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BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

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THE GEOLOGY OF WOODLARK ISLAND

by

D.S. Trail

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SUMMARY

Woodlark is an isolated island about 170 miles north-east of the eastern point of Papua.

In 1960, a Bureau of Mineral Resources field party worked on Woodlark for four months to establish the geological setting of known gold and copper-iron mineralisation, and to test the application of geochemical techniques in rough, heavily forested, terrain and under high-rainfall conditions.

The island is composed of a raised and slightly tilted Quaternary coral platform around a deeply eroded and locally mineralized Tertiary volcanic pile.

The oldest exposed formation, the Loluai Volcanics, is composed of andesitic basalts and associated pyroclastic rocks, interbedded with fine-grained siliceous sediments. This is succeeded unconformably by the Suloga Limestone of Lower Miocene age and this is in turn succeeded by a thick volcanic sequence including andesitic basalts, pyroclastics, and associated sediments and by the Nasai Limestone. The Nasai Limestone contains Lower Miocene foraminifera and was deposited on the flank of the volcanic pile after the main eruptive phase.

The Tertiary rocks are overlain unconformably by Quaternary coral limestone, and marine clays with interbedded conglomerate, which cover most of the Island.

The centres of Tertiary vulcanism are not generally recognisable, but at Mount Kabat there is a discordant breccia which probably represents a filled vent. Gabbro sills intrude formations low in the succession.

Large and small dykes of granite intrude almost the entire Tertiary succession. Porphyries associated with these granites may be metasomatically altered volcanic rocks. Felsites at Kulumadau may represent a phase of acid activity accompanying the granite intrusion.

Dykes of diorite, lamprophyre, basalt, and ultrabasic rock also intrude the Tertiary sediments and volcanics.

During Lower Miocene times Woodlark existed as a volcanic island or island group, changing rapidly in form as periods of volcanic activity alternated with periods of quiescence accompanied by erosion. Quaternary coral reefs and marine clays and conglomerates were deposited during late Tertiary and Quaternary erosion of the volcanic pile and built up a wide shallow platform around the island. Uplift and regional tilting resulted in the formation of the island as it is today.

Structural interpretation is restricted by poor exposures. Regular folding exists only in the oldest volcanics. A zone of steep dips on the south-eastern flank of the Okiduse Range may mark the margin of a volcanic subsidence. Most faults and shear zones strike between 160° and 180°.

Gold was consistently produced from many alluvial and a few small reef deposits on Woodlark between 1895 and 1918. Small parcels of copper carbonate ore were won from superficial workings at Loluai and Norac on Suloga Peninsula in 1917. Many small but rich gold reefs were worked down to the water table only. The Kulumadau mine, which alone successfully tackled the formidable water problem, was mined to a depth of 400 feet.

Most of the gold has come from the Okiduse Volcanics or from rocks intruding them. The gold-bearing reefs are commonly pug-filled shear zones trending between 160° and 180° and ranging from a few inches to 100 feet in width.

In the primary zone, gold is associated with galena, sphalerite, chalcopyrite, pyrite, calcite and quartz and appears to be the product of a late hydrothermal phase of volcanic activity.

Pyrite is common throughout the Tertiary rocks. A small deposit of manganese oxide is known.

At Loluai and Norac on Suloga Peninsula, dyke-like copper-bearing magnetite-hematite lodes occur in skarn rocks near gabbro sills intrusive into the lower members of the Tertiary succession. These copper deposits were tested by a geochemical survey and the results suggest that they should be drilled.

Alluvial gold in payable quantities may exist in the conglomerates interbedded with soft Quaternary marine clays both east and west of the Okiduse Range. The alluvial flats of the Sinkurai River where it emerges from the Okiduse Range warrants testing as a gold dredging prospect.

INTRODUCTION.

General.

Woodlark Island lies about 170 miles north-east of Samarai, the District headquarters at the eastern tip of Papua. The island is about 40 miles long, (east to west), has a maximum width of fifteen miles, and is about 280 square miles in area.

Brass (1959) has compiled an excellent history of Woodlark and the surrounding islands.

At Kulumadau, near the centre of the island, the average annual rainfall is 180 inches. Monthly rainfall ranges between 5 and 30 inches, with less rain in November than other months.

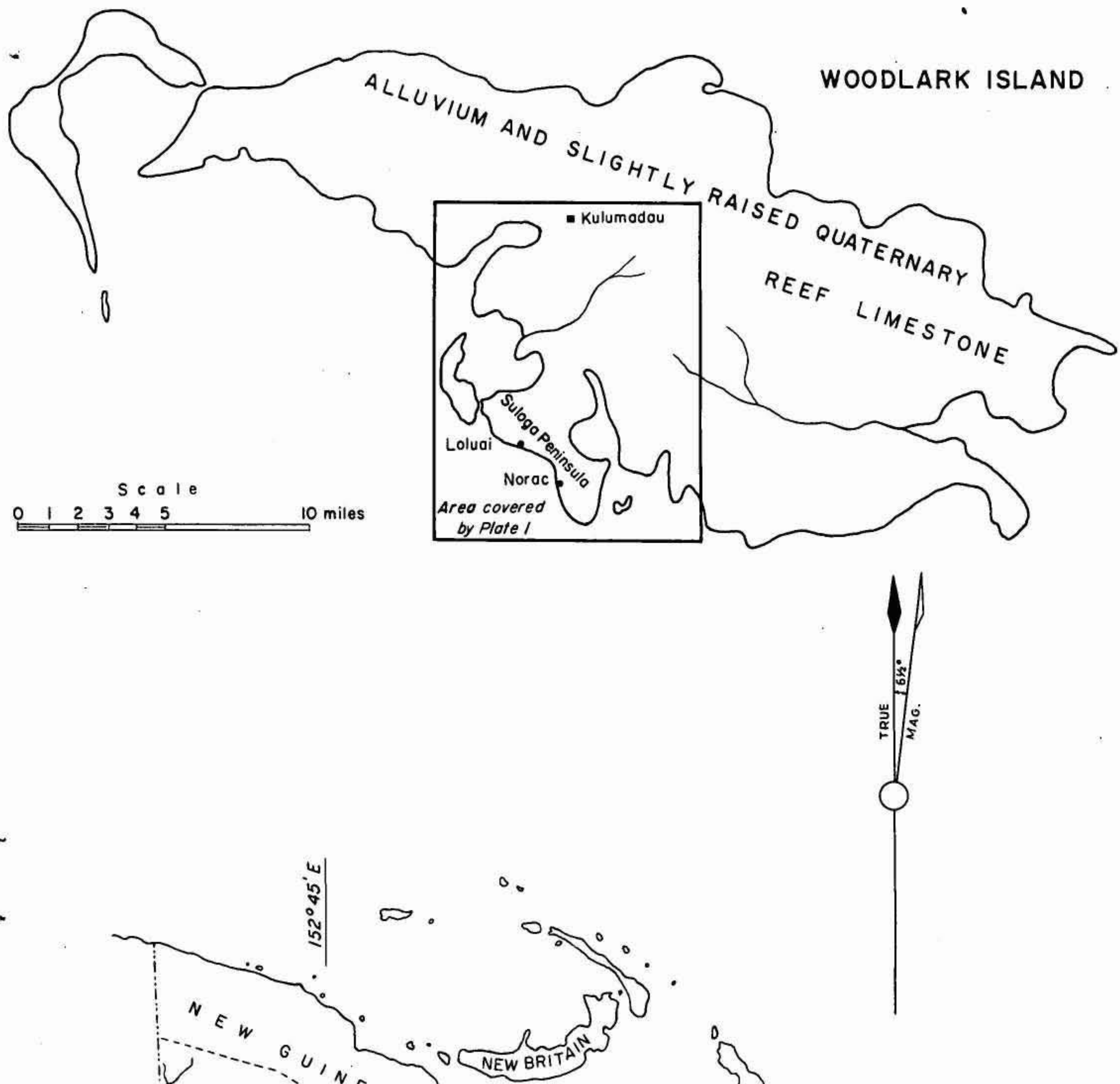
Two European families living at Kulumadau maintain daily radio contact with Samarai. About 1,000 natives live on the island in villages of up to 130 persons, and as small isolated family groups. An irregular supply of fish, fruit, and vegetables may be purchased with cash, tobacco or trade goods from the natives.

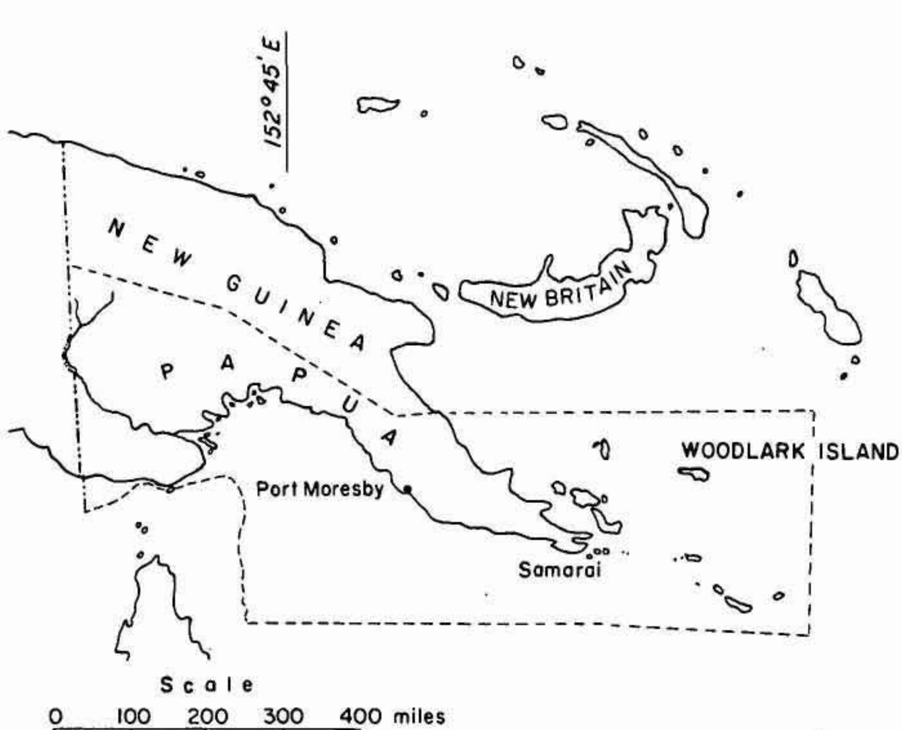
Roads formerly used by vehicles connect Kulumadau with the old mining centres of Busai, Reilly's Creek, Karavakum and Bonivat. All bridges on these roads have collapsed.

Kwaiapan Bay, the port for Kulumadau, is a well-sheltered anchorage used by small ships. Ships of large tonnage can find perfect shelter in Suloga Harbour, about 10 miles east of Kwaiapan Bay.

FIGURE I

LOCALITY MAPS - WOODLARK ISLAND
PAPUA





Bureau of Mineral Resources, Geology and Geophysics. September 1961. To accompany Record 1961/111. PNG 19/3. EJ

Figure 2. Suloga Harbour from former Suloga mining area; Okiduse Range on left and Wasilas Range on right.

The M.V. "Yelangili", a 60 ft. coastal vessel, maintains a monthly service between Samarai and Woodlark. A grass airstrip suitable for DC-3 aircraft is located at Gausopa, at the eastern end of the island. Although not providing a regular service, Papuan Air Transport Ltd. of Port Moresby will fly passengers and freight to Woodlark, as an extension of the fortnightly service from Port Moresby to the Trobriand Islands.

The Department of Civil Aviation should be advised well in advance of any proposed landings at Gausopa so that an inspection may be made and approval granted.

Field Work.

A Bureau of Mineral Resources field party, consisting of a geologist (D.S. Trail), a chemist (A.G. Fricker), a survey hand, and twenty-two native labourers, worked on the island from May to September, 1960.

The geologist mapped an inlier of about 50 square miles of Tertiary volcanic rocks in the central southern part of Woodlark, which contained all the known gold and copper-iron mineralisation. Geology was mapped at 1:20,000 scale, using vertical aerial photographs taken by the U.S. Air Force in 1943; the map compiled from these photographs by the U.S. Army Engineers served as a base map. Vertical aerial photographs at 1: 30,000 scale taken by the U.S. Air Force in 1948 were also available. The value of geological interpretation from aerial photographs is limited by thick forest cover and the lack of differential erosion.

Geological observations were made along the rocky part of the south coast and along many creek beds. In the steep hills of the southern part of the area, fresh rubble is abundant, though outcrops are rare. In the low hills in the centre of the island, the rocks are deeply weathered.

Approximate heights above sea level on the crests of the most prominent hills were determined by corrected aneroid barometer readings.

The chemist tested a number of geochemical methods for detecting copper, lead and zinc under the prevailing conditions of high rainfall and rapid run off. Analyses of soils proved most successful and this method was applied to several areas of gold and copper-iron mineralisation by close sampling with hand augers. At Loluai and Norac on the Suloga Peninsula copper values were contoured to indicate anomalous areas possibly related to concealed mineralisation. The details of these geochemical investigations are presented as separate records but the main results are included in this report.

Previous Investigations

E.R. Stanley (1912) carried out the first geological investigation of mining activities on Woodlark Island. His report covers the regional geology, and describes in detail many gold mines and prospects.

Other reports on mining and mineral deposits on Woodlark have been made by Newman (1912), Rich (1936), Gray (1952), Broken Hill Proprietary Company Limited (1956), Thompson (1960), and Fricker and Trail (1961).

In 1955, Adastrá Hunting Geophysics Ltd. were commissioned by Broken Hill Pty. Company Ltd. to carry out an aeromagnetic survey of the Suloga Peninsula on the south coast of Woodlark.

PHYSIOGRAPHY

Woodlark Island is the crest of a well-defined broad rise in the sea floor trending about 100° and extending over 250 miles from the Lusancay Reefs in the west through the Trobriand Islands, the Marshall Bennett Islands, Woodlark, and Cannac Island, to the Laughlan Islands in the east.

Woodlark Island consists of a broad, sub-circular platform of coral limestone built asymmetrically around the eroded remnant of a Miocene volcanic pile. The platform, thirty to forty miles in diameter, is tilted gently southwards so that on the south-west it is submerged and supports living coral and a few islets of coral sand.

The south coast of Woodlark, where the platform emerges from the sea, is low and covered by mangrove swamp, except where the core of Miocene rocks forms the steep and hilly Suloga Peninsula. The hills on the peninsula are the highest on the island, reaching a height of 1,100 feet above sea level. The peninsula trends north-west for about five miles, where it is closely adjoined by Nasai Island. North-east of the peninsula the Okiduse Range extends inland for five miles, diminishing in height towards the centre of the island.

Figure 3. South coast of Suloga Peninsula looking west from Norac towards Loluai.

Figure 4. Manau Hill, an isolated volcanic vent.

From the south coast, the coral platform slopes gently upwards to form an escarpment along the north coast which reaches a maximum height of 300 feet. Terraces, escarpments, and well-defined depressions in the limestone surface which are evident in aerial photographs suggest that uplift of the coral platform may have been spasmodic and differential, with movement along fault planes. Remnants of a coral reef are preserved 380 feet above sea level on Kulumadau Hill in the centre of the island.

The isolated and steep hills at Mount Kabat and Manau Hill are eroded vents of the youngest vulcanism. No vents were recognised in the Okiduse Range or on the Suloga Peninsula. However, a zone of steep dips parallel to the south-east margin of the Okiduse Range may represent the eroded wall of a caldera-like subsidence.

In the Tertiary rocks, and in much of the coral platform, creeks occupy shallow, steep-sided valleys. East of the Okiduse Range, the Sinkurai River flows in broad meanders, incised to about 50 feet, through Recent marine clays which elsewhere underlie the coral. This rejuvenation of drainage is probably related to the latest recession of the sea when a large area of the coral platform emerged.

STRATIGRAPHY

The stratigraphy of Woodlark Island is summarized in the following table :

AGE	FORMATION	THICKNESS	DESCRIPTION
QUATERNARY		+300 feet	Swamp mud, alluvium coral limestone; marine clay, conglomerate.
	---------- UNCONFORMITY ----------		
TERTIARY (LOWER MIOCENE.)	Nasai Limestone	+600 feet	Organic limestone.
	---------- INTRUSION OF GRANITES, DYKES ----------		
	Okiduse Volcanics	+2,000 feet	Agglomerate, conglomerate, lava, tuff, ashy siltstone
	Wonai Hill Formation	850 feet	Mudstone; tuff, tuffaceous siltstone; conglomerate.
	---------- UNCONFORMITY ----------		
	---------- INTRUSION OF GABBRO ----------		
	Tabukui Beds	1,800 feet	Tuff, tuffaceous and ashy siltstone mudstone; conglomerate.
	Suloga Limestone	500 feet	Organic limestone
	---------- (?) UNCONFORMITY ----------		
TERTIARY(?)	Loluai Volcanics	+3,000 feet(?)	Thermally metamorphosed, uralitised tuffs and lavas some fine-grained sediments.

The Tertiary rocks represent a period of almost continuous volcanic activity, mainly in Lower Miocene times, during which a volcanic island or island group was created. Lulls in vulcanism are represented by fine-grained clastic sediments, limestone and coarse alluvial deposits.

I. Tertiary (?)

(i) Loluai Volcanics.

Near Suloga Point the Loluai Volcanics underlie Lower Miocene limestone with probable unconformity. Their similarity to volcanic rocks stratigraphically above suggests Tertiary age.

Interbedded volcanic rocks and fine-grained sediments crop out on the shore east and west of Loluai. The volcanic members are dark-grey to black, massive rocks, commonly sheared and indurated. They are cut by irregular veins of epidote and a few quartz veins. The rocks are fine-grained tuffs, lavas, pillow lavas, and thin agglomerates; commonly their textural features have been obscured by thermal metamorphism.

These volcanics have the composition of altered pyroxene-andesite or andesitic basalt and contain altered plagioclase feldspar, calcic andesine, and uralitised pyroxene; fresh pyroxene is rare. Both magnetite and pyrite are abundant and epidote veining is common.

The sedimentary members of the Loluai Volcanics are green, grey, red, and cream-coloured indurated siltstones and mudstones, with some shales and a few thin beds of quartzite. The sediments are well-laminated and individual beds are commonly less than one foot thick. Thin beds and nodules of blue-grey chert within the Loluai Volcanics do not persist laterally and they locally exhibit slump structures. Iron-staining is common in the weathered sediments and some thin beds of quartzite contain small lenses of rusty or steely-black hydrated iron oxides. The sedimentary members of this formation range from a few feet to 400 feet in thickness. Only the larger members are shown on the accompanying map (Plate 1).

North of Loluai, the volcanic members of the Loluai Volcanics are almost completely replaced by concordant sills of medium-grained gabbro while the interbedded sedimentary beds appear not to have been disturbed by the intrusion. Inland, similar sediments enclosed within intrusive gabbro have been seen.

Pillow lava and agglomerate crop out on Suloga Point at the south-eastern end of Suloga Peninsula. The pillow lava, with pillows up to 8 feet long, is dark and fine-grained. The agglomerate is subordinate and has sub-rounded fragments of basaltic volcanics which grade from 6 inches diameter down to a fine-grained, indurated tuffaceous matrix. The pillow lava is andesitic basalt, containing uralitised pyroxene, altered andesine plagioclase feldspar, and epidote veins.

Figure 5. Pillow lavas in Loluai Volcanics, $\frac{1}{2}$ mile north-east of Suloga Point.

Mapas Island, one and a half miles north-east of Suloga Point, is mostly gabbro containing large inclusions of indurated basalt, some of which show vague relics of pillow structure. On the southern shore of the island there are a few large boulders of cherty siltstone.

The Wasilas area, north-east of Mapas Island, is composed of andesitic basalt, similar to the volcanics at Loluai. Although locally metamorphosed by large granite dykes, some of the Wasilas rocks, particularly those at Seota Point, have retained epidote veins and pillow structure. On the shore, east of Wasilas Point, boulders of cherty siltstone are included in the volcanics.

The Suloga Point and Loluai rocks are similar and they have been grouped together as the Loluai Volcanics, at the base of the depositional succession.

The exposed thickness of the Loluai Volcanics at Wasilas is about 1,500 feet but at Loluai, if the gabbro sills have replaced volcanic rocks without dilation, the Loluai Volcanics are at least 3,000 feet thick. The base of the Loluai Volcanics was not seen.

At Loluai they are overlain unconformably by tuffs of the Wonai Hill Formation. The contact of the Loluai Volcanics with the Suloga Limestone at the southern end of the Okiduse Range is concealed, but unconformity is suspected.

II. Tertiary, Miocene

(i) Suloga Limestone

This limestone is well exposed in low cliffs along the coast on the east side of Suloga Point. Lesser exposures were seen in the low country west of the mangrove swamp between Suloga Point and Wabeo Point, and along the south-east flank of the Okiduse Range.

The limestone is dark grey to black, appearing fine-grained and massive when fresh but showing coarse bedding on weathered surfaces. Microfossils identified by D. Belford* as Lower Miocene foraminifera, are common in the Suloga Point outcrop. Small pyrite crystals were noted in the matrix and in thin calcite veins.

The maximum exposed thickness of the Suloga Limestone, about 500 feet, was seen on the south-east flank of the Okiduse Range. The limestone thins westwards from the Okiduse Range exposure and, in the Suloga Point area, it has been locally removed by erosion before deposition of the succeeding formation. This phase of erosion may also account for the complete absence of the Suloga Limestone in the Loluai area. In the Okiduse Range, the limestone grades upwards through calcareous siltstone to the fine tuff of the Tabukui Beds. The absence of a basal conglomerate member for the Tabukui Beds in this locality also suggests continuous deposition with gradual introduction of volcanic components.

(ii) Tabukui Beds

These rocks occupy most of the south-eastern part of the Suloga Peninsula, including Tabukui (1,120 feet above sea level), the highest hill on Woodlark Island.

The Tabukui Beds are predominantly green-grey, fine-grained and very fine-grained tuff and ash with subordinate siltstone and thin beds of red mudstone. They are massive to well-laminated, usually cleaved, and invariably hard and tough.

Thin lenses of conglomerate and agglomerate are common and a large lens of conglomerate, 800 feet thick and about 1,000 yards long forms the base of the formation near Suloga Point. The conglomerate is a dark grey, massive rock with sub-angular to round pebbles ranging from 6 inches diameter downwards into the poorly sorted tuffaceous matrix. Some pebbles of a dark glassy rock with a few small phenocrysts of calcic andesine plagioclase and pyroxene, may be volcanic bombs and lapilli. The matrix is a poorly sorted aggregate of angular fragments of labradorite plagioclase and uralitised pyroxene; pyrite is common throughout.

Typically, the tuffs are composed of angular fragments of andesine plagioclase, uralitised pyroxene, and some amphibole set in a fine-grained groundmass of amphibole and sericitised plagioclase feldspar. Pyrite is abundant throughout the Tabukui Beds. Some tuff members have bands containing abundant pyrite which weathers readily to limonite. Near the base of the formation, the tuffs contain small calcite crystals and (?)*Globigerina*, spp.

Stone axe-heads, known as "suloga" formerly used by natives throughout the East Papuan Islands, are made from an indurated tuff member of the Tabukui Beds. Many heaps of rock chippings from the manufacture of axe heads and other stone tools were seen on the peninsula, but no certain exposure of this rock was located.

* B.M.R. palaeontologist, (pers.comm.)

The thickest exposure of the Tabukui Beds is probably in the Okiduse Range, where about 1,800 feet thickness was seen. At Tabukui, the formation is about 1,400 feet thick; it thins northwards to about 800 feet where it is in contact with the Wonai Hill Formation. Towards Loluai, erosion, before deposition of the Wonai Hill Formation, has reduced the thickness of the Tabukui Beds to about 200 feet.

At Suloga Point, the basal conglomerate of the Tabukui Beds lies directly and probably unconformably on the Suloga Limestone. Northwards, fine-grained members of the Tabukui Beds lie on the limestone and, in the Okiduse Range, tuffs of the Tabukui Beds grade downwards into calcareous siltstones at the top of the limestone formation.

The contact between the Tabukui Beds and the Loluai Volcanics east of Loluai is not exposed. Since the tuffs of the Tabukui Beds exposed on the beach appear to strike directly into the outcrop of the Loluai Volcanics, a fault has been postulated between these two formations.

(iii) Wonai Hill Formation.

This formation occupies the high ground in the centre of the Suloga Peninsula, culminating in Wonai Hill, about 1,000 feet above sea level. This broad, gently dipping outcrop extends north-east as a narrow, more steeply dipping belt striking across Suloga Harbour and along the south-eastern front of the Okiduse Range.

Between Wonai Bay and the Ben mining area, on the west side of Suloga Harbour, the basal member of the Wonai Hill Formation is a succession of tuffaceous rocks. These are typically blue-grey, fine-grained to medium-grained, massive to well-bedded, and apparently unmetamorphosed. They are composed of broken fragments of calcic-andesine plagioclase and pyroxene crystals, partly or wholly uralitized, in a microcrystalline groundmass containing much disseminated pyrite. Thin beds of tuffaceous siltstone, shale, and conglomerate are interbedded with the tuffs.

At the Ben mining centre, a thick bed of conglomerate overlies the Tabukui Beds and grades upwards into typical tuffs of the Wonai Hill Formation. This basal conglomerate member is a dark brown-grey rock composed of sub-angular to sub-rounded fragments of volcanic rocks, ranging from 6 inches diameter down into the poorly sorted tuffaceous matrix. The fragments, which are glassy and contain a few small phenocrysts of uralitised pyroxene and plagioclase, are probably volcanic bombs and lapilli. The matrix of the conglomerate is an aggregate of fresh pyroxene, uralite and saussuritised plagioclase, with thin lenses of calcite and a calcitic cement.

Around the summit of Wonai Hill, the tuffaceous member of the Wonai Hill Formation is succeeded by a mudstone member. The mudstone is a black, very fine-grained, uniform and massive rock with a few silty lenses. It is a micro-crystalline aggregate of quartz and feldspar with a few lenses of calcite, some thin black carbonaceous bands and some small foraminifera.

In a narrow outcrop extending north-east of the Ben, the tuffaceous member thins and the conglomerate thickens. In theOkiduse Range, the mudstone member lies directly on the conglomerate.

Between the Ben and the summit of Wonai Hill, the tuffaceous member is about 600 feet thick but it thins northwestwards to about 200 feet at Wonai.

The conglomerate member attains a maximum thickness of about 300 feet in the Okiduse Range. The thickness of the mudstone is constant at about 250 feet throughout its outcrop.

North of Loluai, the tuffs of the Wonai Hill Formation lie on an irregular, eroded, surface of Loluai Volcanics and gabbro. Near Loluai the Wonai Hill Formation and the Tabukui Beds are separated by a disconformity. Disconformity may also occur at the base of the conglomerate at Suloga Point.

In the Okiduse Range, the mudstone member is succeeded by green-grey, fine-grained tuff and tuffaceous siltstone, but westwards, towards Wonai Bay, coarse conglomerate lies on the mudstone.

(iv) Okiduse Volcanics.

Green-grey tuffaceous rocks overlying the mudstone of the Wonai Hill Formation form a discontinuous basal member of the Okiduse Volcanics. They are banded, hard and tough and strongly resemble the tuffs of the Tabukui Beds.

A large lens of these green-grey tuffaceous rocks in the Okiduse Range and in the Suloga Peninsula is succeeded by a thick group of dark grey lavas, tuffs, and volcanic agglomerates and conglomerates. These volcanics form the bulk of the Okiduse Range, and large inliers within Quaternary sediments at Busai and Kulumadau. The rocks of Manau Hill and Mount Kabat have been grouped with the Okiduse Volcanics.

The Okiduse Volcanics are massive, porphyritic and nonporphyritic rocks. In the conglomerates and agglomerates, fragments may be angular or well-rounded and range from 2 feet in diameter down to coarse tuff size. Tuffs were recognised only where they are associated with agglomerates and conglomerates; elsewhere, they are fine-grained, indurated rocks, indistinguishable in hand specimen from lava.

This volcanic succession has an essentially andesitic basalt composition with calcic-andesine plagioclase feldspar and pyroxene. The pyroxene is commonly altered to uralite or actinolite. Calcite pseudomorphs after plagioclase and pyroxene are common. Pyrite is common to abundant and leucoxene has been noted in thin section.

A few light-grey rocks of apparently dacitic compositim are included within the Okiduse Volcanics.

The Okiduse Volcanics have a maximum exposed thickness of 2,000 feet. Since these rocks have been subjected to erosion from Miocene times and the present low level of erosion exposes coarse-grained granites, it is probablo that the original thickness may have been considerably more than that now exposed.

There is no evident regularity in the distribution of volcanic agglomerate within the main outcrop of the Okiduse Volcanics. The agglomerates may have been deposited near vents but these have not been identified.

Three outcrops of coarse-grained volcanics at Kulumadau, Mount Kabat and Manau Hill, which are isolated from the main mass of this formation may represent sites of the most recent volcanic activity.

At Kulumadau, a triangular patch of volcanic conglomerate about 500 yards long lies on lavas or tuffs. A boulder of medium-grained tuff found within this conglomerate outcrop contained abundant oyster shells and carbonised wood. The conglomerate is probably a young member of the Okiduse Volcanics and may lie near the centre of latest activity at Kulumadau.

Mount Kabat, an isolated hill 4 miles east of Kulumadau, is probably an eroded remnant of a late-stage volcanic vent. It is composed of coarse volcanic agglomerate and conglomerate. Angular and round fragments in these rocks range from 2 feet diameter down to a medium-grained, fragmental matrix. The fragments are black, very fine-grained and contain small phenocrysts of feldspar and pyroxene in a glassy groundmass.

Manau Hill, another isolated volcanic outcrop on the north side of Wonai Bay is regarded as a vent of the most recent eruptive phase. At this locality volcanic agglomerate and well-bedded tuff surround a well-defined circular vent filled with coarse volcanic breccia.

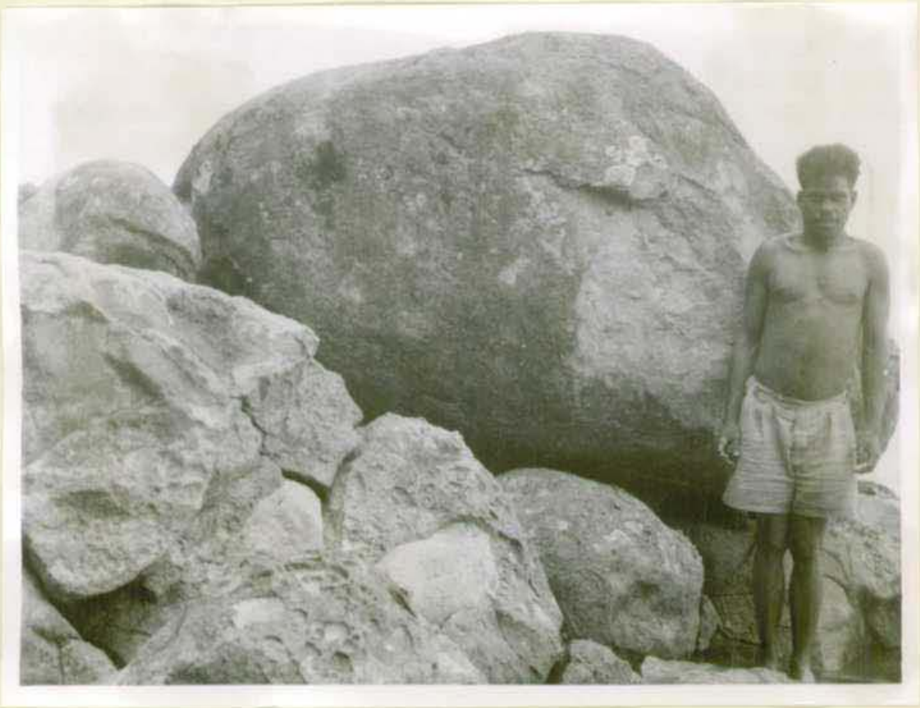


Figure 6. Vent breccia on shore near Manau Hill.

(v) Nasai Limestone.

Nasai Island and the western end of the Suloga Peninsula are composed of gently dipping Lower Miocene limestone lying with marked unconformity on the Loluai Volcanics and the gabbro sills intrusive into them.

When weathered the Nasai Limestone is light-grey and bedding is obvious. The fresh rock is dark-grey to black, very fine-grained, massive, and hard. Lower Miocene, "e"stage, foraminifera are locally abundant in the limestone.

There is no pyrite visible in the Nasai Limestone, it is unaffected by igneous activity, and it contains no detrital or pyroclastic material. Hence, the Nasai Limestone is thought to be younger than the Okiduse Volcanics, though its field relationships indicate only that it is younger than the intrusion of the gabbro.

The present-day thickness of the Nasai Limestone is about 600 feet, but this was no doubt originally much greater before the limestone was weathered into its present rugged outcrop.

Figure 7. Nasai Limestone, west coast of Nasai Island.

III Quaternary

Along the south-east and north-west flanks of the Okiduse Range, around the large volcanic outcrop containing Busai and Reilly's Creek, and at the north end of the Kulumadau inlier, the volcanic rocks are overlain unconformably by soft blue marine clays and silts containing large and thick lenses of boulder and pebble conglomerate. The abundant marine macrofauna found in some clays is apparently Recent; other clays carry carbonised wood and seeds.

At McKenzie's Creek, the clays become more calcareous upwards and grade into the overlying coral limestone.

At Busai and in Reilly's Creek, the coarse conglomerate beds in the clays have been successfully washed for gold.

East of the Okiduse Range, the Sinkurai River and its tributaries reveal extensive exposures of blue marine clay and interbedded conglomerate. The plain of the Sinkurai River is probably composed dominantly of clay, with little overlying coral.

West of the Okiduse Range, the clays are probably no more than 50 feet thick. In the plain of the Sinkurai River, the clays may be hundreds of feet thick.

Raised coral limestone forms the bulk of Woodlark Island. The rock is a yellowish-white limestone commonly recrystallised by solution and re-deposition to coarse calcite. Coral remains and marine shells are found locally. Caves and sink-holes are common throughout the limestone outcrop.

Along the north coast, the coral is more than 300 feet thick. In the centre of the island it is about 50 feet thick, and many creeks have cut through the limestone into underlying clay or alluvium. The limestone is thin or absent along the south coast of the central part of the island.

Large areas of low coral platform are covered by thin swamp muds composed almost entirely of organic material.

Around the volcanic outcrops, fine and coarse sediments containing alluvial gold have accumulated on top of the coral limestone. Stanley (1912) recorded that at Busai in a sandy loam below the surface clay a stone pestle and mortar were found. Such implements are unknown to the present native inhabitants of Woodlark Island (R.C. Neate, pers. comm.).

INTRUSIVE IGNEOUS ROCKS.

The gabbro sills in the Loluai Volcanics and the Tabukui Beds are the earliest intrusives. The granite intrusions described by Stanley (1912) range from granite to diorite, have a variety of textures and intrude all formations older than the Nasai Limestone. Lamprophyre dykes are confined to a small area about a mile east of Wonai Bay and basalt dykes are associated with the young volcanics at Mount Kabat.

Vent Breccia.

At Manau Hill, coarse breccia forms a circular outcrop, about 400 yards in diameter, surrounded by volcanic conglomerate, agglomerate, and bedded tuffs. The breccia is composed of large angular and broken blocks of reddish porphyritic andesite or basalt in a matrix of small broken rock fragments. The breccia outcrop is the surface expression of a volcanic vent.

Gabbro

Between Loluai and Wonai Bay, the thick volcanic members of the Loluai Volcanics are invaded and almost completely replaced by gabbro sills. Uskweilele, a hill above Suloga Point, is capped by a gabbro sill overlying pillow lavas of the Loluai Volcanics, and, about one mile north of Uskweilele, on the eastern slope of Tabukui, sill-like masses of gabbro have invaded the conglomerate member at the base of the Tabukui Beds. The gabbro sill on Uskweilele probably occurs in the position originally occupied by the conglomerate. Mapas Island is composed almost entirely of gabbro.

The gabbro is a dark grey, medium-grained, massive rock commonly containing basic volcanic xenoliths. In hand specimen, the feldspar is greenish-grey and forms about 50% of the rock. Many gabbro specimens contain abundant magnetite which is obvious on crushing. The rock has an ophitic texture with laths and plates of sodic-labradorite plagioclase partly embedded in large plates of augite. Green amphibole has replaced the pyroxene to a limited extent; a very small amount of quartz is present interstitially. At Mapas, veins of epidote were seen in the gabbro.

The gabbro sills of the Loluai area have a total thickness exceeding 2,000 feet. The sill east of Tabukui is probably about 300 feet thick. The form of the gabbro intrusion at Mapas is unknown.

North-west of Loluai, thin selvedges of fine-grained basic rock commonly lie between the gabbro and the undisturbed beds of siliceous sediments within the sill complex. These selvedges are probably remnants of the volcanics replaced by the gabbro. Large inclusions of volcanics are common within the gabbro.

Skarn rock is developed at the margin of the gabbro sill complex at Loluai and at Watavai Creek, 600 yards north-east of Loluai. Skarn rock also occurs at Norac, on the west shore of the south-east arm of the Suloga Peninsula. Samples of skarn from Norac have analysed from 0.2% to 6% copper.

The skarn is a reddish, massive, friable rock composed of garnet crystals with fine-grained interstitial epidote, and some quartz and calcite; pyroxene is rare.

This garnet-epidote rock was probably formed by metasomatic alteration of limestone (Magnusson, 1936). Presumably at Loluai and Watavai Creek, limestone, originally as sedimentary members of the Loluai Volcanics, has been completely altered to skarn during the intrusion of the gabbro.

The gabbro sill emplaced in the conglomerate member of the Tabukui Beds, 1½ miles east of Norac, is the nearest large intrusive body to the Norac skarn and iron-copper mineralization.

This gabbro may extend westwards along the base of the Tabukui Beds to approach the Norac area, and the skarn is possibly the altered continuation of the Suloga Limestone exposed at the base of the Tabukui Beds in a gentle anticline.

The magnetite bodies within the skarn outcrops at Loluai and Norac have been described in detail by Thompson (1960). These dyke-like lodes which are from 5 feet to 50 feet wide, and trend about 170° are composed of massive and crystalline magnetite and hematite with small quantities of garnet, epidote, quartz, pyrite, (?) chalcopyrite, and secondary copper minerals. The magnetite boulders on Mapas are probably derived from a similar body. These magnetite bodies are concentrations of the latest expressed, fugitive constituents of the gabbro magma, and they have been deposited in tension fissures. Magnusson (1936) suggests that such concentrations may form at relatively low temperatures.

The contact of the gabbro with the Suloga Limestone which crops out from Wabeo Point for about 1½ miles south towards Uskweilele, is not well exposed but appears to be a sharp contact between medium-grained gabbro and limestone which is recrystallised but otherwise unaffected by the intrusion.

The fine-grained and coarse-grained members of the Tabukui Beds in contact with the gabbro, are no more indurated than those distant from obvious igneous intrusives. A small intrusive quartz mass within the conglomerate at the old Suloga mining centre may be a differentiate of the gabbro.

In Elliott's Creek, near Wonai, the contact between gabbro and granite is gradational with a hybrid medium-grained dioritic rock formed along the margin of the granite by reaction with the gabbro.

Granite, Porphyry, and Felsite.

In the Okiduse Range and at Granite Point, in the Wasilas area, rocks of almost the entire Tertiary succession are intruded by large and small dykes and dyke-like masses of granite and porphyry. These intrusives extend westwards into the Suloga Peninsula and northwards into the Busai inlier. Felsite dykes intrude the volcanic rocks at Kulumadau.

Coarse-grained biotite-hornblende granite with elongated xenoliths of basic volcanic rock crops out at Granite Point. This granite contains 3mm. laths of hornblende and plates of biotite scattered through a medium-grained groundmass of orthoclase, albite plagioclase and minor quartz and pyrite.

In many exposures, large aggregates of corroded hornblende crystals adjoin ill-defined basic xenoliths and broad veins of acid differentiate. Some of the hornblende, at least, seems to have been derived by reaction during intrusion of acid magma into pyroxene-bearing andesitic basalts. In one exposure, a medium-grained felsic granite cuts the typical coarse-grained hornblende granite.

The intrusive bodies mapped in the Okiduse Range, the Wasilas area, Suloga Peninsula, and the Busai inlier, cover a wide petrological range. Most of the intrusions are medium-grained hornblende granites and associated porphyries composed of feldspar and dark mineral phenocrysts in a fine-grained groundmass. Biotite granite is rare.

The typical yellow-weathering, medium-grained, hornblende granite, though commonly lacking biotite, resembles, in hand specimen, the granite of Granite Point. It is quite unlike the dark fine-grained Okiduse Volcanics, yet the contact between a large mass of granite and these volcanics is rarely distinct.

Near the granite contact, feldspar crystals and crystals or granular clumps of ferromagnesian minerals of the volcanics are larger than average. At the granite contact, the volcanics grade into a porphyry within which the fine-grained groundmass is more felsic, feldspar crystals are large and the dark minerals form clots of enlarged, frayed and corroded crystals. Inclusions of granular basic volcanics are common within this contact porphyry. A zone of volcanics intensely veined by felsic fine-grained granite occurs near the contact of some large granite bodies.

The boundary between granite and porphyry is usually well defined, though gradational boundaries are known.

The porphyries have been mapped as intrusive rocks where they are sufficiently distinct from the volcanics. In some intrusive bodies only porphyry was seen. Large masses of porphyry and of altered volcanics are common within the large granite masses. Although the porphyries are probably metasomatic and not intrusive, they are so closely associated with the granites that they were mapped with the granite.

In the Wasilas area, where the Loluai Volcanics are intruded by granite dykes, a zone of medium-grained diorite is commonly found for a few feet around the margins of the dykes. In some places a narrow zone of ultrabasic rock, probably pyroxenite, follows the contact between the diorite and the volcanics.

Felsite boulders are abundant in north-west flowing creeks in the central part of the volcanic outcrop at Kulumadau. No exposure of felsite was found but the boulders are probably derived from dykes which form ridges bounding the creeks. The felsite is typically composed of 5mm. laths of feldspar in a blue-grey, very fine-grained matrix. Boulders of quartz in these creeks may be associated with this felsite.

Most of the granite contacts observed are vertical and none inclined less than 60°.

On Suloga Peninsula, the linear granite intrusives strike between 040° and 080°, towards the granites of the Okiduse Range, with which they are undoubtedly comagmatic. In the Wasilas area, and in the Okiduse Range, the granite contacts trend predominantly between 120° and 150°. In the hills around the headwaters of the Sinkurai River the granite intrusives are arranged in a semi-circle centred near the boundary of Tertiary and Quaternary rocks on the Sinkurai River.

Minor Intrusions

Diorite dykes are common in the Loluai Volcanics along the shore both east and west of Loluai. On the shore, one mile east of Loluai, two diorite dykes cut the Tabukui Beds. The intrusive at Norac described by Thompson (1960) as a granodiorite may be a diorite dyke.

The dykes are porphyritic or non-porphyritic, fine-grained and medium-grained rocks. The porphyritic dykes have a microcrystalline groundmass of saussuritised feldspar laths and dark minerals with phenocrysts of andesine plagioclase and hornblende; pyrite and magnetite are accessory.

The diorite dykes range from a few feet to about 20 feet in thickness and trend between 160° and 180°. Their contact with country rock is often irregular though petrologically abrupt. Some dykes show marginal chilling; others are even-grained right to their contacts.

At Loluai diorite dykes which cut the gabbro are probably tongues from the hornblende granite intrusives.

Lamprophyre dykes between 10 feet and 20 feet wide with various trends intrude the mudstone member of the Wonai Hill Formation, and the adjacent granite east of Wonai Bay. The dykes are grey, very fine-grained and porphyritic. In some places they have biotite phenocrysts, elsewhere hornblende phenocrysts, in a feldspathic groundmass. These rocks were classed as lamprophyres in the field; they are younger than the granite.

Half a mile west of Suloga Point, a one foot dyke and a 9 inch discordant sill of light grey, very fine-grained (?) dacite cut the Suloga Limestone; they trend 005° and the sill dips 45° eastwards.

Poorly exposed basalt dykes up to 25 feet thick cut the volcanic agglomerate and conglomerate at Mount Kabat. One such dyke trends 160°. They are black, very fine-grained and contain phenocrysts of a bronze-coloured dark mineral.

In a large creek, 1,200 yards east of Loluai, a dyke of black, coarse-grained hornblende pyroxenite about 2 feet wide and trending 170° cuts tuffs of the Wonai Hill Formation. The pyroxenite is composed almost entirely of large crystals of augite and brown hornblende with a few altered indeterminate feldspar crystals in a sparse groundmass of light green amphibole.

METAMORPHISM AND METASOMATISM

The metamorphism observed on Woodlark is all of contact type.

The contact metamorphism of the volcanics by the granite intrusions has been described above. Some of the volcanic components have been absorbed by the granite to form mafic constituent minerals, and other volcanic rocks have been metasomatically altered to porphyries of intrusive appearance.

The gabbro sills in the Loluai Volcanics and the Tabukui Beds must have absorbed large quantities of the country rock, which had a composition almost identical with gabbro. So selective is the intrusion of the gabbro into the Loluai Volcanics, apparently without dilating the succession, that the volcanic rocks may merely have been re-melted or absorbed in a relatively small amount of magma, to recrystallise slowly with almost the same composition and volume as before, but with a coarser, gabbroic, texture.

The skarn rock at Loluai and Norac has probably been produced by the contact metamorphism and metasomatic alteration of limestone. Harker (1950) recorded that iron from igneous intrusives may combine with limestone to form garnet. This conversion of limestone to garnet rock involves considerable reduction in the volume of the rock, and excess iron and other ore minerals emanating from the intrusive are deposited in pore spaces created by the reduction in volume. Magnusson (1936) suggested a similar mode of formation for the skarn iron ores of Central Sweden.

The source of the high silica content in the sediments of the Loluai Volcanics is not known. It may be a depositional characteristic of sediments inherited from siliceous waters adjacent to mildly active volcanoes, or silicification of the sediments may have accompanied the intrusion of the gabbro.

Epidote veins are confined to the volcanic members of the Loluai Volcanics. The veins may have been produced in a phase of metamorphism preceding the gabbro intrusion or they may result from the metamorphism of calcite veins during the emplacement of the gabbro.

In all thin sections examined, pyroxene was wholly or partly altered to amphibole, commonly uralite. Uralitisation of pyroxene may be a normal process undergone by igneous rocks while cooling (Harker, 1950), but the fine-grained Tertiary volcanic rocks of Woodlark Island presumably cooled rapidly, and pyroxene was probably not altered until later thermal metamorphism. The widespread replacement of pyroxene by uralite throughout the volcanic succession indicates that all these rocks have been more or less uniformly affected by thermal metamorphism.

The Tertiary rocks of Woodlark Island in late Tertiary time occupied a deep level in a large, active volcanic complex. The uralitisation of pyroxene in all the rocks, and the indurated appearance of many, are not related to any single phase of intrusive igneous activity, but are the results of repeated reheating of deep levels in a volcanic complex beneath a thick blanket of younger volcanic rocks which has since been removed by erosion.

STRUCTURE

Regular folding is confined to the Loluai Beds and steep dips exist only in a monoclinal zone along the south-east flank of the Okiduse Range. Lack of bedding and the paucity of exposure hinder structural interpretation. Faults, in particular, are difficult to locate and of the many faults that undoubtedly exist, only a few could be mapped.

In the sedimentary members of the Loluai Volcanics, the northerly sheet dip steepens steadily northwards, from 10° on the coast west of Loluai to reach 40° at Wonai. Within this regional monoclinal structure, the sediments are folded into gentle synclines and anticlines whose axes pitch north with the sheet dip and whose limbs dip gently north-east and north-west. The copper-bearing skarn at Loluai lies in the trough and along the west limb of a gentle syncline within this system. The fold pitches north at about 15° and the limb dips about 15° north-east.

The folding observed in the sedimentary members, and the shearing and veining in the volcanic members of the Loluai Volcanics are apparently the results of an episode of deformation which preceded the deposition of the succeeding formation, the Suloga Limestone.

The Tabukui Beds dip north at 040° to 080° in a zone which extends inland from Suloga Harbour along the south-east flank of the Okiduse Range. Farther north, the conglomerate and mudstone of the Wonai Hill Formation dip about 030° northwards, and the sheet dip decreases northwards to sub-horizontal in the Okiduse Volcanics.

This zone of northerly dips continues westwards into Suloga Peninsula, where the monocline is less steep. North of Makete Hill, the Tabukui Beds are cleaved where they dip gently under the Wonai Hill Formation, and dips are horizontal again a short distance to the north. The basal conglomerate member of the Wonai Hill Formation on the west side of Suloga Harbour dips north at about 050° as a continuation of the steep monoclinal zone.

This steep monoclinal zone is regarded as the result of caldera collapse rather than lateral compression. To indicate this diagrammatically, a normal fault in the older, and possibly more competent, Loluai Volcanics beneath the Tabukui Beds is shown in Section G-H (Plate I).

This collapse may have followed the first outpouring of the Okiduse Volcanics from a centre north of the steeply dipping zone. The weight of the accumulating pile of pyroclastics on the country to the north combined with the expulsion of the volcanics supporting it, might result in large-scale subsidence bounded by faulting and deformation of this type.

At Suloga Point, the Suloga Limestone abuts against the Loluai Volcanics along a north-trending fault with a vertical displacement of about 200 feet. This fault was probably active during deposition of the Suloga Limestone but had ceased activity before the deposition of the basal conglomerate of the Tabukui Beds.

A north-trending fault with a vertical displacement of about 100 feet extends from the coast at Loluai along the upper valley of Loluai Creek. A low scarp of skarn forming the west bank of the upper part of Loluai Creek marks the fault; it is also indicated by an abrupt change in the copper content of the soils on either side of Loluai Creek from 100 ppm. on the west to 2000 ppm. on the east (Trail and Fricker, 1961). This fault is the east boundary of the cupriferous skarn at Loluai and is also the western limit of the Wonai Hill Formation.

One mile east of Loluai, a north-trending fault with a vertical displacement of about 200 feet has been inferred to explain discordant strike between the Loluai Volcanics and the Tabukui Beds. This fault has probably not been active since deposition of the Wonai Hill Formation.

A fault trending about 080° and dipping 045° north cuts the Loluai Volcanics on Nasai Island. Another fault trending between 140° and 160° and dipping at 070° east was seen in the Nasai Limestone on the west coast of Nasai Island. The vertical displacement on both these faults is unknown.

Indications of faulting and shearing, mainly with trends between 160° and 180°, are common throughout the Okiduse Volcanics. In the areas previously mined for reef gold, the gold-bearing lodes are zones of blue pug occupying faults or shear zones ranging from a few inches to one hundred feet wide.

Almost all faults observed on Woodlark Island trend between 160° and 180°; this is also the strike of the magnetite lodes, and the diorite dykes of the Suloga Peninsula. The persistent northerly trend of faults and dykes suggests regional east-west tension.

Van Bemmelen (1949) postulates a non-volcanic outer arc of the D'Entrecasteaux orogenic system extending from the Lusancay Reefs to the Laughlan Islands and a volcanic inner arc along the "tail" of Papua and the D'Entrecasteaux Islands. This interpretation seems unlikely as Woodlark Island is composed entirely of volcanics, clastic sediments derived from these volcanics, and limestone. The nearby island of Cannac, also on van Bemmelen's proposed non-volcanic arc, is probably also composed of volcanic rocks, for Stanley (1917b) stated that the rocks of Cannac are similar to the rocks of the south coast of Woodlark Island.

The Lusancay - Laughlan submarine swell may be a drowned or eroded belt of Tertiary volcanoes, parallel to the belt of dormant Recent volcanoes which extends from Dobu to Goodenough Island, in the D'Entrecasteaux group.

GEOLOGICAL HISTORY

The Suloga Limestone, near the base of the Tertiary succession on Woodlark Island, and the Nasai Limestone, at the top of the Tertiary succession, both contain Lower Miocene "e" stage foraminifera *. Most of the Tertiary rocks of Woodlark Island were probably extruded or deposited in a comparatively short time.

During Lower Miocene time, the Woodlark area was a group of volcanic islands subject to alternating rapid growth by accumulation of ejecta during eruptive periods and rapid mass erosion to low islands, shoals and shallow submarine platforms. Coral reefs developed in the shallow areas and protected from heavy sedimentation and during periods of volcanic/erosional stability.

The remarkable growth and denudation of the Krakatau group of islands within the last century (van Bemmelen, 1949) and at Isla San Benedicto (Richards, 1959) demonstrates the rapidity with which a group of volcanic islands may spectacularly change their form.

During deposition of the Loluai Volcanics, flows of andesitic basalt flowed over volcanic islands, and pillow lavas formed in the surrounding sea. The quiet extrusion of lava was interrupted by periods of explosive activity when large showers of tuff and agglomerate built up the islands both vertically and laterally.

* D. Belford, B.M.R. palaeontologist, (pers.comm.)

When an eruptive phase temporarily ceased, the soft pyroclastics of the volcanic pile were rapidly eroded by rain and waves and redeposited as fine marine sediments around remnant islands. Silicification of these sediments may be due to volcanically derived silica in the depositional environment or alternatively, to the later gabbro intrusion. The Loluai Volcanics were subjected to compressive folding and shearing some time before the deposition of the Suloga Limestone, and they may be considerably older than Lower Miocene.

During a prolonged period in which there was no volcanic activity, the Suloga Limestone was deposited, probably as a reef around a low island or shoal of deeply eroded Loluai Volcanics. The deposition of the limestone was immediately followed by intense and prolonged explosive volcanic activity which built up a high volcanic land mass composed of the Tabukui Beds. The thick coarse conglomerate with volcanic components at Suloga Point may lie close to this eruptive centre. During the building of the Tabukui pyroclastic pile, gabbro sills were intruded into the underlying Loluai Volcanics and into basal levels of the Tabukui Beds possibly from the magma chamber from which the eruptive rocks were derived. Limestones adjacent to these intrusives were metasomatized to skarn with accompanying shrinkage and development of north-trending tension openings, into which magnetite-hematite mineralizing fluids were injected.

When the volcanoes became dormant a great thickness of soft pyroclastic rock was again washed away before renewed eruptions deposited the tuffs of the Wonai Hill Formation on an irregular erosion surface. This was a short-lived outburst followed by a long period of subdued erosion of a low-lying, forested and swampy land mass to produce the uniform mudstone of the Wonai Hill Formation.

Prolonged and vigorous volcanic activity then accumulated the very thick pile of lavas, tuffs, and agglomerates, now represented by the Okiduse Volcanics. The monoclinal zone bounding the present Okiduse Range may be due to regional collapse around the centre of this volcanic activity.

After a very thick volcanic pile had accumulated, granite intruded the lower levels of the Okiduse Volcanics and underlying rocks. The felsite dykes and eruptive dacitic rocks at Kulumadau suggest that while the granite was intruding lower levels of the pile, volcanic activity at the surface was more acid than usual. The diorite and lamprophyre dykes were probably emplaced in the latter stages of the eruptive phase which produced the Okiduse Volcanics.

The isolated andesitic and basaltic vents at Manau Hill and Mount Kabat probably represent the last expression of a long history of vulcanism.

The exact position of the Nasai Limestone in the stratigraphic succession is uncertain, but it is probably younger than the Okiduse Volcanics and was deposited as an extensive fringing reef around the volcanic land mass after volcanic activity had ceased.

The erosion of the thick pile of the Okiduse Volcanics has probably proceeded, more or less continuously, from the Lower Miocene to the present day. Small changes in sea level in at least Pleistocene and Recent times have produced alternations of coarse-grained fluviatile and fine-grained marine sediments derived from and deposited around the volcanic hills. While these sediments were being laid down, coral grew extensively wherever the environment was favourable, in some places on earlier terrigenous sediments derived from the volcanics.

After the latest lowering of sea level, alluvium was deposited on the coral. This alluvium contains relics of human habitation which the present-day natives of Woodlark Island do not recognise.

ECONOMIC GEOLOGY

History

The history of the economic mining on Woodlark Island has been compiled from reports by Stanley (1912, 1917a), Thompson (1960), and various Mining Warden's Reports (1910-1926).

In 1895, alluvial gold was discovered on Suloga Peninsula, in the Okiduse Range, and in the Bonivat-Karavakum area. Gold was next discovered at Kulumadau and a rich alluvial deposit which yielded several thousand ounces, was found in McKenzie's Creek. About the same time gold was found in Coleman's Creek at Busai. Alluvial gold was also won at Sinkurai near the head of the Sinkurai River, Reilly's Creek, Wonai and the Ben on Suloga Peninsula.

When the gold-bearing soil was sluiced off, gold lodes in bedrock were uncovered in many places and lode mining followed. Lode mining commenced at Kulumadau in 1900 and at Busai in 1902. An open cut on the McKenzie's Creek lode began in 1906; in 1910, gold was being produced from lodes at Karavakum and late in 1911 lodes were found and worked at Wonai.

By 1912, the Kulumadau (Woodlark Island) Gold Mining Company had a mine at Kulumadau developed vertically over 400 feet on five levels. This was the only mine on Woodlark Island to overcome the serious underground water problem which has frequently been quoted for the failure of several smaller mines. The Kulumadau mine produced between 2,500 and 6,000 ounces of fine gold each year until the company went into liquidation in 1918.

The other principal lode-mining centres were Busai and Bonivat-Karavakum. Mining was hampered by abundant water underground and by a shortage of water at the surface. The "Federation" and the "Murua United" at Busai, the "Woodlark King" at Bonivat, and the "Little McKenzie" at Karavakum were the most successful and lasting. Many other small mines were worked down to the water table with varying success.

Lode mining activity declined after 1918 and was at a very low ebb in 1925, but the "Federation", the "Murua United", and the "Woodlark King" mines continued through the 1930's. The "Woodlark King" at Bonivat closed in 1942.

In 1957, R.C. Neate produced some gold from an adit driven in the main lode at Kulumadau. In 1952, G.J. Gray, consulting mining engineer, sampled and reported on exposures in the old open cut at Kulumadau but the underground workings were inaccessible.

From 1895 to 1932, the total production of gold from Woodlark Island is recorded as 207,850 ounces, but much of the gold from the early alluvial mining was probably not recorded.

The history of investigation of the copper-iron mineralisation on the Suloga Peninsula is given in detail by Thompson (1960).

In 1914, Captain A.S.R. Osborne, manager of the Dubuna Copper Mine near Port Moresby, examined the copper deposit at Norac. In 1917, a small quantity of ore averaging 10% copper was exported to Australia from Suloga Peninsula and exploratory work continued at Loluai until 1918, though no returns were made for that year.

Geologists of the Broken Hill Proprietary Company Ltd. examined Loluai and Norac in 1954, and an aerial magnetic survey of the Suloga Peninsula was made for this company in 1955.

In 1956, J.E. Thompson made a detailed survey of the iron-copper deposits at Loluai and Norac.

Mr. R.C. Neate, the current leaseholder, shipped a ten ton parcel of hand-picked copper ore from Loluai to Japan for assaying in 1957.

Alluvial Gold Deposits

Traces of small alluvial workings are found everywhere within the outcrops of the Tertiary rocks, including the inliers at Mount Kabat, Manau Hill, and in the Wasilas area, though there are no records of production from these three localities.

Many of the early gold workings were on eluvial concentrations of gold in the soil from the in situ weathering of lodes. Small alluvial deposits were commonly found in small gullies where the coarse and little worn gold had been transported, mainly by soil creep, and concentrated in the gullies.

The alluvial gold has been derived from several rock types. The most extensive deposits were shed from Okiduse Volcanics and from granites and porphyries intrusive into these volcanics. The alluvial gold in the Suloga mining area was apparently derived from the Loluai Volcanics, the Tabukui Beds and possibly the gabbro sill at Uskweilele. The Ben and Wonai alluvial mining areas probably derived their gold from the Wonai Hill Formation and from the granite intruding it.

At Busai and Reilly's Creek thick deposits of conglomerate within the marine clays older than the sub-horizontal raised coral were profitably worked for gold. In the 1930's, an inconclusive attempt was made to prove a dredging area in the conglomerates interbedded with the marine clays south of Busai, though good values of gold were obtained. (R.C. Neate, personal communication.)

Little attention has been paid to the extensive Recent gravel deposits east of the Okiduse Range, along the course of the Sinkurai River. Gravel beds up to 50 feet thick were observed in the banks of the Sinkurai River within Recent sediments which may be several hundred feet thick. If these coarse beds carry profitable quantities of gold, a large dredging area would be available in flat, well-watered country extending eastwards along the plain of the Sinkurai River. An indication of the gold content of these gravels could easily be obtained by dish-prospecting in the steep banks exposed by the Sinkurai River. Further detailed testing by drilling would be necessary to prove the field.

Lode Gold Deposits.

During the survey, only a few weathered reefs were located at Karavakum and Kulumadau. Other reefs recorded by Stanley at Kulumadau, Busai, McKenzie's Creek, Bonivat-Karavakum, Okiduse, and Wonai are concealed by vegetation, rock detritus, and mud.

(i) Kulumadau.

The Kulumadau inlier is an isolated outcrop of volcanic rocks cut by a few felsite dykes. The outcrop measures about one and a half miles, north to south, by three-quarters of a mile east to west. It is surrounded by Recent coral limestone, and small outliers of coral occur up to 400 feet above sea level within the inlier.

The entire outcrop has been investigated by prospectors. The most important workings are in the southern part which was mapped in detail by Stanley (1912). During this survey, only the lode in Kayao Creek, the "Great Northern" lode and the main Kulumadau lode were found and examined with the assistance of local natives.

The Kayao Creek lode is a shear zone about 4 feet wide and trending about 170°, within carbonated volcanics. The shear is filled with rock fragments and hard and soft blue pug. The pug carries abundant pyrite, some galena, and gold. This lode was recorded by Stanley (1912) as the lode on Lease 31 which prospected at one ounce of gold to the ton.

The "Great Northern" lode is 6 to 8 feet wide and trends about 110°, an uncommon trend on Woodlark, and ranges in dip from 60° north to 60° south. The lode is a shear zone within brecciated volcanics and is composed of rock fragments in an abundant matrix of blue pug. Both oxidised and fresh pyrite occur at outcrop. In places the lode yields a good dish prospect for gold. Stanley recorded this as the large lode on Lease No. 32, assaying 3 dwts of gold per ton.

At Kulumadau, the main lode is exposed in the old open cut as a shear zone about 100 feet wide, trending 170° and dipping almost vertically. The shear zone contains fragments of carbonated volcanics in a matrix of blue pug with abundant pyrite; the gold appears to be concentrated in the pug. The footwall of this lode is carbonated volcanic rock.

J.M. Newman reporting on the Kulumadau (Woodlark Island) Gold Mining Compan's mine in 1912 recorded that the main Kulumadau lode is 700 feet long and ranges from 18 inches to 20 feet wide and that it was worked to a depth of 400 feet. The lode strikes north and dips 80° east. Sampling on No.4 level indicated an average gold content of 14 dwts per ton for 140 feet over an average width of 6 feet. Towards the north end of the lode, a gold-enriched zone over 100 feet long adjoining a fault was also noted by Newman.

Stanley (1912) and Mining Warden's Reports (1910-1919) give details of production from the Kulumadau mine. Available, but probably incomplete, records indicate that between 1901 and 1912 the Company produced about 40,000 ounces of gold from about 40,600 tons of ore, by crushing and cyaniding. The total production from the mine between 1901 and 1918 was about 69,000 ounces of gold from about 110,000 tons of ore. When the mine closed the Mining Warden (1918) considered that it could be profitably worked as a low-grade proposition, though ore reserves are quoted as only 8,000 tons. The shafts at Kulumadau have collapsed and underground workings are no longer accessible.

When G.J. Gray, consultant mining engineer, visited the mine in 1952 he sampled exposures of the lode and the surrounding country rock. Gray concluded that the reserves of low grade ore in the vicinity of the mine, and the large quantities of tailings and leached ore at the surface might justify a revival of mining on a large-scale low-grade basis.

(ii) Busai

The Busai mining centre is about 3 miles south-east of Kulumadau, at the west end of a large outcrop of volcanics extending north-west from the north end of the Okiduse Range.

The lodes mapped by Stanley (1912) and the large open cut on the "Murua United" lease are now obscured by rubble and bracken. The party did not locate any lodes at Busai, but Messrs. Neate and Darsen have since sampled reefs on the "Federation" and "Vulcan" leases in the Busai area.

Pyritic shear zones are common in both granite and volcanic rocks which are exposed in creeks at Busai and in Reilly's Creek nearby. Stanley described one blue quartz lode and lodes of blue sulphidic pug veined with quartz and calcite. Most lodes at Busai are probably shear zones similar to those at Kulumadau and Karavakum.

(iii) McKenzie's Creek.

At McKenzie's Creek, 1¾ miles south-east of Busai, Stanley (1912) described a lode of ferruginous quartz, 15 feet wide with very rich pockets of gold both in the lode and in the decomposed porphyry around it.

(iv) Bonivat - Karavakum

Bonivat and Karavakum are located on a broad, low rise extending about 1½ miles north-west from the north-western flank of the Okiduse Range. The outcrops are mainly intermediate porphyry with a network of granite dykes and numerous inclusions of volcanic rocks.

The gold mines of the area were mapped and described by Stanley (1912) when they were most active. Lode mining began at Karavakum in 1910 and by 1917 most mines had been developed and possibly worked out down to the water table, about 70 feet below the crest of the rise. The problem of dewatering was tackled with some success at the "Woodlark King" mine at Bonivat, and production continued from shallow levels in this mine until 1942.

During this survey a few of the lodes mapped by Stanley were recognised in creeks at Karavakum. Though weathered, they are evidently shears in granite, porphyry, and metamorphosed volcanics. They are grey pug zones containing rock fragments and in some places have a soft calcitic matrix. The lodes seen ranged from 1 to 4 feet in width and trend about 170°.

Stanley (1912) recorded lodes up to 20 feet wide composed of fault breccia with quartz, calcite, iron oxide, manganese oxide, and sulphides. The lodes of the Karavakum area trend between 160° and 180°, and the "Woodlark King" lode at Bonivat trends 140°. All the lodes dip steeply. Gold-bearing leaders and quartz veins are commonly associated with the lodes.

Between 1910 and 1912, the "Little McKenzie" mine at Karavakum yielded 1,048 ounces of gold from 612 tons of ore. At the "Woodlark King" mine, 2,000 tons of ore produced averaged 3 oz gold per ton.

The Okiduse mine about one mile south of Bonivat on the north-west flank of the Okiduse Range is close to a contact between volcanic rocks and a large granite body. Stanley (1912) reported ferruginous lodes trending 125° and dipping 80° south-west in grey porphyry. This mine is now completely overgrown and no exposures could be located.

(v) Wonai.

The exact position of the Wonai lodes is not known. From Stanley's description, they probably occur within sedimentary or volcanic members of the Loluai Volcanics which are intruded by gabbro. Stanley suggested that the lodes occupy fault zones which strike 165° and dip 75° north-east. Pyritic quartz veinlets with visible gold have also been recorded from this area.

(vi) Loluai and Norac

Stanley recorded auriferous quartz leaders at both localities but they were not seen during this survey.

Gold Mineralisation

Except at Wonai, all the productive gold lodes occur in the Okiduse Volcanics or in rocks intrusive into them.

At the surface, the gold-bearing lodes occupy shear zones which range in width from a few inches to 100 feet; they all dip steeply and, with few exceptions, trend between 160° and 180°. The shear zones contain blue pug with rock fragments. Pyrite, both fresh and oxidised, is usually abundant in the pug and fine galena is visible in some lodes. Calcite and less commonly quartz, occur as gangue, in pockets or in thin irregular veins.

The lodes in the underground workings at Kulumadau were interpreted as shear zones by Newman (1912). The Mining Warden (1918) reported a pug seam in the Kulumadau mine which broadened into an ore vein 14 feet thick. Pyrite, galena, sphalerite, manganese oxide, and traces of copper minerals were recorded in the deeper levels. Stanley (1912) and Newman (1912) both noted that calcite veins and quartz veins with visible galena contained high gold content.

Edwards (1954) described an ore sample from 400 feet in the Kulumadau mine as massive and medium-grained to coarse-grained, consisting of sphalerite, galena, pyrite, chalcopyrite, quartz and calcite. He noted that pyrite which was the least abundant sulphide was corroded where in contact with the other sulphides and that gold, associated with most minerals, had been introduced with the latest deposited galena.

The gold, sulphides, quartz, and calcite in the shear zone lodes are probably concentrations of minerals deposited from solutions migrating up or along the shear zones in the late hydrothermal stage of volcanic activity. The gold-bearing lodes are usually in shears in the younger volcanic rocks, which were presumably in direct connection with the latest centres of dying volcanic activity.

Pyrite Mineralisation

Pyrite is common to abundant in all the volcanic and intrusive rocks and in all Tertiary sediments except the Nasai Limestone. The pyrite is generally disseminated as both large and small clusters or individual crystals. Veins of pyrite are less common. In the Tabukui Beds, pyritic layers are represented in thin beds of massive limonite on weathered surfaces.

This pyrite mineralisation is attributed to widespread permeation of the lower levels of a volcanic pile by pyrite-bearing solutions, particularly during eruptive phases.

Manganese Mineralisation

A small lode of manganese oxides was found on the seaward side of an islet in the mangrove swamp at Wasilas Point. The lode is vertical, about 4 feet wide and trends 180°. It is composed of weathered brecciated rock and black, earthy manganese oxide; a typical specimen assayed 41% manganese.

Thin layers of black manganese oxides are common in the weathered Tabukui Beds exposed along the west shore of Suloga Harbour, below Makete Hill. Black films on boulders of volcanic rock in Loluai Creek contain manganese as well as iron. Abundant manganese in the Little McKenzie gold lode was recorded by Stanley (1912). The manganese was probably introduced in a late hydrothermal phase of volcanic activity but had a less widespread distribution than the gold and sulphide mineralisation.

Copper and Iron Deposits

The magnetite outcrops at Loluai and Norac on the Suloga Peninsula have been described in detail by Thompson (1960), and Fricker and Trail (1961) have discussed a geochemical investigation of the copper mineralisation at Loluai.

In addition to the extensive outcrops of magnetite at Loluai and Norac, magnetite and hematite boulders are found at three localities within half a mile of the old Loluai workings; namely at Sililoi Creek, Watson's Creek, and Watavai Creek. At Watavai Creek the iron oxide boulders are near an outcrop of cupriferous skarn. Boulders of magnetite with quartz, pyrite and (?) chalcopyrite occur on Mapas Island and boulders of hematite with malachite were seen in the headwaters of Sigebai Creek, 300 yards north of Suloga Point. Stanley (1912) recorded micaceous hematite in a shaft on the saddle 600 yards north of Suloga Point.

(i) Loluai

At Loluai there are four or five lodes of magnetite, ranging in width from 4 feet to 30 feet and possibly to 50 feet. They are steeply dipping to vertical and, except for one small lode, strike at north/north-west. Magnetite and hematite comprise about 60% of the lodes, malachite occurs patchily as a surface coating and veinlets, azurite is rare, and pyrite has been noted. Gangue minerals are garnet, epidote, and quartz. The magnetite bodies at Loluai are mainly within the outcrop of the skarn, and a geochemical investigation has indicated that copper mineralisation is confined to the skarn outcrop.

Magnetite and hematite boulders are scattered over a broad zone from Loluai Creek for about 800 yards north to the headwaters of Sililoi Creek. This zone extends beyond the skarn outcrop and it was noted that in the Sililoi Creek area the copper content of the soil around the magnetite boulders is lower than in the skarn area.

Magnetite boulders in Watavai Creek, 700 yards north-east of Loluai, overlie a small outcrop of cupriferous skarn. This magnetite may continue northwards under the outcrop of the Wonai Hill Formation to the headwaters of a tributary of Watson's Creek, where magnetite boulders lie on soil with a low copper content.

Partial analyses of samples taken by Thompson (1960) from the sorted dumps of magnetite and copper ore are set out below:-

Sample from	% SiO_2	Fe	Cu	Mn	TiO_2	S	P_2O_5
"high copper" dump	5.0	55.8	12.3	0.05	0.1	T	T
"obvious copper" dump	9.2	49.4	9.2	0.04	-	0.35	T
"no copper" dump	4.5	62.5	0.67	0.12	-	T	T

T = trace; arsenic and gold not determined.

A geochemical investigation of Loluai, described by Fricker and Trail (1961), revealed that the soil overlying the extensive skarn outcrop at Loluai has an abnormally high copper content. Some large areas of this soil contain more than 1,000 ppm. of copper. Previously the copper had been regarded only as an associate of the magnetite lodes, but the geochemical results indicate that the copper is disseminated within the skarn beyond the limits of the magnetite lodes.

The secondary copper minerals, malachite and azurite, have been seen in the skarn and in the magnetite bodies only at the old workings low on the steep hillside behind Loluai. This may be the exposure of a zone of secondary copper enrichment in the skarn near the water table. The total area of soil containing over 1,000 ppm. of copper is about 450,000 square feet.

(ii) Norac.

The magnetite deposits at Norac were mapped and described in detail by Thompson (1960). They lie within a skarn outcrop at the foot of the steep lower slope of Tabukui Hill. The skarn and magnetite outcrops are partly concealed by boulders derived from the overlying Tabukui Beds.

Thompson (1960) recorded six magnetite lodes at Norac, but only two were sufficiently large for consideration as orebodies. The lodes strike about due north and dip about 60° west. One lode is 30 feet wide; the other 50 feet wide. They are separated by 40 feet of cupriferous skarn. The lodes are mainly hematite at the surface and are locally stained with malchite. Native copper was also recorded.

Analyses of grab samples taken by Thompson from dumps at Norac gave the following results:-

Sample from	% SiO_2	Fe	Cu	Mn	TiO_2	S	P_2O_5
50 ft. lode (no obvious copper minerals)	4.6	65.7	0.25	0.25	-	-	T
50 ft. lode (obvious copper carbonates)	6.6	55.2	4.3	0.06	-	-	T
30 ft. lode (obvious copper carbonates)	6.7	56.3	3.2	0.06	-	-	T

T = trace; gold and arsenic not determined.

Figure 8. Excavating an old ore dump at Norac.

Thompson (1960) estimated that 420,000 tons of iron ore may be available above sea level in the two main lodes at Norac.

The magnetite lodes at Norac appear to lie entirely within a skarn outcrop about 2,000 feet long and up to 400 ft. wide. The skarn is probably a concordant lens, possibly altered Suloga Limestone, about 100 feet thick which may extend into the hillside under the Tabukui Beds.

Most soil samples taken over the Norac skarn outcrop contained more than 1,000 ppm. of copper; the highest value recorded was 7,000 ppm. As at Loluai, the presence of secondary copper minerals in the old Norac workings may indicate a zone of secondary copper enrichment of unknown extent. The detailed results of the geochemical survey of the Norac area are presented in a separate report by A. Fricker (in preparation).

(iii) Other deposits

Magnetite, hematite, and limonite boulders with traces of malachite were seen on Loluai Volcanics near the head of Sigebai Creek north of Suloga Point. This copper-iron mineralisation is probably associated with the gabbro sill which forms Uskweilele Hill. Neither sediment nor skarn is exposed in this area.

In a small area on Mapas Island small boulders of magnetite and hematite containing quartz, brassy pyrite, and (?) chalcopyrite were noted. This mineralisation is associated with the gabbro of Mapas Island, and the mineralized boulders may be near a contact of gabbro and a remnant of Loluai Volcanics.

Magnetite boulders reported by former prospectors from the Wasilas area, probably from within an area of Loluai Volcanics were not located.

Copper-Iron Mineralisation

The copper-iron mineralisation is attributed to the intrusion of gabbro sills comagmatic with the volcanic rocks of Woodlark Island. Fugitive metallic constituents after the emplacement of the gabbro concentrated in the porous skarn rocks formed by the metasomatic alteration of limestone. The magnetite occupied north-trending tension fissures, mainly in the skarn, but also in gabbro and the volcanic rocks. The copper disseminated through the skarn may have been redistributed and concentrated by ground water into a zone of secondary enrichment.

CONCLUSIONS AND RECOMMENDATIONS

The geochemical investigation at Loluai has indicated a previously unsuspected dispersed copper content in weathered skarn rock which, as recommended by Fricker and Trail (1961), warrants further delineation by diamond drilling. Diamond drilling is also recommended to prove the extent and grade of the cupriferous skarn at Norac, and to test the possibility of an extension of the magnetite lodes beneath the Tabukui Beds.

Further geological and geochemical exploration for copper should begin in the Loluai Volcanics and gabbro at Suloga Point, Mapas Island, and in the Wasilas area.

Further investigation at Busai and Bonivat - Karavakum, where near-surface gold values were high, should be directed towards determining the grade of the known lodes below the water table. This could only be done by drilling. If high gold values persist then the water problem, which reputedly caused the closure of the old mines, could be tackled with modern pumping equipment to permit development below the water table. Systematic sampling of the Kulumadau open cut and the sand and slime dumps may offer encouragement for re-opening the Kulumadau area as an open-cut low grade gold mine. Lateral and depth extensions of the Kulumadau lode could only be tested by drilling.

Payable alluvial gold may exist in the coarse-grained unconsolidated sediments interbedded with the blue marine clays exposed in the banks of the Sinkurai River east of the Okiduse Range, and also in the alluvial flats south of Busai.

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REFERENCES

BRASS, L.J., 1959 - Results of the Archbold Expeditions. No. 79 Bull.Amer.Mus.Nat.Hist.118.art.1

BROKEN HILL PTY.CO.LTD. 1955 - Iron Ore, Woodlark Island. (Unpublished report).

de KEYSER, F., 1960 - Misima Island - Geology and Gold Mineralisation. Bur.Min.Resour. Aust. Records 1960/53 (unpub.) *

FRICKER, A.G. & TRAIL, D.S., 1961 - Geochemical Investigation of Copper Mineralisation at Loluai, Suloga Peninsula, Woodlark I. Bur.Min.Resour., Aust. Records 1961/1 (unpub.)

GRAY, G.J., 1952 - Report on Kulumadau Mine (Unpublished Report)

HARKER, A., 1950 - Metamorphism. Methuen & Co.Ltd.London

MAGNUSSON, N.H., 1936 - The Evolution of the Lower Archaean Rocks of Central Sweden and their Iron, Manganese, and Sulphide Ores. Q.J.G.S., 92,332-359.

NEWMAN, J.M., 1912 - Report on Kulumadau Mine (Unpublished report of the Kulumadau Gold Mining Company).

RICH, C.E., 1936 - Unpublished report by the Mining Engineer to the Territory of Papua Administration.

RICHARDS, A.F., 1959 - Birth and Development of Volcan Boncera, Isla San Benedicto. Bull. Volc.Ser.II, Tome XXII.

STANLEY, E.R., 1912 - Report on the Geology of Woodlark Island. Comm.Aust., Report on the Territory of Papua, 1911-1912.

STANLEY, E.R., 1917a- Report of Government Geologist. Comm.Aust. Report on the Territory of Papua.1916-1917.

STANLEY, E.R., 1917b- Report on the Occurrence of Phosphate at Cannac Island (Inene). Unpublished Report by the Government Geologist, Territory of Papua.

THOMPSON, J.E., 1960 - The Iron-Copper Lodes, Suloga Peninsula, Woodlark Island, Papua. Bur.Min.Resour. Aust.Records 1960/119, (unpub.)

Van BEMMELEN, R.W., 1949- The Geology of Indonesia, I,201. Govt.Printing Office, The Hague.

WARDEN'S REPORTS, 1910-1926 - in Comm.Aust., Reports on the Territory of Papua, 1910 - 1926.

* EDWARDS, A.B., 1954 - Lead-zinc ore from Kulumadau Mine, Woodlark Island, New Guinea. Miner.Invest Circ., Sci.ind. Res.Org., Melb., No.602 (unpub.).

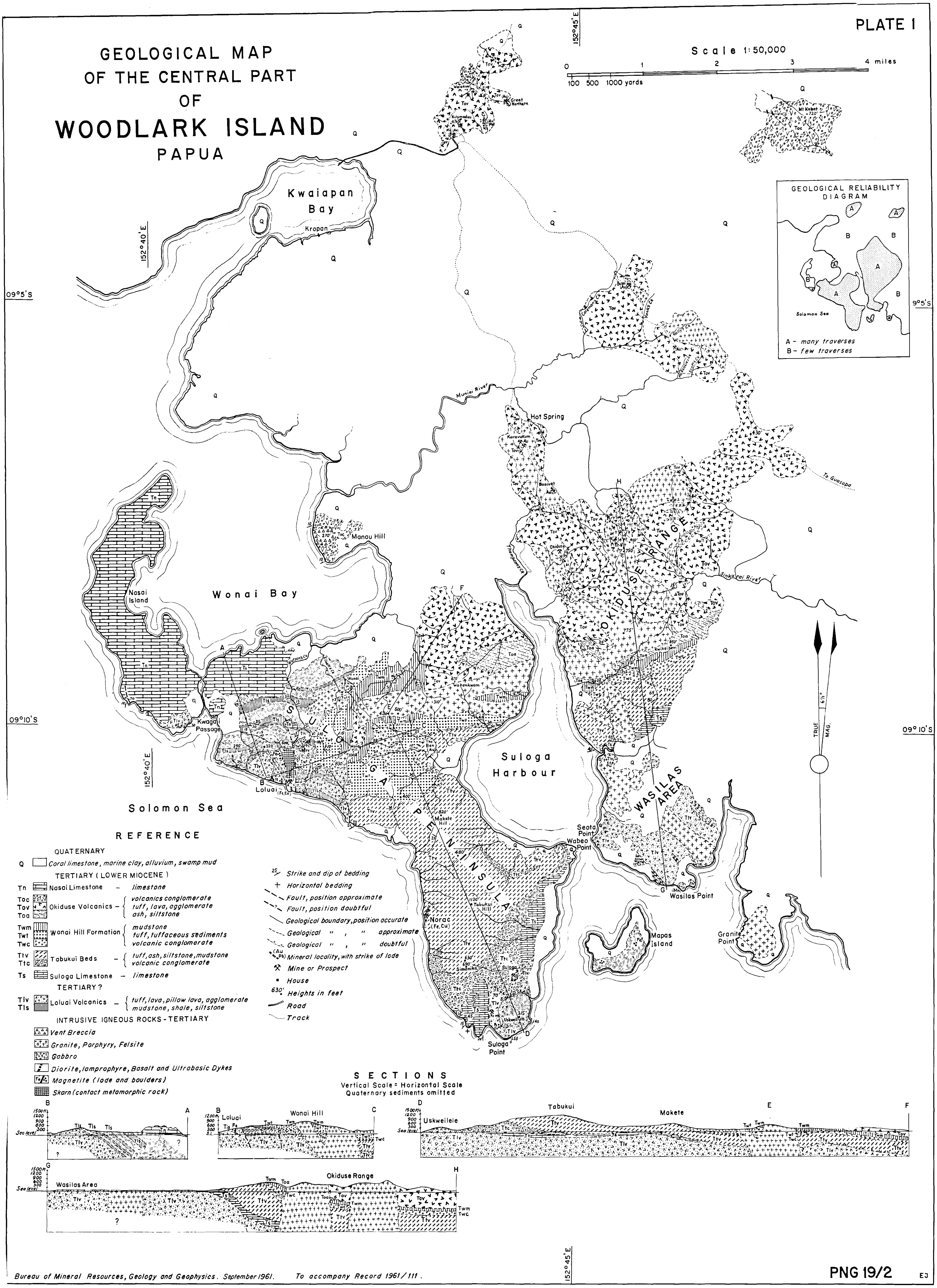
PLATE I
GEOLOGICAL MAP
OF THE CENTRAL PART
OF
WOODLARK ISLAND
PAPUA
Scale 1:50,000
0 1 2 3 4 miles
100 500 1000 yards
152°45'E
152°40'E
09°5'S
09°10'S
GEOLOGICAL RELIABILITY DIAGRAM
A - many traverses
B - few traverses
Solomon Sea
Kwaiapan Bay
Kropan
Muniai River
Hot Spring
Karavakum
Manou Hill
Wonai Bay
Nasai Island
Kwagal Passage
SULOGA PENINSULA
OKIDUSE RANGE
Sinkurai River
To Guasopa
Suloga Harbour
WASILAS AREA
Seota Point
Wabeo Point
Wasilas Point
Mapas Island
Granite Point
Loluai
Makete Hill
Tabukui Hill
Norac
Simoniko
Uskweilele
Suloga Point
TRUE
MAG.
REFERENCE
QUATERNARY
Q Coral limestone, marine clay, alluvium, swamp mud
TERTIARY (LOWER MIOCENE)
Tn Nasai Limestone - limestone
Toc Tov Toa Okiduse Volcanics - volcanics conglomerate; tuff, lava, agglomerate; ash, siltstone
Twm Twt Twc Wonai Hill Formation - mudstone; tuff, tuffaceous sediments; volcanic conglomerate
Tlv Ttc Tabukui Beds - tuff, ash, siltstone, mudstone; volcanic conglomerate
Ts Suloga Limestone - limestone
TERTIARY ?
Tlv Tls Loluai Volcanics - tuff, lava, pillow lava, agglomerate; mudstone, shale, siltstone
INTRUSIVE IGNEOUS ROCKS - TERTIARY
Vent Breccia
Granite, Porphyry, Felsite
Gabbro
Diorite, lamprophyre, Basalt and Ultrabasic Dykes
Magnetite (lode and boulders)
Skarn (contact metamorphic rock)
Strike and dip of bedding
Horizontal bedding
Fault, position approximate
Fault, position doubtful
Geological boundary, position accurate
Geological " " approximate
Geological " " doubtful
Mineral locality, with strike of lode
Mine or Prospect
House
Heights in feet
Road
Track
SECTIONS
Vertical Scale = Horizontal Scale
Quaternary sediments omitted
Wonai Hill
Tabukui
Makete
Wasilas Area
Okiduse Range
Sea level
Bureau of Mineral Resources, Geology and Geophysics. September 1961. To accompany Record 1961/111.
PNG 19/2
EJ