedral; most are fractured; they are partly made over to marcasite and typically form poorly defined curved zones. Chains of subhedral pyrite crystals which occur through the matrix and cut the spongy masses appear to be recrystallized. A straight vein of severely fractured anhedral coarse-grained pyrite cuts through the section. The grains appear to have been pulverized by being forced together.

Calcite fills most voids in the rock and cements fragments of pyrite.

Chalcopyrite forms porous masses mainly in the calcite gangue, in cavities between euhedral pyrite-marcasite crystals.

Sphalerite associated with minor chalcopyrite occurs along the edge of the coarse pyrite vein. Veins of calcite through the pyrite aggregate carry chalcopyrite and pyrite grains.

64071703C: The scalloped bands seen in the hand specimen are made up of granular pyrite and marcasite. Marcasite is much more abundant than in sections A & B; it commonly forms the margins of iron sulphides and grades imperceptibly into a core of pyrite. Some grains consist entirely of marcasite. Typically, alternate bands of marcasite and pyrite make up grains which surround pockets of calcite; the marcasite under crossed nicols is seen to form oriented crystals radiating in a fan from the calcite contact.

It appears that where the carbonate gangue makes contact with pyrite the pyrite has been made over to marcasite. The alternate compositional banding suggests a fluctuation of conditions of crystallization of the iron sulphides.

Fine bands of sphalerite and galena commonly occur with the pyrite banding, adjacent to, or one or two bands removed from, some calcite-filled cavities. The galena forms euhedral and subhedral crystals 0.5mm across, fractured and cut by calcite crystals.

Chalcopyrite occurs as small masses, associated with calcite and enclosed in pyrite.

Sapphire Mine, Reg. No. 64071704

Minerals identified: Major pyrite, chalcopyrite, chlorite; minor sphalerite, hydrated iron oxides.

Hand-specimen: A massive ore which consists mainly of iron sulphides and chalcopyrite.

Polished section: The specimen consists mainly of irregular masses of chalcopyrite which contain sporadic granular pyrite aggregates, veins of granular pyrite, minor sphalerite, and hydrated iron oxides.

Chalcopyrite generally has a leached or corroded texture and in many grains zones of various degrees of leaching have formed parallel to the grain boundaries. Small (0.08mm) spherical bodies consisting of anastomosing sphalerite blebs are scattered through most of the chalcopyrite; their position is controlled by the crystal structure of the chalcopyrite. Chalcopyrite masses are extensively veined and their edges are commonly rimmed by reticulated intergrowth of granular pyrite. The pyrite generally grades imperceptibly into marcasite, which is the major iron sulphide in many veins. Chalcopyrite also enclosed grains of quartz with pyrite inclusions. Veins of granular pyrite cut all three of these components.

Voids between the chalcopyrite are filled with skeletal masses and fibrous aggregates of hydrated iron oxides (limonite). Limonite encloses and partly encloses grains of pyrite and chalcopyrite; it does not appear to be derived from them since the contact is sharply defined and much of the pyrite has a sharp euhedral outline.

Some cavities in the specimen are filled with extremely fine-grained aggregates of randomly oriented chlorite flakes. The mineral could not be identified but is probably leuchtenbergite (clino-chlorite). It is not glauconite or antigorite.

These patches of chlorite make up about 15% of the section; they are commonly rimmed and stained by limonite. Minor amounts of brucite also fill some small voids in this specimen.

Mount Diamond, Reg. No. 64071705

Minerals identified: Pyrite, chalcopyrite.

Hand-specimen: A dark grey extremely fine-grained siliceous rock which contains narrow leached cavities more or less parallel to poorly defined banding. Fine-grained pyrite is disseminated through the siliceous matrix. Narrow bands of quartz give rise to small veins which cut across the ?bedding.

Thin section: A micromosaic of cryptocrystalline quartz which contains fairly evenly distributed fine opaque grains. Under crossed nicols most of the quartz grains in the matrix show spherulitic extinction, which is characteristic of chalcedony and chert. Several thin fracture-fill veins of crystalline quartz are randomly distributed through the rock. Isolated patches of medium-grained allotriomorphic quartz aggregates incorporate minor amounts of interstitial clay. In some areas, quartz grains which show a minutely fibrous texture are arranged in spherulitic aggregates. Some chains of quartz form colloform bands.

The rock is essentially chalcedony. The patches of siltstone may have been incorporated while the chalcedony was forming or they may represent the original rock which has been replaced by chalcedonic silica.

Polished section: Fine-grained pyrite is ubiquitous; individual grains generally are subhedral and their average size is 0.04mm. The distribution of the grains appear to be unrelated to the banding in the chert or to the quartz veins. A few chalcopyrite grains are disseminated through the rock at random. They make up about 2% of the section.

Mount Diamond, Reg. No. 64071706

Minerals identified: Major pyrite; minor sphalerite, chalcopyrite, ?enargite.

Hand-specimen: A massive sulphide ore, mainly fine-grained pyrite. Most of the pyrite is concentrated in poorly defined disjointed granular bands which are intercalated with ill-defined discontinuous bands of non-carbonate gangue.

Polished section: Most of the pyrite occurs as moderately euhedral grains with an average size of about 0.12mm. The coarse grains seem to have a random distribution in aggregates; the fine grains form short disjointed bands. Coarse euhedral grains are commonly enclosed by a spongy rim of pyrite, with a sharp or diffuse contact. This zoning may be primary or a recrystallization, corrosion, or leaching effect. Some coarse euhedral pyrite carries bleb-like inclusions of sphalerite and rarely chalcopyrite; commonly they are concentrated in zones parallel to the edges of the host crystal. Pyrite also contains a few anisotropic brown-grey inclusions, too small and rare to be identified; they are most probably enargite. Irregular patches of chalcopyrite and sphalerite occur in voids in pyrite aggregates; commonly these partly envelop some pyrite crystals. Much of the chalcopyrite contains bleb-like inclusions of sphalerite. Sphalerite is typically peppered with pyrite and minor chalcopyrite blebs.

Laloki, Reg. No. 64071707 (Pl.4, fig.2; Pl.5, fig.2)

Minerals identified: Major pyrite-marcasite, chalcopyrite; minor sphalerite, galena, gold.

Hand-specimen: A massive ore consisting of almost equal amounts of chalcopyrite and pyrite with minor sphalerite. In some parts of the specimen these minerals form contorted disjointed bands up to 1cm wide. Other parts are massive and show no banding.

Polished section: The pyrite generally occurs as grains averaging about 0.015mm, many of which are partly made over to marcasite. The grains are subhedral or less commonly euhedral or spheroidal. The fine-grained pyrite is generally concentrated in patches and discontinuous bands which may fill voids within chalcopyrite masses. Relatively coarse-grained euhedral pyrite is associated with the chalcopyrite and sphalerite intergrowths, and contains bleb-like inclusions of sphalerite. The pyrite is typically fractured.

The spheroidal pyrite occurs most commonly in the less fine-grained aggregates and bands, and also in the gangue between the other sulphide minerals. The spheroidal pyrite grains are rounded or irregular; within the grain there are one or more concentric inner shells of pyrite and what appears to be a siliceous material. In some the presence of concentric cavities suggests that the original material has been removed. Some spheroidal pyrite has a radial structure made up of intergrowths of pyrite and siliceous material; in some, sphalerite blebs are arranged concentrically and radially. Grains consisting of 2 to 5 spheroids were apparently joined early in their development to form one grain. Several anhedral pyrite grains contain incomplete relic spheroidal forms.

Admixed chalcopyrite and sphalerite enclose spheroidal pyrite. Chalcopyrite occurs in large botryoidal, subhedral, and some brecciated masses in which it is intimately associated with sphalerite and accessory amounts of galena. Close to cavities filled with barytes, sphalerite forms rims around coarse subhedral chalcopyrite which is almost free of inclusions. The outer margin of the sphalerite rim is typically botryoidal. In other areas, where the minerals are more crowded, sphalerite also forms complex graphic and dendritic intergrowths with chalcopyrite. The intergrowths commonly have a scalloped colloform type of banding which form a cockade texture in some grains. These textures appear to have derived by the segregation of sphalerite and chalcopyrite from an amorphous homogeneous mixture of copper and zinc sulphides, in some places containing minor lead sulphide.

Amorphous-looking masses in which sphalerite is the most abundant component are riddled by extremely fine anastomosing veinlets and blebs of chalcopyrite. These have a random distribution and they give the sphalerite a brassy veneer.

In less segregated grains chalcopyrite shows the beginnings of a crystalline form and sphalerite forms banded, colloform, and emulsion-type inclusions within it. The density of these varies and appears to depend on the extent to which the two minerals have segregated from their original state.

The various types of intergrowths and the extent of segregation are differentiated more or less into zones, which impart a poorly defined macroscale banding to the specimen. In some parts these bands are intercalated with bands of pyrite aggregate; in others all the sulphide minerals form complex aggregates with no discernible differentiation.

Small masses of sphalerite which are unrelated to admixed chalcopyrite commonly carry inclusions of anhedral chalcopyrite grains, spheroidal pyrite, and minor amounts of galena. Botryoidal banding occurs in some free grains of sphalerite in the carbonate gangue.

One grain of gold 0.02mm across was observed in chalcopyrite, one 0.003mm across in sphalerite, and one 0.006mm across in the barytes gangue between spheroids of pyrite.

Voids between and within the ore minerals are filled by barytes and less commonly chalcedonic silica. The barytes occurs in aggregates of medium-sized tabular crystals; the silica is minutely crystalline, subtranslucent, and variegated by fine scalloped bands which are roughly conformable to the shape of the cavity. Both minerals may occur in the same void, and rarely fine veins of barytes cut through the silica.

Laloki, Reg. No. 64071708

Minerals identified: Major pyrite, chalcopyrite, sphalerite; minor galena, gold.

Hand-specimen: A massive ore of chalcopyrite, pyrite, and sphalerite. Banding is better developed than in any other specimen examined. The banding consists of more or less conformable bands of chalcopyrite (up to 5mm wide), fine-grained pyrite (up to 2mm wide), sphalerite (up to 3mm wide), round a core of barytes.

Polished section: Associations, textures, and structures are similar to those described in 64071707. Folds within the ore are made up of a fairly consistent sequence of mineral bands which occur in the following order, outwards from the core of the fold:

a. Cores of folds commonly consist of barytes.

b. The inner band consists of coarse subhedral grains of chalcopyrite rimmed by sphalerite. The sphalerite is commonly crustiform and its contact with barytes is typically botryoidal or a reticulated intergrowth zone.

c. Band (b) grades imperceptibly outwards into a zone which consists of chalcopyrite containing colloform, banded, graphic, and dendritic intergrowths of sphalerite as described in 64071707. Rims of sphalerite in chalcopyrite are roughly conformable with the edges of the chalcopyrite host. Blebs of galena were observed in the centre of many of these mixed grains.

d. Zone (c) grades into an area where sphalerite is the dominant mineral, with chalcopyrite in an extremely fine anastomosing vein system through the sphalerite. These masses are frequently made up of concentric colloform layers. The average size of the sphalerite spheroids is about 0.15mm. Chalcopyrite forms radial and concentric structures in sphalerite, and commonly narrow concentric bands of galena occur towards the outer margins of the sphalerite.

e. Zone (d) merges into an irregular band of fine euhedral, subhedral, and spheroidal pyrite grains. Loose pyrite aggregates also partly fill voids between copper and zinc sulphides and in several places pyrite spheroids 0.07mm across are enclosed in chalcopyrite and sphalerite. The pyrite is moderately brecciated and the fragments displaced. One grain of gold 0.003mm across was observed in chalcopyrite.

DDH SC4, Laloki, 274-275 feet

Hand-specimen: Massive, severely brecciated chalcopyrite with fine-grained magnetite filling some of the fracture cavities.

Polished section: Magnetite is mostly localized in voids within chalcopyrite. The magnetite in patches and veins generally occurs in irregular masses up to 0.5mm across; these are enclosed in a similar gangue to that in the specimen from 284 feet, which proved to be talc. Most isolated grains of magnetite (also mostly in voids) are subhedral, but some are euhedral. Accessory amounts of small (0.01mm) subhedral grains of magnetite are enclosed by chalcopyrite. These seem to have been incorporated during the formation of the chalcopyrite host.

DDH SC4 Laloki, 281-282 feet

Hand-specimen: Strongly magnetic; mainly massive chalcopyrite which contains irregularly shaped veins and masses up to 5mm across of fine-grained magnetite.

Polished section: Chalcopyrite contains abundant voids which typically contain subhedral grains and small masses of magnetite. Much of the magnetite, particularly subhedral grains, has grown into the chalcopyrite walls of these cavities. The magnetite in the centre of some of the larger masses has a bladed form and in some places foliae of magnetite form sheath-shaped aggregates, some of which appear to have been forced between fragments of chalcopyrite. Most magnetite is fractured. Chalcopyrite carries minor bleb-like inclusions of pyrite.

DDH SC4, Laloki, 284-285 feet

Hand-specimen: A fine-grained aggregate of bladed magnetite. Small films of talc show fine slickensides. The rock is strongly magnetic.

Polished section: Magnetite blades and foliae have a random distribution. Some are grouped in sheath-like aggregates, some form small irregular masses. Magnetite carries extremely fine inclusions of pyrite and rarely chalcopyrite and hematite. Several euhedral pyrite grains in the section are brecciated and partly replaced by magnetite.

In thin section the gangue material was identified as talc.

DDH SC4, Laloki, 285-286 feet

Hand-specimen: Strongly magnetic; densely packed fine-grained magnetite which contains disseminated grains of pyrite. Cavities in the rock are filled with talc, and a small shear-plane is lined by talc marked with fine slickensides.

Polished section: magnetite occurs most commonly in loosely packed shredded blades and foliae. Individual foliae are up to 0.3mm long, and some of these are grouped in sheath-like aggregates. Magnetite is also present in irregularly shaped masses and subhedral grains. Some magnetite carries fine (0.001mm) inclusions of pyrite and rarely chalcopyrite. Some is fractured.

Grains of pyrite average 0.4mm across; they are generally fractured and the breccia fragments are slightly displaced. Blades and subhedral grains of magnetite partly enclose pyrite and typically they partly fill fracture cavities and voids within the pyrite. In many places it appears that the magnetite (carried by gangue) has been forced between breccia fragments of pyrite and this has been largely responsible for their displacement. Many blades of magnetite have grown into pyrite.

Several small spheroidal grains of pyrite occur in the rock matrix. Small irregular grains of chalcopyrite are disseminated through the section and make up about 2% of the rock. They occur near pyrite, and commonly the two minerals are intergrown. The chalcopyrite is also fractured and magnetite partly encloses it and occurs in voids of most grains.

Moresby King, Reg. No. 64071710

Minerals identified: Major pyrite, quartz; minor marcasite, chalcopyrite, specularite, sphalerite, rutile.

Hand-specimen: A finely cellular mass of sulphide minerals consisting of laths and masses of quartz enclosed by fine crystals of pyrite. Cryptocrystalline silica fills some cavities in the rock. Hydrated iron oxides encrust the weathered surface.

Polished section: The mineral associations differ slightly from those in 64071709, which is also from Moresby King. Quartz fills most of the cavities of a fine skeletal network of euhedral iron sulphides. Pyrite is the dominant mineral and is intimately intergrown with minor amounts of marcasite. Some euhedral pyrite forms tabular aggregates; but it generally occurs in short chain-like bands, many of which form the perimeter of roughly quadrangular structures. The outer margin of these forms is usually straight, the inside margin is irregular, indicating that the pyrite crystals only grew freely towards the centre. Quartz typically fills the space enclosed by pyrite rims so that much of the quartz occurs in tabular crystals. Quartz also fills intercrystal voids of pyrite aggregates, and veins of quartz cut through some of the iron sulphides.

Abundant flakes of specularite are carried by the quartz; most of these have a random distribution, but in some of the laths the long axis of the flakes is oriented parallel to the length of the lath.

Quartz also carries inclusions of euhedral pyrite, minor amounts of small chalcopyrite masses, and abundant long fine needles of a highly refractive mineral. These needles have a random distribution; in some places they form dense fibrous aggregates. They are almost certainly rutile. Some of the quartz filling the cavities is zoned by scalloped colloform bands which are roughly conformable to the walls of the cavity.

Chalcopyrite occurs in spongey-looking masses, extensively replaced by quartz and fine-grained pyrite in quartz. The quartz and granular pyrite have invaded chalcopyrite along crystal planes and in many places chalcopyrite is pseudomorphed by quartz rimmed with pyrite grains. This pyrite is the same as the second generation pyrite described in 64071709. Some chalcopyrite carries small inclusions of sphalerite.

Moresby King, Reg. No. 64071709

Minerals identified: Major arsenopyrite, pyrite, marcasite, chalcopyrite; minor sphalerite, specularite, chlorite, quartz, limonite.

Hand-specimen: A massive sulphide ore, oxidized on the weathered surface to boxworks.

Polished section: Large (average 1mm across) subhedral and euhedral grains of arsenopyrite, most of which are brecciated and pulverized, are distributed at random through the section. In some places euhedral arsenopyrite grains form scalloped bands and spheroidal structures; in one area they form a roughly oval rim around an irregular core of spongey-looking pyrite. The outer margins of the pyrite core are intergrown with fine bands and lenses of marcasite and arsenopyrite.

Two generations of pyrite occur in this section. One consists of large tabular masses of spongey-looking pyrite which fill cavities between and cement fragments of arsenopyrite. In places pyrite forms a mottled intergrowth with arsenopyrite, extensively replacing it. The spongey tecture of this pyrite has facilitated its alteration to limonite. The second-generation pyrite occurs in fine-grained aggregates which commonly form a reticulated intergrowth surrounding chalcopyrite; and in granular chain-like veins which cut through chalcopyrite and in feathery acicular aggregates and bands.

Chalcopyrite occurs in fractured and leached masses, many of which contain banded leach-zones roughly conformable to the outline of the grains. Some chalcopyrite encrusts and intrudes into the spongy laths of first-generation pyrite, but it is itself extensively replaced by second-generation pyrite. A few small (0.22mm) sphalerite inclusions occur in some chalcopyrite. Many voids between the ore minerals are filled with extremely fine-grained aggregates of chlorite flakes, some of which carry specularite and hydrated iron oxides. In one section a narrow vein of specularite (1mm wide) cuts through all the other minerals.

Some cavities are filled with quartz.

Paree, Reg. No. 64071711

Minerals identified: Major pyrite, marcasite; minor chalcopyrite, hematite, calcite.

Hand-specimen: A massive sulphide ore cut by stringers and veins of calcite.

Polished section: Fine euhedral and subhedral grains of iron sulphide are scattered in loose aggregates through a calcite gangue. The grains consist of intimately intergrown pyrite and marcasite; they have an average size of 0.04mm. In part of the section the iron sulphide grains form finely scalloped bands, some of which surround small pockets of calcite. Patches of chalcopyrite up to 0.5mm across occur in the gangue; they typically intrude pyrite aggregates. Minor-accessory grains of hematite also occur randomly in the gangue.

Ventura

Minerals identified: Major pyrite; minor chalcopyrite, covellite.

Polished section: Fine euhedral and subhedral pyrite grains of two sizes are disseminated through a siliceous gangue. The fine-grained pyrite has an average size of 0.02mm and is generally localized in patches. The coarse-grained pyrite has an average size of 0.4mm; it commonly forms chain-like bands through the gangue, some of which surround the fine-grained patches. Many of the pyrite grains are brecciated, and fine fragments have been strung out through the quartz gangue.

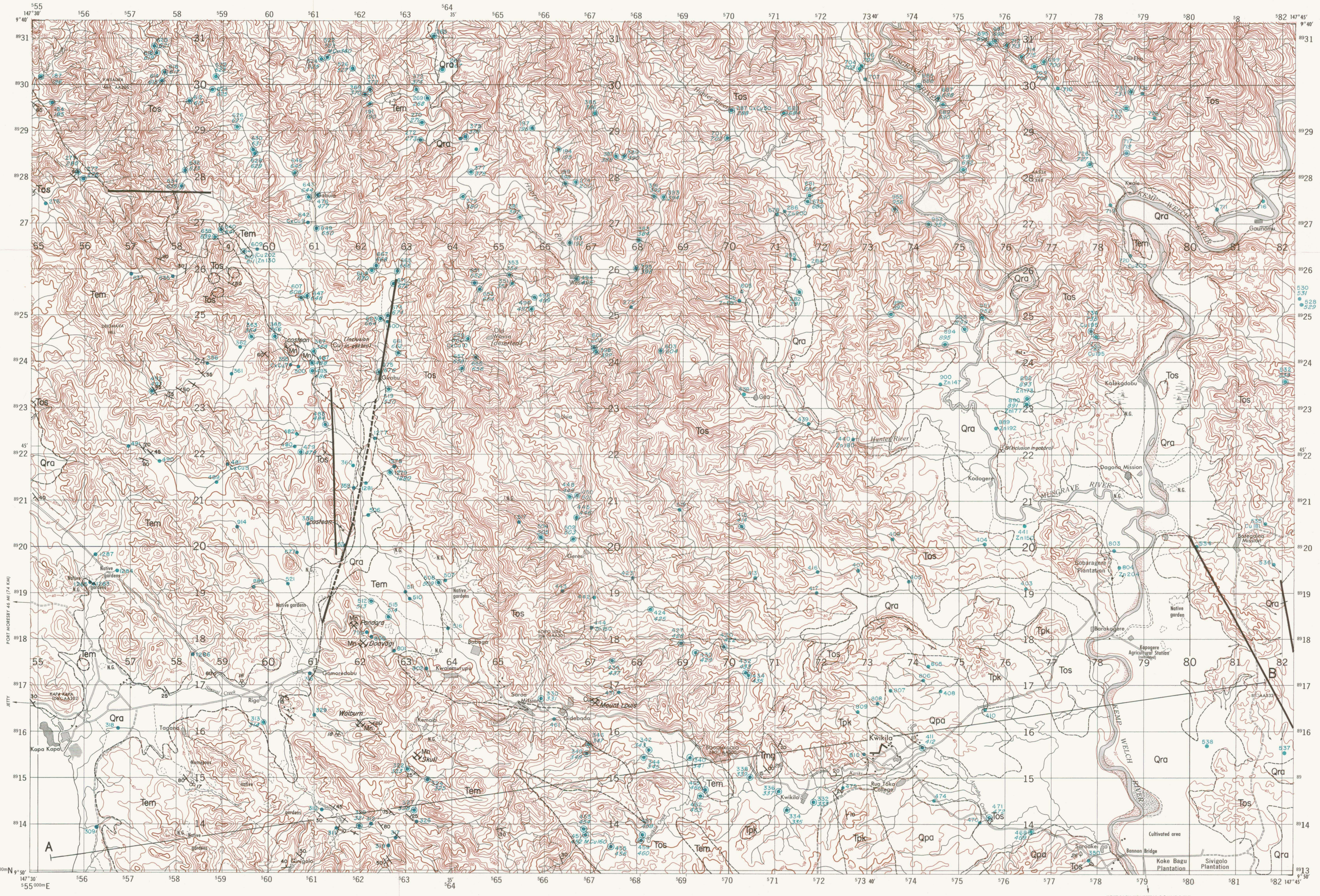
Small masses of chalcopyrite occur in quartz within interstices of pyrite; they are commonly partly altered to covellite and in some places single grains of covellite indicate complete replacement. This is the only evidence of supergene alteration of the chalcopyrite in all the sections examined.

NEW GUINEA 1:50,000

GEA
TERRITORY OF PAPUA

PLATE 12

GEOLOGY AND GEOCHEMISTRY



Reference

CAINOZOIC	QUATERNARY	Recent		Qra	Alluvium
		Pleistocene	Ararabu Conglomerate	Qpa	Poorly consolidated, coarse conglomerate; siltstone
	TERTIARY	Pliocene	Kwikila Agglomerate	Tpk	Massive basaltic to andesitic agglomerate, tuff, fine tuffaceous conglomerate
		Lower Miocene	Gidobada Limestone	Tmg	Massive, medium, cream to buff limestone
		Oligocene	Sadowa Gabbro	Tos	Dolerite, olivine dolerite, gabbro
		Eocene	Port Moresby Beds	Tem	Buff, pink, maroon or light grey calcilutite; thin bedded, light grey chert, fine grained, light grey, calcareous sandstone, shale

Geological boundary – position approximate
Fault – broken where concealed
Strike and dip of strata
Vertical strata
Trend line
Mn Pandora Mine, not worked
Mn Skull Open cut
Mn Unworked deposit
Cu Copper
Mn Manganese
g Gossan
Microfossil locality and number
Plant fossil locality and number
Stream sediment sample locality
Stream sediment and Magnetite sample locality
532 Stream sediment sample number
533 Magnetite sample number
Cu181 Anomalous stream sediment 250 p.p.m. Copper
M Cu160 250 p.p.m. Copper in Magnetite
Cx Cu10 250 p.p.m. cold extractable Copper
Zn204 250 p.p.m. Zinc

Scale 1:50,000

1 ½ 0 1 2 3 Miles
1000 500 0 1000 2000 3000 4000 Metres
1000 500 0 1000 2000 3000 4000 Yards

CONTOUR INTERVAL 20 METRES
VERTICAL DATUM IS BASED ON MEAN SEA LEVEL, PORT MORESBY

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM IS BASED ON PAGA HILL, PORT MORESBY, LATITUDE 09°29'00.31"S LONGITUDE 147°08'21.66"E

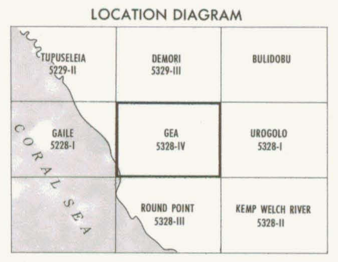
BLACK NUMBERED LINES INDICATE THE 1,000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 55, INTERNATIONAL SPHEROID
THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Royal Australian Survey Corps. Aerial photography (1956-57) complete vertical coverage at 1:50000. Transverse Mercator Projection.

LEGEND

Built-up area; native village, garden
Road hard surface all weather; embankment
Road loose or light surface all weather; cutting
Road loose surface fair or dry weather; bridge
Road unimproved earth
Track jeep
Track foot or pack; footbridge
Telephone line; power transmission line
Mine; quarry; levee or dyke
Building (s); church; school; mission
Post office; wireless transceiver; cemetery
Control point major, minor, astronomical
Bench mark; spot elevation in metres
Mud; gravel; sand
Contours with value; depression contours
Auxiliary contour; form lines
Cliff inland; cliff coastal
Forest rain
Forest secondary growth
Forest open; plantation
Grassland; scrub
Palm (nipa, sago, pandanus)
Mangrove; rice field
Permanently inundated (swamp)
Subject to inundation
Lake; river or stream
Falls; rapids; drain or ditch
Breakwater; pier, dock or wharf
Fathom line; low water mark; lighthouse
Wreck sunken, exposed; vessel anchorage
Shoal with soundings
Rocks submerged, bare or awash
Reef, rocky or coral

LOCATION DIAGRAM



GRID ZONE DESIGNATION: 55L
100,000 METRE SQUARE IDENTIFICATION
EK

IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number; example: 89 22 000

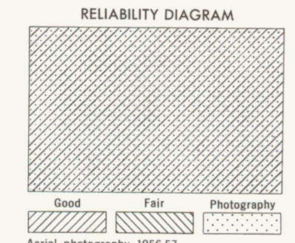
TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METRES

SAMPLE POINT: 319 ○ AA301			
1 Read letters identifying 100,000 metre square in which the point lies:	EK		
2 Locate first VERTICAL grid line to LEFT of point and read LARGE figures labelling the line either in the top or bottom margin, or on the line itself:		66	
3 Estimate tenths from grid line to point:		1	
4 Locate first HORIZONTAL grid line BELOW point and read LARGE figures labelling the line in either the left or right margin, or on the line itself:			18
5 Estimate tenths from grid line to point:			1
SAMPLE REFERENCE:	EK661181		
If reporting beyond 18° in any direction, prefix Grid Zone Designation, as:	55LEK661181		

GN
CONVERGENCE 0°06' OR 1.8 MILS WEST
6°00' OR 106.7 MILS

APPROXIMATE MEAN DECLINATION 1960 AT THE CENTRE OF THE SHEET FOR THE UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 55. ANNUAL MAGNETIC CHANGE IS 02' EASTERLY.

RELIABILITY DIAGRAM



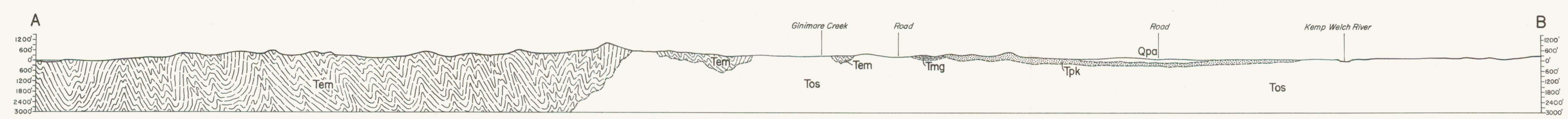
Aerial photography 1956-57
Using stereophctogrammetric methods

GEA, NEW GUINEA

Section

Folding schematic. Recent alluvium omitted from section

Scale ratio: $\frac{V}{H} = 1$



Bureau of Mineral Resources, Geology and Geophysics, May 1965.

Geology, 1964, by: K.R. Yates, R.Z. de Ferranti, D. French
Compiled, 1965, by: R.Z. de Ferranti
Drawn by: A. Skoda and E. Jurello

To accompany Report 105 and Record 1965/161

C 55/A 7/ 36

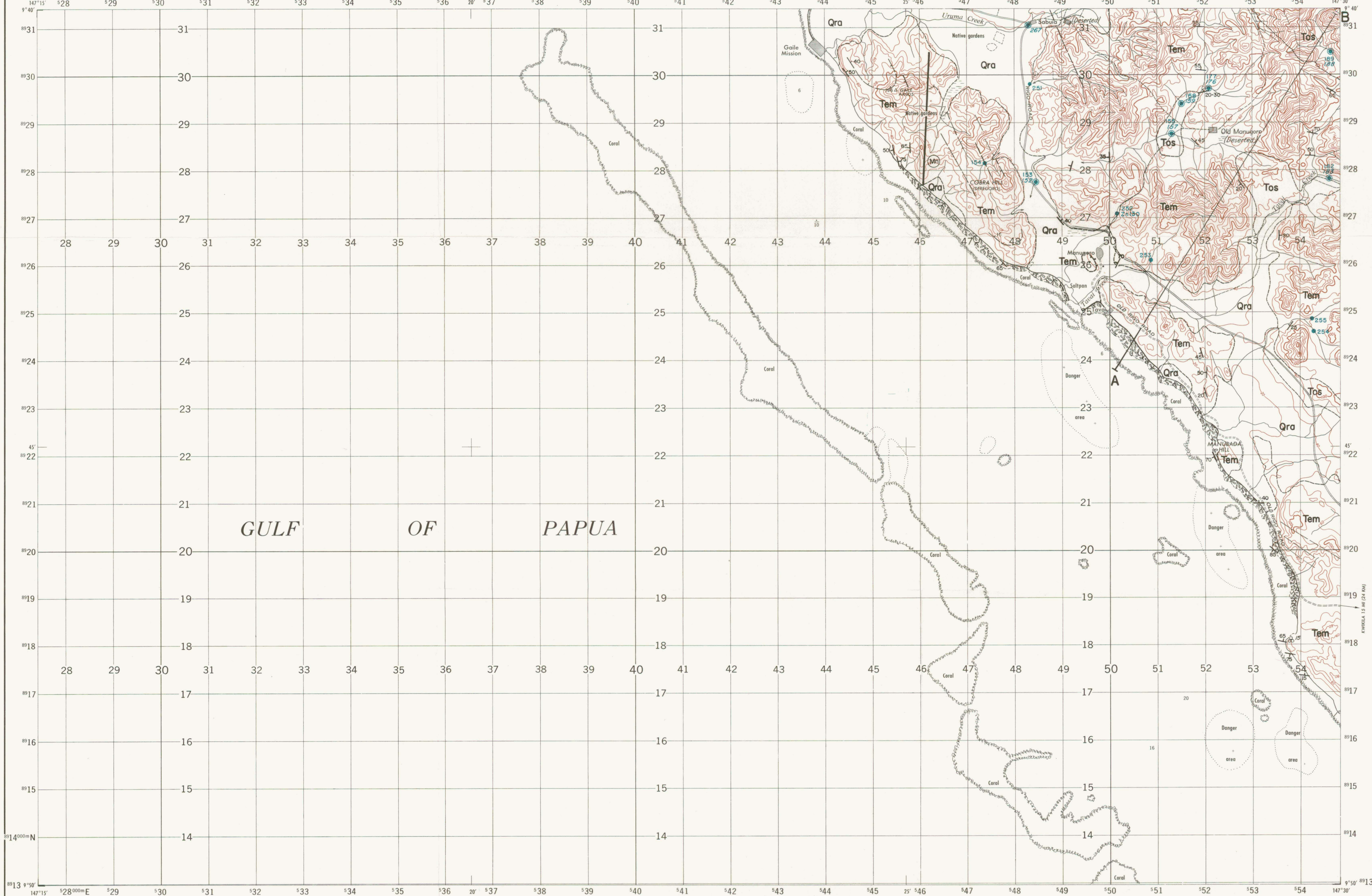
NEW GUINEA 1:50,000

GAILE

TERRITORY OF PAPUA

PLATE 11

GEOLOGY AND GEOCHEMISTRY



Reference

CAINOZOIC	QUATERNARY	Recent		Qra	*Alluvium*
	TERTIARY	Oligocene	Sadowa Gabbro	Tos	*Fine to medium dolerite and olivine dolerite*
		Eocene	Port Moresby Beds	Tem	*Thin-bedded, buff, pink or light grey calcilutite; thin-bedded light grey chert; fine, light grey calcareous sandstone*

Geological boundary–position approximate

Fault

Strike and dip of strata

Trend line showing direction of dip

Unworked deposit of manganese

Microfossil locality and number

Stream sediment sample locality

Stream sediment and Magnetite sample locality

Stream sediment sample number

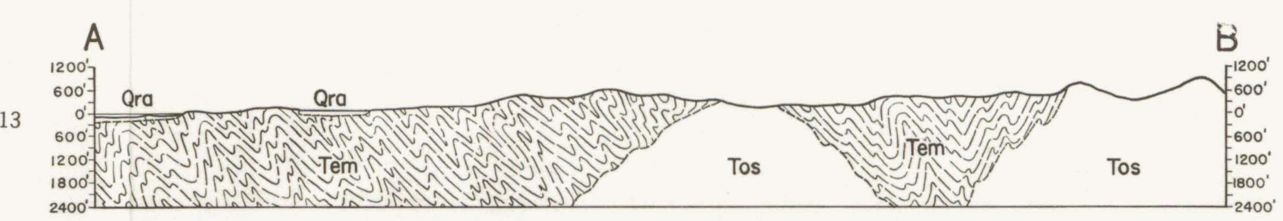
Magnetite sample number

250 p.p.m. Zinc

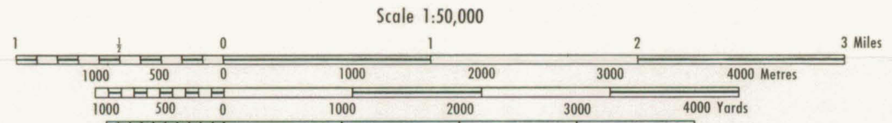
Section

Folding schematic

Scale ratio $\frac{V}{H}=1$



Scale 1:50,000



CONTOUR INTERVAL 20 METRES

VERTICAL DATUM IS BASED ON MEAN SEA LEVEL, PORT MORESBY

TRANSVERSE MERCATOR PROJECTION

HORIZONTAL DATUM IS BASED ON PAGA HILL, PORT MORESBY, LATITUDE 09°29′00.31″S LONGITUDE 147°08′21.66″E

BLACK NUMBERED LINES INDICATE THE 1,000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 55, INTERNATIONAL SPHEROID

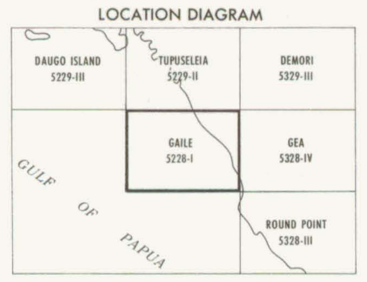
THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.
Topographic base compiled by the Royal Australian Survey Corps.
Aerial photography (1956-57) complete vertical coverage at 1:50000.
Transverse Mercator Projection.

LEGEND

Built-up area; native village, garden
Road hard surface all weather; embankment
Road loose or light surface all weather; cutting
Road loose surface fair or dry weather; bridge
Road unimproved earth
Track jeep
Track foot or pack; footbridge
Telephone line; power transmission line
Mine; quarry; levee or dyke
Building (s); church; school; mission
Post office; wireless transceiver; cemetery
Control point major, minor, astronomical
Bench mark; spot elevation in metres
Mud; gravel; sand
Contours with value; depression contours
Auxiliary contour; form lines
Cliff inland; cliff coastal
Forest rain
Forest secondary growth
Forest open; plantation
Grassland; scrub
Palm (nipa, sago, pandanus)
Mangrove; rice field
Permanently inundated (swamp)
Subject to inundation
Lake; river or stream
Falls; rapids; drain or ditch
Breakwater; pier, dock or wharf
Fathom line; low water mark; lighthouse
Wreck sunken, exposed; vessel anchorage
Shoal with soundings
Rocks submerged, bare or awash
Reef, rocky or coral

LOCATION DIAGRAM



GRID ZONE DESIGNATION: 55L

100,000 METRE SQUARE IDENTIFICATION

EK

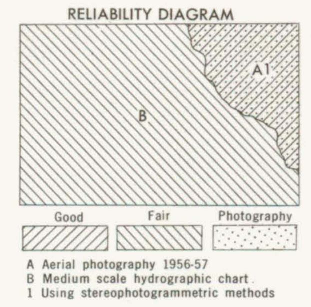
TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METRES

SAMPLE POINT: 196 △ GAILE

1 Read letters identifying 100,000 metre square in which the point lies:
2 Locate first VERTICAL grid line to LEFT of point and read LARGE figures labelling the line either in the top or bottom margin, or on the line itself:
3 Estimate tenths from grid line to point:

APPROXIMATE MEAN DECLINATION 1960 AT THE CENTRE OF THE SHEET FOR THE UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 55. ANNUAL MAGNETIC CHANGE IS 02′ EASTERLY.

RELIABILITY DIAGRAM



GAILE, NEW GUINEA

Bureau of Mineral Resources, Geology and Geophysics, April 1965.

Geology, 1964, by: K.R.Yates
Compiled, 1965, by: K.R.Yates
Drawn by: A.Skoda and E.Jurello

To accompany Report 105 and Record 1965/161

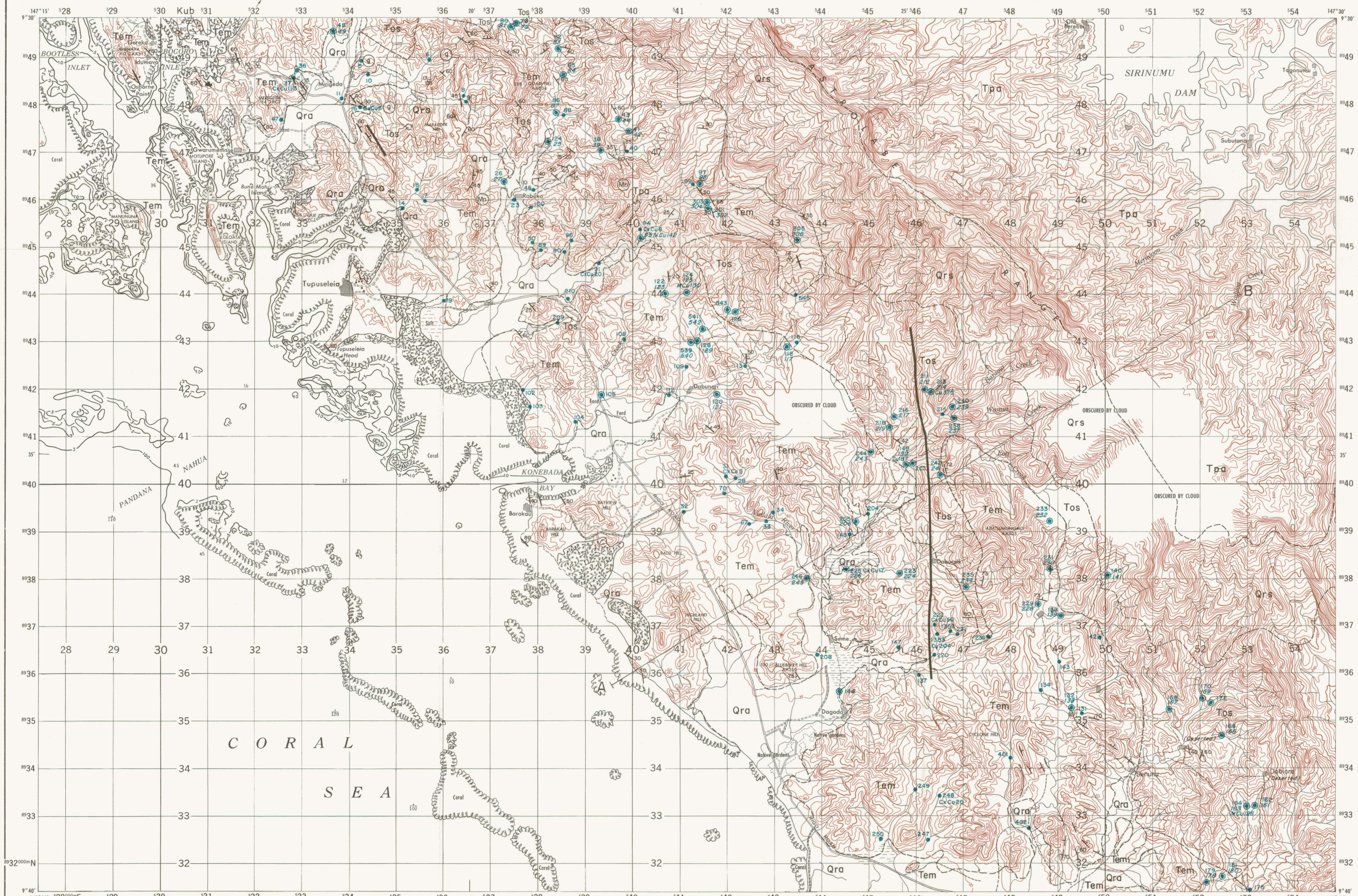
C55/A7/35

NEW GUINEA 1:50,000

TUPUSELEIA
TERRITORY OF PAPUA

PLATE 10

GEOLOGY AND GEOCHEMISTRY



Reference

CAINOZOIC	QUATERNARY	Recent		Qra	Alluvium
				Qrs	Scree (Astrolabe Agglomerate)
	TERTIARY	Pliocene	Astrolabe Agglomerate	Tpa	Massive coarse, dark grey basaltic agglomerate; tuff and basalt lenses
		Oligocene	Sadowa Gabbro	Tos	Medium to coarse gabbro, dolerite
		Eocene	Port Moresby Beds	Tem	Thin-bedded buff, pink, maroon or grey calcilutite to lutite; thin-bedded light grey chert; shale; tuff; limestone, calcarenite
MESOZOIC	UPPER CRETACEOUS		Bogoro Limestone	Kub	Highly sheared, fine pink limestone

- Geological boundary - position approximate
- Fault
- Anticline
- Strike and dip of strata
- Vertical strata
- Trend line showing direction of dip
- Joint line
- Microfossil locality and number
- Unworked deposit of manganese
- Unworked deposit of copper
- Unworked deposit of gossan
- Stream sediment sample locality
- Stream sediment and Magnetite sample locality
- 205 Stream sediment sample number
- 206 Magnetite sample number
- Cu 375 Anomalous stream sediment - 375 p.p.m. Copper
- MCu 126 126 p.p.m. Copper in magnetite
- CxCu 17 17 p.p.m. cold extractable Copper

Scale 1:50,000

CONTOUR INTERVAL 20 METRES
VERTICAL DATUM IS BASED ON MEAN SEA LEVEL, PORT MORESBY

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM IS BASED ON PAGA HILL, PORT MORESBY, LATITUDE 09°29'00.31"S LONGITUDE 147°08'21.66"E

BLACK NUMBERED LINES INDICATE THE 1,000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 55, INTERNATIONAL SPHEROID
THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Royal Australian Survey Corps. Aerial photography (1956-57) complete vertical coverage at 1:50000. Transverse Mercator Projection.

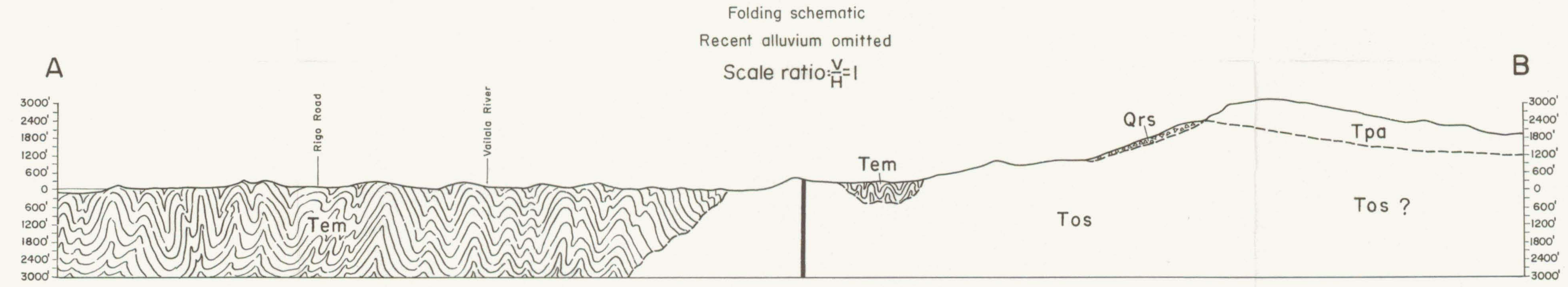
LEGEND

- Built-up area; native village, garden
- Road hard surface all weather; embankment
- Road loose or light surface all weather; cutting
- Road loose surface fair or dry weather; bridge
- Road unimproved earth
- Control point major, minor, astronomical
- Bench mark; spot elevation in metres BM • 750 750
- Mud; gravel; sand
- Contours with value; depression contours
- Auxiliary contour; form lines
- Mangrove; rice field
- Permanently inundated (swamp)
- Subject to inundation
- Lake; river or stream
- Falls; rapids; drain or ditch

LOCATION DIAGRAM

TUPUSELEIA, NEW GUINEA

Section
Folding schematic
Recent alluvium omitted
Scale ratio $\frac{V}{H}=1$



Geology, 1964, by: D. J. French, R. Z. de Ferranti
Compiled, 1965, by: R. Z. de Ferranti
Drawn by: J. Kopras and E. Jurello

Bureau of Mineral Resources, Geology and Geophysics. May 1965

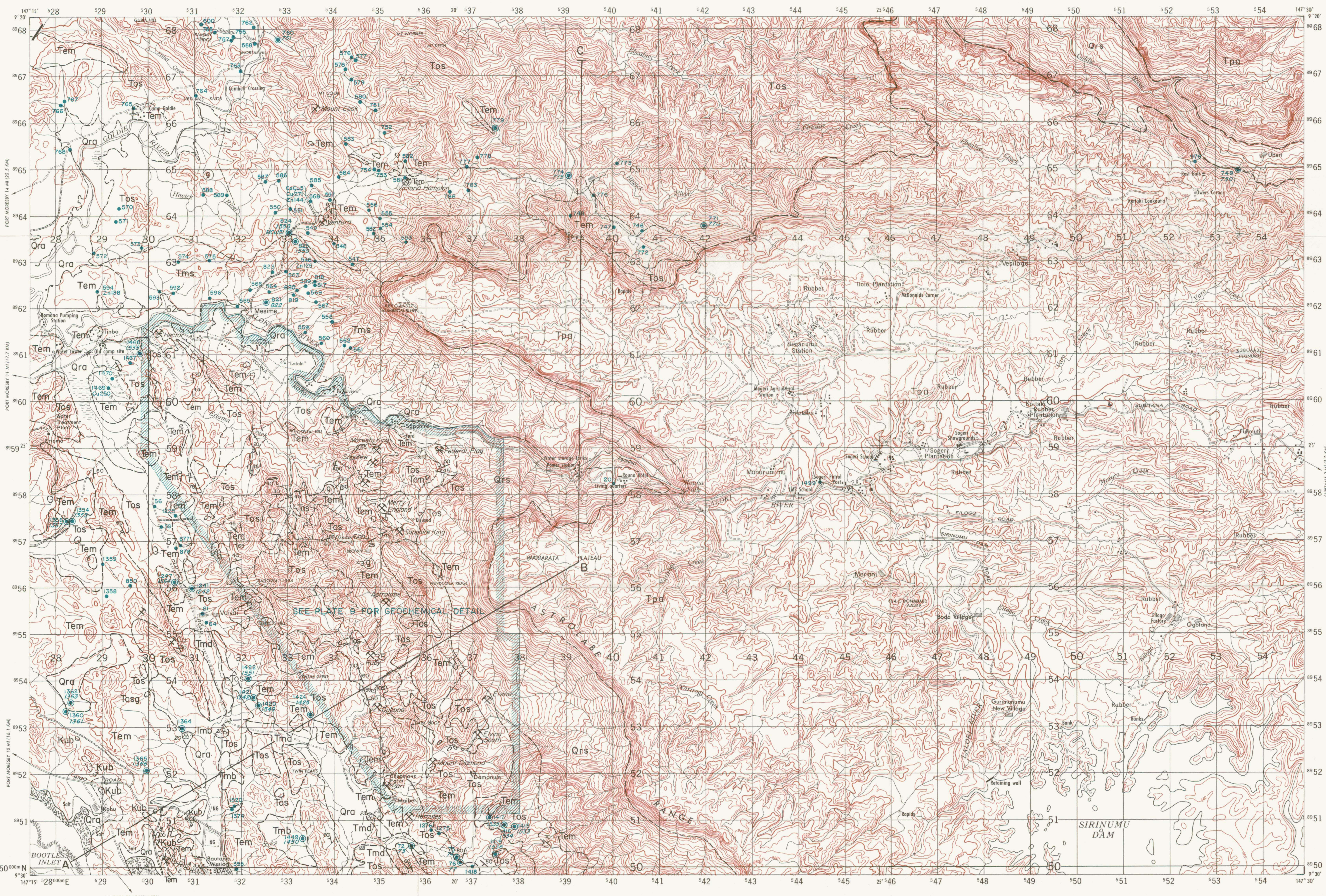
To accompany Report 105 and Record 1965/161

C55/A7/34

NEW GUINEA 1:50,000

GEBORIA
TERRITORY OF PAPUA

PLATE 9
GEOLOGY AND GEOCHEMISTRY



Reference

CAINOZOIC	QUATERNARY	Recent		Qra	Alluvium
				Qrs	Scree
	TERTIARY	Pliocene	Astrolabe Agglomerate	Tpa	Massive, coarse, dark grey basaltic agglomerate; tuff and basalt lenses
		Middle-Upper Miocene	Siro Conglomerate	Tms	Poorly consolidated conglomerate; siltstone
		Lower Miocene	Dokuna Tuff	Tmd	Laminated, fine vitric tuff; medium grained crystal and lithic tuff; very coarse calcareous agglomerate
			Bootless Inlet Limestone	Tmb	Blocky, medium tuffaceous detrital limestone
		Oligocene	Sadowa Gabbro	Tos	Coarse to fine olivine gabbro, gabbro, pyroxene hornblende diorite
				Tosg	Granophyre
		Eocene	Port Moresby Beds	Tem	Thin-bedded grey, greenish grey, green, buff, red calcilutite to lutite; shale; breccia; calcarenite; calcareous sandstone; chert; tuff
MESOZOIC	UPPER CRETACEOUS		Bogoro Limestone	Kub	Highly sheared, fine pink limestone

- *Geological boundary - position approximate*
- *Fault*
- *Strike and dip of strata*
- *Vertical strata*
- *Trend line showing direction of dip*
- *Microfossil locality and number*
- *Mine*
- *Mine not worked*
- *Prospect*
- *Minor occurrence of gossan*
- Cu — *Copper*
- *Stream sediment sample locality*
- *Stream sediment and Magnetite sample locality*
- 774 — *Stream sediment sample number*
- 775 — *Magnetite sample number*
- Cu 250 — *Anomalous stream sediment - 250 p.p.m. Copper*
- MCu 151 — *151 p.p.m. Copper in Magnetite*
- CxCu 5 — *5 p.p.m. cold extractable Copper*
- Zn 138 — *138 p.p.m. Zinc*

Geology, 1964, by: K.R.Yates, R.Z.de Ferranti, D.French, J.F. Ivanac, I.Pontifex
Compiled, 1965, by: R.Z.de Ferranti
Drawn by: J. Kopras and E. Jurello

Bureau of Mineral Resources, Geology and Geophysics. May 1965

To accompany Report 105 and Record 1965/161

Scale 1:50,000

CONTOUR INTERVAL 20 METRES
VERTICAL DATUM IS BASED ON MEAN SEA LEVEL, PORT MORESBY

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM IS BASED ON PAGA HILL, PORT MORESBY, LATITUDE 09°29'00.31"S LONGITUDE 147°08'21.66"E

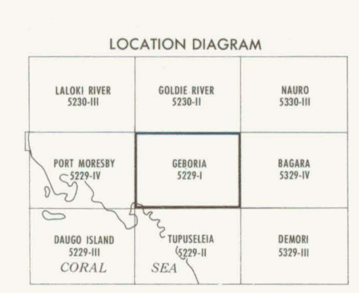
BLACK NUMBERED LINES INDICATE THE 1,000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 55, INTERNATIONAL SPHEROID
THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

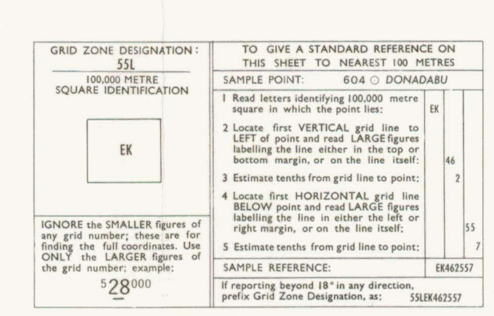
Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development.
Topographic base compiled by the Royal Australian Survey Corps.
Aerial photography (1956-57) complete vertical coverage at 1:50000.
Transverse Mercator Projection.

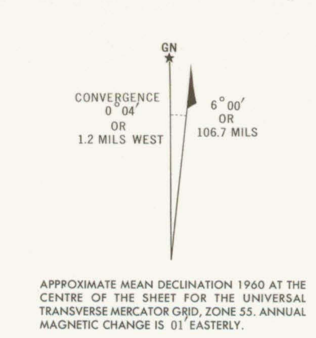
LEGEND

- Built-up area; native village, garden
- Road hard surface all weather; embankment
- Road loose or light surface all weather; cutting
- Road loose surface fair or dry weather; bridge
- Road unimproved earth
- Track jeep
- Track foot or pack; footbridge
- Telephone line; power transmission line
- Mine; quarry; levee or dyke
- Building (s); church; school; mission
- Post office; wireless transceiver; cemetery
- Control point major, minor, astronomical
- Bench mark; spot elevation in metres — BM·750 ·750
- Mud; gravel; sand
- Contours with value; depression contours
- Auxiliary contour; form lines
- Cliff inland; cliff coastal
- Forest rain
- Forest secondary growth
- Forest open; plantation
- Grassland; scrub
- Palm (sago, sago, pandanus)
- Mangrove; rice field
- Permanently inundated (swamp)
- Subject to inundation
- Lake; river or stream
- Falls; rapids; drain or ditch
- Breakwater; pier, dock or wharf
- Fathom line; low water mark; lighthouse
- Wreck sunken, exposed, vessel anchorage
- Shoal with soundings
- Rocks submerged, bare or awash
- Reef, rocky or coral

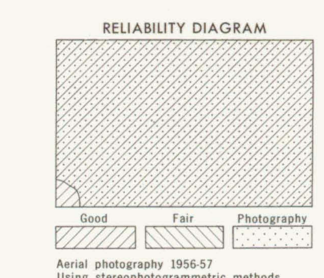
LOCATION DIAGRAM







RELIABILITY DIAGRAM



GEBORIA, NEW GUINEA

Section
Folding schematic
Scale ratio: $\frac{V}{H} = 1$

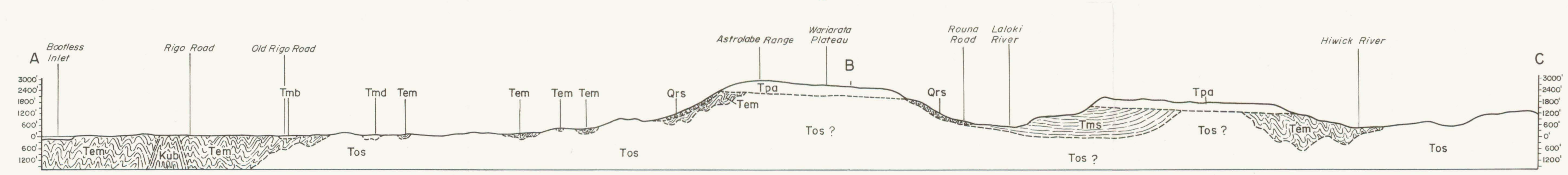



PLATE 8
GEOLOGY AND GEOCHEMISTRY
ASTROLABE MINERAL FIELD
TERRITORY OF PAPUA-NEW GUINEA
SCALE 1:12,000
0 1000 2000 3000 FEET
CAINOZOIC
QUATERNARY
Recent
Qra Alluvium
Qrs Scree
TERTIARY
Pliocene Astrolabe Agglomerate Tpa Massive, coarse, dark grey basaltic agglomerate; tuff and basalt lenses
Middle-Upper Miocene Siro Conglomerate Tms Poorly consolidated conglomerate, siltstone
Oligocene Sadowa Gabbro Tos Coarse to fine olivine gabbro, gabbro, pyroxene hornblende diorite
Eocene Port Moresby Beds Tem Thin-bedded to laminated, grey or pink calcilutite and lutite; black, grey, green shale; calcilutite and lutite breccia; dark grey tuff. Red to pink massive calcilutite or limestone
g Gossan
gs Iron stained sediments
Geological boundary (broken where location approximate, queried where inferred)
65 Strike and dip of strata – measured
Strike and dip of strata – prevailing
Vertical strata
Strike and dip of foliation
Shaft
Shaft-inaccessible
Portal and approach of adit
Portal and approach of adit-workings inaccessible
Mine dump
Costean
Cu Unworked deposit of Copper
Cu Minor occurrence of Copper
Road
Vehicle track
Foot track
Power transmission line
Timber edge
"Laloki" Homestead
Buildings
200 Contours at 10' intervals; datum: mean sea level, Port Moresby
Trigonometrical station
1267 Stream sediment sample
295/4 Stream sediment sample and detrital magnetic concentrate
Cu250 Anomalous stream sediment sample containing 250 p.p.m. Copper
Cu250 Contaminated anomalous stream sediment sample containing 250 p.p.m. Copper
MCu250 Anomalous detrital magnetic concentrate containing 250 p.p.m. Copper
CxCu Cold extractable Copper
Zn Zinc
Compiled and published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Base map compiled for the Division of National Mapping, Department of National Development by Queensland Aerial Survey Company Pty Ltd and Australian Aerial Mapping Pty Ltd from aerial photographs flown in 1964. Some additions to the base map by the Bureau of Mineral Resources field party
Geology, 1964, by: K. R. Yates, R.Z. deFerranti, J. F. Ivanac, I. R. Pontifex
Compiled, 1965, by: R. Z. deFerranti, A. Skoda
Drawn by: A. Skoda
To accompany Report 105 and Records 1965/132, 1965/161
C55/A7/28
HOSPITAL HILL
BROWN HILL
FORTRESS HILL
KATHS CREST
WINDSOCK RIDGE
Sapphire
Moresby King
Merrie England
Sapphire King
Astrolabe
Ruby
Dubuna
Mount Diamond
Elvina
Federal Flag
Chapman's Farm
Maiberi Village
Hercules
SECTION
Scale ratio: V/H = 1
Folding partially schematic. Recent scree omitted from section
A
B
Foot track
Eriama Creek
Sapphire Mine
Sapphire Creek
Track
Rouna Road
Laloki River
Tem
Tos
Tem ?
Tms
1000'
500'
0'
200'