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Contributions to the Geology of Northernmost New Zealand: II—The Stratigraphy of the North Cape District

By E. C. LEITCH

University of Auckland.

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Abstract

ROCKS of widely varying type ranging in age from Cretaceous to Recent occur in the North Cape district. The lithostratigraphy of these rocks is described, their ages are discussed, and comments are made on the petrography and provenance of several of the sedimentary formations.

The oldest unit, the Cretaceous Whangakea Volcanics, is composed of altered basalt flows and pillow-lava accumulations. Faulted against a mass of these rocks is the Kerr Pluton, a complex of partially serpentinised peridotite and gabbros cut by more acid dykes. This body is also possibly of Cretaceous age.

Sandstones and finer-grained sediments containing Arowhanan and Haumurian fossils are grouped in the Rahia Formation; tuffaceous shales in these are believed to be of the same age as the Whangakea Volcanics. A small fault-bounded block marginal to the Rahia rocks is formed of inter-bedded limestones and glauconitic sandstones of Arnold age, to which the name Porotu Limestone has been applied.

The Waitemata Group, a thick clastic sequence of Waitakian to Upper Pareora or Altonian age derived in large part from andesitic volcanics, has been divided into three formations. The oldest unit, the Tom Bowling Formation, consists of a basal breccia overlain by sandstones, siltstones, and mudstones; intercalated in the lower part of this unit in some sections are thick pyroclastic deposits considered by the writer to be the result of submarine explosive volcanism. Andesitic conglomerates and lensoid sandstones of Otaian age, at least 1,000m thick, overlie the Tom Bowling Formation. These have been termed the Kaurahoupo Conglomerate. Sandstones, siltstones, and polymictic conglomerates collectively referred to as the Paratoetoe Formation succeed the Kaurahoupo Conglomerate. Microfaunas ranging in age from Otaian to perhaps as young as Altonian occur in these rocks, which also contain an abundant megafauna. The Upper Lillburnian or Waiauan Waikuku Limestone is a shelly calcarenite of very restricted distribution.

Emplaced in the Tom Bowling Formation are several microdiorite bodies grouped together as the Tawakewake Intrusives and considered to be of Middle Miocene age.

Scattered Quaternary deposits include sands and carbonaceous rocks, a microflora from which indicates significant Pleistocene cooling.

INTRODUCTION

THE Aupouri Peninsula, formed of Quaternary beach-dune complexes that tie together several inliers of dominantly volcanic rock considered to be of Cretaceous

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age, stretches forty miles north-north-west of Kaitaia. At the northern end of this neck of land is the rugged North Cape block, where a sequence of igneous and sedimentary units are found that range in age from Cretaceous to Recent. The stratigraphy of the eastern part of this block is the subject of this report (Fig. 1).

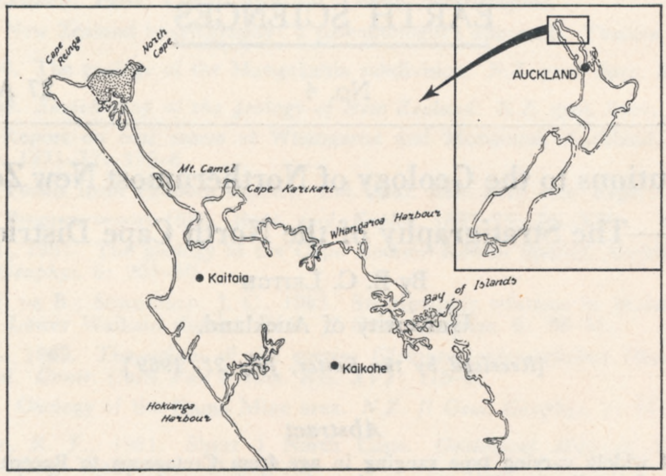

Fig. 1.—Locality map. The area shown in Fig. 2A is stippled.

Previous Investigations

The first recorded geological observations made in this region were those of Dieffenbach (1843), whose writings contain occasional references to the Tertiary rocks. Hector visited the area in 1866 and incorporated his findings in his 1869 map and in a note published in 1872. McKay (1894) presented a report accompanied by the first detailed geological map of the district, and Bell and Clarke undertook a brief reconnaissance of the geology in 1908 to corroborate the work they were undertaking in the Whangaroa Subdivision (Bell, 1909; Bell and Clarke, 1910).

Bartrum and Turner (1928) published the most authoritative account to date of the geology of northernmost New Zealand; their stratigraphic subdivision of the rocks is essentially the same as that recognised at present.

Short notes on specific aspects of the geology are those of Bartrum (1934) and Milligan (1961); other work has been concerned with the age (Hay, 1960; Bowen, 1965) and origin (Quennell and Hay, 1964) of the Cretaceous volcanics and with a regional study as part of the New Zealand 1: 250,000 mapping programme (Kear and Hay, 1961).

Stratigraphy

A generalised stratigraphic column for the district is given in Table I and the distribution of the rocks is outlined on the geological map (Fig. 2A).

Stratigraphic Nomenclature

The first local stratigraphic scheme for the North Cape district was tentatively put forward by Bell and Clarke (1910). The terms that they used are now considered to be those of time-stratigraphic nomenclature, and they were regarded as such by some later writers (Bartrum, 1934), although most of the original descriptions are those of rock units. Recent workers have generally changed the names from series to formation without attempting to formalise the terms or to examine their validity. In the present work some name changes were considered desirable

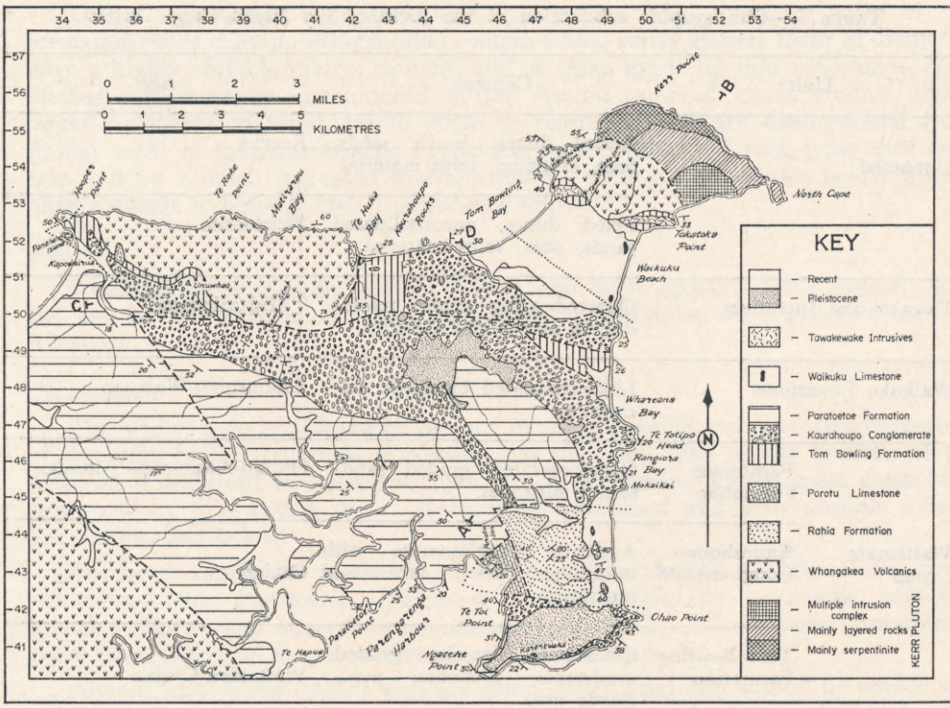

FIG. 2A.—Geological map of the North Cape District.

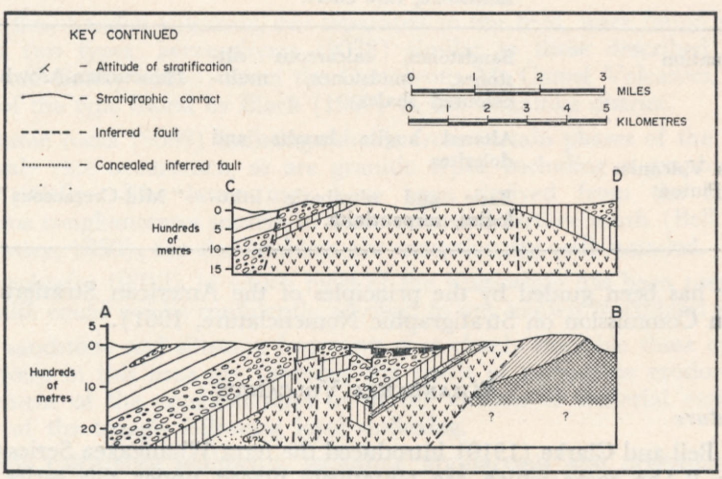

FIG. 2B.—Geological cross-sections, North Cape District.

and a number of new terms are introduced. Changes have only been made where the feature from which the original name was taken lies within the area studied, for it is only the rocks in the immediate vicinity of such features that can be considered to constitute the "type exposure" of named units when their introduction is unaccompanied by a formal statement. Where the type area apparently lies outside the North Cape district the name has been provisionally used, although it may require alteration after study of the assumed type exposure. In defining new units

Table I.—Stratigraphic subdivision of the rocks of the North Cape District.

Unit		Content	Age
Unnamed		Active dunes, beach sands, peat, alluvium, talus material.	Recent
		Fixed dunes, unconsolidated sands, peat, talus material.	Pleistocene
Tawakewake Intrusives		Quartz-bearing augite micro-diorite and minor dolerite.	" Mid-Miocene "
Waikuku Limestone		Little-indurated bioclastic calcarenite.	Lillburnian-Waiauan
Waitemata Group	Paratoetoe Formation	Conglomerates, graded sandstones, siltstones.	Otaian-Awamoan-?Altonian
	Kaurahoupo Conglomerate	Andesitic conglomerate with sandstone lenses, rare coal measures.	Otaian
	Tom Bowling Formation	Calcareous breccia, graded sandstones, siltstones, pyroclastic grits.	Waitakian-Otaian
Porotu Limestone		Argillaceous limestone, green sandstone, rare chert.	Arnold Series
Rahia Formation		Sandstones, calcareous siltstones, mudstones, multi-coloured shales.	Haumurian-Arowhanan
Whangakea Volcanics and Kerr Pluton		Altered augite basalts and dolerites.	
		Basic and ultrabasic lithologies, serpentinite.	" Mid-Cretaceous "

the writer has been guided by the principles of the American Stratigraphic Code (American Commission on Stratigraphic Nomenclature, 1961).

Whangakea Volcanics

Nomenclature

When Bell and Clarke (1910) introduced the term Whangakea Series they stated (p. 617): " The rocks which are tentatively placed under this series consist of greenish and purplish indurated stratified rocks, possibly in part argillites, associated with basic and semi-basic igneous rocks, probably both intrusive and contemporaneous." Earlier, McKay (1894) had described the rocks as sediments and, while Bell and Clarke (1910) recognised the presence of some igneous material, it was Bartrum and Turner (1928) who pointed out the almost exclusively igneous nature of this unit.

Bartrum (1934) advocated the elimination of the term Whangakea Series from the North Cape district because of evidence of the contemporaneity of these rocks and Bell and Clarke's Rahia Series.

Hay (in Fleming, 1959) referred to the rocks as the Whangakea Volcanics, and this was subsequently used by Kear and Hay (1961). No type section for this unit has been designated, the name is taken from outside the area under consideration, and no attempt is made to redefine it here. In the North Cape district the writer has applied the term to all extrusive and high-level intrusive basic rocks, plus their altered equivalents, that lie stratigraphically below the Waitemata Group and are separated from it by a marked unconformity. Rare sedimentary material within the lava pile is also included in this formation.

Distribution

Between Hooper Point and Tom Bowling Bay a steep, cliffed coastline is backed by rough hills of Whangakea Volcanics that emerge from beneath surrounding Tertiary sediments. This block will be referred to as the Te Rake mass, while a second, smaller area of Whangakea rocks that forms the southern part of the North Cape Headland will be referred to as the Waipahirere mass.

Content

The rocks of the Whangakea Volcanics are almost exclusively igneous and dominantly extrusive. Augite basalt lacking modal olivine or pyrogenic quartz is the predominant rock type, with the petrography varied by the occasional development of hornblende or bronzite. Lavas form the most widespread volcanic product, although minor breccias are also present. Intrusive bodies, mainly of discordant nature but probably also including sills, have been emplaced penecontemporaneously with volcanism. Sedimentary material of negligible volume was found at only two localities. Descriptions of the various phases of the formation follow:

Normal Flows: The Waipahirere mass is formed predominantly of lava flows that vary from 0.3 to 3m in thickness. Similar flows are less common in the Te Rake mass, where some flows are massive at their base and become pillowed in their upper part. The flows of both masses show slight marginal chilling, basal brecciation is rare, amygdular horizons are occasionally present, and primary jointing is masked by tectonic joints and shears.

Pillow Lavas: In the Te Rake mass pillow lavas are the most widespread volcanic product, and such lavas also occur in the Waipahirere mass. Pillow accumulations are of two types; they may form readily recognisable stratiform pillow flows, individual pillows in which are ellipsoidal with their major and intermediate axes lying parallel to the flow contacts and with a major to minor axis ratio of about 2: 1, or they may occur as a jumbled pile in units at least 30m thick. The pillows in the latter show considerable variation in shape but are generally less inequidimensional than those of the pillow flows.

In both types of deposits pillows average about 1m in longest dimension, with an observed range of 0.3 to 3m. Connecting necks between pillows are very rare, no regular concentric or radial jointing is discernible and there is little inter-pillow debris. Some pillows have a vesicular zone near their margins; glassy selvedges seldom exceed 3cm in thickness and multiple selvedges were found at only one locality (417519*).

Intrusions: Dykes up to 35m wide cut the Waipahirere lavas and larger stock-like bodies accompany similar features in the Te Rake mass. It is possible that some of the thicker flow-like bodies in the Waipahirere mass are shallow sills.

Breccias: Small irregular masses of breccia generally less than a metre thick are associated with both normal flows and pillow lavas, but such rocks form only a minor part of the Whangakea Volcanics in the North Cape district.

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* All grid references refer to N.Z.M.S. 2, sheet N2; they were read off N.Z.M.S. 2, sheets N2/4, N2/5, N2/7, N2/8 (1: 25,000).

Peperite: A thin lense of dull red material associated with pillow lavas at 342523 is composed of fragments of basaltic material up to 2.5cm in diameter in a clastic matrix of small augite crystals, elongate zeolite pseudomorphs after plagioclase, and an extremely fine irresolvable red base (9080*). This rock is apparently the result of the advance of lava across a local deposit of wet mobile sediment that incorporated minor igneous material from the over-riding body and was baked by it to a natural brick.

Chert: Small shattered blocks of Radiolaria-bearing chert are found in weathered Whangakea lavas at 485531.

Paleontology, Age, and Correlation

Apart from Radiolaria in the chert no fossils were found by the writer in Whangakea rocks.

Early statements concerning the age of the formation are those of Hector (1893, 1894) and McKay (1894). The latter collected fossils from a limestone lens in the volcanics near Pandora, on the western side of Spirits Bay, which were reported by Hector (1893) to include *Inoceramus, Aucella,* and *Halobia,* from which he deduced a Jurassic age. Later, however, Hector referred to the fauna as obscure fossils and apparently considered them to have little age significance (Hector, 1894). McKay (1894) recorded *Inoceramus* and what appeared to be a species of *Halobia* from this locality. He regarded the rocks as Lower Mesozoic.

Bell and Clarke (1910) noted a close lithological resemblance between the Whangakea Volcanics and Late Paleozoic–Early Mesozoic strata near Whangaroa, a correlation accepted by Bartrum and Turner (1928), although they mentioned the possibility of a Cretaceo–Eocene age.

Bartrum (1934) revised his previous opinion in view of studies of Foraminifera from Pandora and correlated the volcanics with the Rahia Formation, which he considered to be Upper Cretaceous.

Hay (1960) recorded *Inoceramus* and *Meleagrinella* from Pandora, which led him to suggest an Upper Jurassic age for the Whangakea rocks, but Quennell and Hay (1964) assigned them a Motuan to Arowhanan age. Bowen (1965) presented micropaleontological evidence for a Middle or Upper Cretaceous age.

The present writer has found no new direct evidence of the age of the Whangakea Volcanics. Mid-Cretaceous multicoloured shales of the Rahia Formation are in part volcanogenic, and it is possible that these are a correlative of the Whangakea. The contemporaneity of volcanism and sedimentation is further indicated by the interbedding of Rahia and Whangakea rocks at Rahia Bay (Bartrum and Turner, 1928).

Correlation of this formation with units outside the northern part of the Aupouri Peninsula is hampered by the lack of age and petrographic data. Quennell and Hay (1964) indicated a broad correlation of the Tangihua, Whangakea, and Mt Camel Volcanics, and Bartrum (1948) suggested that certain quartz andesites from the Three Kings Islands were correlatives of the Whangakea Volcanics.

Eruption of the Whangakea Volcanics

The widespread development of pillow lavas, the occurrence of marine fossils in limestone lenses at Pandora and of radiolarian chert in the lavas of the Waipahirere mass, the interbedding of the Whangakea and Rahia rocks at Rahia Bay, and the absence of plant remains, swamp deposits, or oxidised horizons often found in terrestrial volcanic sequences indicate that the Whangakea Volcanics were erupted in a marine environment. They could be the product either of eruptions of

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* Numbers are those of the petrology collection, Geology Department, University of Auckland, where specimens have been deposited.

central type, building edifices above the general sea floor, or of fissure extrusions that resulted in sheets of lava with little topographic expression.

Quennell and Hay (1964) postulated that these rocks formed seamounts that may have had a relief of 2,000–3,000 feet. Their major evidence is the shape of the blocks and the nature of the contacts between the members of the Tangihua Group and the surrounding sediments. They apparently believed that the present form of the volcanic masses survived essentially unchanged from the Mesozoic and that later sediments were banked against these long-standing mountains. However, the age of the rocks suggests that it may not be valid to argue from their present morphology. The Whangakea Volcanics have certainly been considerably deformed, for while lavas may have notable initial dips, the inclination of flows at angles up to 80° must be the result of tectonic movements. The contacts of the Tangihua rocks with surrounding Cretaceous and Lower Tertiary sediments appear to be obscure, judging from the diversity of interpretations proffered (Hay, 1960; Kear and Hay, 1961; Quennell and Hay, 1964).

Hay (1960) has suggested that the Tangihua Volcanics were outpoured as a sheet of lava that was subsequently deformed. The Whangakea lavas might also have originated as a single or as several essentially stratiform sheets. The presence of clastic sedimentary material interbedded with the lavas, as recorded by Bartrum and Turner (1928) and Quennell and Hay (1964), is more readily comprehended if the volcanic rocks were not significantly elevated above the sea floor. It is also noted that volcanic-derived detritus is not common in the Upper Cretaceous and Lower Tertiary sedimentary rocks at North Cape. Such detritus might be expected to be widespread if the Whangakea rocks had always formed high-standing features.

RAHIA FORMATION

Nomenclature

The name Rahia Series, derived from Rahia Bay, 25km west of the North Cape district, was applied by Bell and Clarke (1910) to thin-bedded purplish and greenish claystones found in the northern part of the Aupouri Peninsula.

A well-defined stratigraphic unit that includes a horizon of distinctive multi-coloured shales occurs in the North Cape district. The apparent similarity between these shales and the Rahia rocks, coupled with their similar stratigraphic position, has led the writer to apply this name to the North Cape unit. Inasmuch as the description of Bell and Clarke is that of a rock-stratigraphic unit, the unit is referred to as the Rahia Formation.

Distribution, Contacts and Thickness

Rocks of the Rahia Formation occupy an area of one square mile, north of the entrance to the Parengarenga Harbour. All contacts with surrounding rocks are faulted.

Owing to the incompleteness of exposure little direct measurement of thickness is possible, and calculated thicknesses are suspect because of variable dip angles. A combination of direct measurement and calculation suggests that at least 1,200m of strata are present.

Content and Stratigraphy

Outcrops on a series of inliers emerging from beneath Quaternary sands between Ohao Point and Mokaikai, together with more meagre data from inland exposures, provide the basis for the local stratigraphic subdivision of the formation outlined below.

Member 4 (youngest): Infrequently concretionary, interbedded grey to green soft sandy siltstones and poorly cemented sandstones constitute member 4. Near the base of the unit the rocks are predominantly sandstones up to 1.3m thick, separated by much thinner laminated siltstones. Current bedding is discernible in places and some strata are lensoid. Passing upwards, material of fine grade becomes dominant and massive siltstone beds appear, but at the top of the exposed sequence there is a return to alternating strata. Minimum thickness 650m.

Member 3: The beds of this member are poorly exposed and possibly complicated by both faulting and slumping. The predominant lithology is a highly calcareous mudstone containing calcareous concretions, barite masses, and cone-in-cone calcite. Occasional sandstones are interbedded with the mudstone. Thickness 200m.

Member 2: Fine-grained grey quartzose sandstones and fine silicified mudstones are overlain by alternating silicified and unsilicified mudstones interstratified with sandstones and rare calcareous beds. Thickness 200m.

Member 1: This unit is formed of multicoloured shales including green, red, chocolate, white, and purple varieties; all are well bedded with individual strata up to a metre thick. Minimum thickness 100m.

Age and Paleontology

The only paleontological evidence for the age of the Rahia Formation comes from the two upper members. A microfossil sample, N2/560, collected from member 4 at 487424 was examined by Dr N. de B. Hornibrook, who identified a Haumurian fauna that included the Foraminifera *Dorothia elongata* Finlay, *Rzehakina epigona* (Rzehak), and *Pelosinella* (pers. comm. 3/7/64). Fragments of the Arowhanan marker *Inoceramus rangatira* Wellman were found in member 3 at 485433.

Correlation

The Haumurian member 4 is a correlative of the lower part of the widespread Mangakahia Group, the distribution of which is summarised on the maps of Kear and Hay (1961) and Thompson (1961). Milligan (1959) and Hay (1960) both subdivided this group, but apart from some similarity to Milligan's Narrows Formation member 4 appears lithologically distinct from other North Auckland Haumurian rocks.

Arowhanan rocks are known in North Auckland from only a few scattered localities (Milligan, 1959; Hay, 1960).

Petrography and Provenance

Overall the most common constituent of the sediments of the Rahia Formation is quartz; feldspar and heavy minerals are most abundant in member 4, and glauconite is widespread in the upper three members, which also contain infrequent rock fragments of sedimentary and volcanic origin. Typical specimens from individual members are discussed below:

Member 1: The purple shale (specimen 9000) was too fine-grained for detailed optical investigation, for apart from aggregates of authigenic pyrite, grain diameter rarely exceeds 0.07mm and is generally less than 0.015mm. Microscopic examination indicates the presence of quartz, plagioclase, and sericite, and shows that the colouration is due to minute grains of the order of 0.005mm in diameter. X-ray diffraction traces confirmed that quartz and plagioclase are the major constituents, but no definite iron oxide peaks were identified, and the nature of the coloured phase remains unknown. Appreciable zeolite is apparently lacking, although occasional crystals that appear to be pseudomorphs after tiny glass shards were noted optically. The mineralogy of the sediment provides little evidence of its origin although the high proportion of feldspar is notable.

Red and green rocks apparently similar to these shales have been recorded from the Lower Mesozoic near Wellington by Wellman (1949), who has termed them tuffaceous siltstones. He showed that chemically they are intermediate between typical argillites found in the sequence and associated spilites, and although Reed (1957) has pointed out that the texture of the siltstones could not result from a mechanical mixing of the two sorts of material and has suggested they represent deep-sea lutite sedimentation, he agrees that their formation was closely connected with submarine volcanism and termed them volcanic argillites. The writer similarly believes that the coloured shales of the Rahia Formation are in part of volcanic origin.

Member 2: Thin sections 9001 and 9002 prepared from sandstones from this member are characterised by their siliceous nature, their high matrix content, and the paucity in them of unstable materials. The main detrital mineral is quartz in subrounded to subangular grains up to 0.18mm in diameter. Feldspar is lacking in 9002, but 9001 contains 3 percent plagioclase and rare microcline. Small muscovite flakes are widespread, and partially bleached shreds of biotite in 9001 show progressive changes towards glauconite. Such a sequence is not apparent in 9002 but it also contains irregular glauconite grains. Heavy minerals in 9001 are zircon and very rare elbaite and in 9002 zircon, clinozoisite, magnetite, and leucoxene. In both rocks the matrix is quartzose. The mineralogy suggests that these rocks were derived from a highly quartzose source containing appreciable amounts of mica.

Member 3: The only specimen suitable for examination (9003) is part of a calcareous concretion. In this, angular quartz sometimes showing strain polarisation is the major detrital phase. Small scattered feldspars are mainly oligoclase but include rare orthoclase. Occasional lithic detritus is predominantly quartzose, although there are fragments of mudstone, argillaceous sandstone, and volcanic rock. Carbonaceous fragments and infrequent glauconite pellets occur throughout the section. Muscovite and chlorite together with small rounded zircons constitute the major heavy minerals, and detrital magnetite and authigenic pyrite make up the opaque fraction. About 55 percent of the concretion is composed of fine-grained calcite which has partially replaced both quartz and feldspar.

The lithic fragments suggest that this sediment was derived from a terrain including both sedimentary and volcanic rocks. Muscovite, chlorite, magnetite, quartz, feldspar, and zircon could all have been derived from a granitoid body, or from slightly metamorphosed sediments.

Member 4: Specimen 9004 is a coarse argillaceous sandstone. Subangular to subrounded quartz fragments, which may be multiple, show strain polarisation, or include intergrown feldspar, range up to 0.9mm. Sodic plagioclase is common but subordinate to quartz and at times shows incipient alteration to epidote; orthoclase is a rarer detrital phase. Infrequent lithic material includes grains of pilotaxitic lava. Discoloured green and brown biotite flakes up to 1.3mm long are widespread, and muscovite is a minor constituent. The heavy mineral suite is rich in comparison with the underlying members: apatite, epidote, zircon, sphene, rutile, and opaque ores. The rock is poorly sorted, with the matrix composed in part of irresolvable clay material.

Both the light and heavy mineral fractions indicate a granitic, perhaps granodioritic, source for much of this sediment, although volcanic rocks contributed minor debris.

KERR PLUTON

The name Kerr Pluton, taken from the Kerr Point trigonometrical station, is applied to the intrusive complex formed dominantly of basic and ultrabasic rocks that occurs northeast of a line from Ngawhenua Stream mouth (487548) to the mouth of Kararoa Stream (509529). These rocks were mapped by Kear and Hay (1961) as part of the North Cape Ultramafites, a term which should be replaced as the name North Cape has previously been used for a stratigraphic unit (Suggate, 1956).

Contacts

The only pre-Quaternary rocks found in contact with the Kerr Pluton are the Whangakea Volcanics of the Waipahirere mass. Bartrum and Turner (1928) considered the relationship to be intrusive, but the writer's mapping of the contact indicates that it is a fault, a conclusion supported by the absence of thermal metamorphism from the rocks immediately adjacent to the pluton.

Rock Sequence and Content

The Kerr Pluton consists of diverse petrographic types that range from serpentinised ultrabasic rocks to granophyres. Field relations indicate that they consolidated in the following sequence:

Ultrabasic rocks (now much serpentinised)
Rhythmically layered ultrabasic and basic types
Granophyre } Interval of intrusion overlapped
Hornblende diorite }
Augite dolerite (youngest)

The three younger members occur as narrow dykes in the older rocks that constitute the bulk of the pluton. Some data on the alteration of these rocks have been given by Coleman (1966).

Age and Correlation

Bartrum and Turner (1928) were of the opinion that this pluton was a syntectonic body intruded in early Cretaceous time, during the orogenic period that followed deposition of the Waipapa Group, but following his revision of the age of the Whangakea Volcanics, Bartrum (1934) correlated the pluton with small serpentinite masses in southern Northland, of supposed Eocene age.

Battey (1950) recorded intermediate and basic intrusive rocks at Karikari Peninsula, which he correlated with the gabbroic phase of the Kerr Pluton and with gabbros found in the Whangaroa Subdivision (Bell and Clarke, 1909). He suggested that the rocks might all be as young as Miocene. Kear and Hay (1961) supported Battey's correlation but considered the rocks to be Cretaceous. In the North Cape district boulders of gabbro closely comparable with certain Kerr Pluton rocks occur in Lower Miocene (Otaian) conglomerates and it is likely that most of the body was emplaced before this time.

Recently Challis (1965) has argued that the association of olivine-poor volcanics and ultramafic intrusions may not be fortuitous but that the ultramafics may have accumulated in magma chambers from which the volcanics were extruded. The Whangakea Volcanics lack olivine and might be genetically related to the closely associated rocks of the Kerr Pluton. If this is so the pluton is of Cretaceous age.

Porotu Limestone

This name is introduced for a distinct lithologic unit composed predominantly of argillaceous limestone but including calcareous sandstone and minor chert. The type section is that exposed immediately south of the mouth of Porotu Stream, along the shore of the Parengarenga Harbour between 462429 and 461433.

Distribution, Contacts, and Thickness

Porotu Limestone is restricted to an area less than half a square mile in extent, bordering the north-eastern corner of the Parengarenga Harbour. The contacts between this formation and neighbouring rock units are nowhere exposed, but structurally it appears to form a fault-bounded block marginal to the larger Rahia mass. The paucity of structural data and the discontinuity of exposures prevent accurate estimation of thickness, but at least 100m of strata are believed by the writer to be present.

Content, Petrography, and Provenance

All the rocks are thinly bedded, with individual strata rarely exceeding 0.3m in thickness. The limestone is dense, fine grained, and argillaceous, in places shattered and seamed by calcite veins. Calcite, minor siliceous matter, and clay minerals are the dominant components of this rock, and the only heavy mineral extracted is rare pyrite.

Glauconite concentrations occur at the base of some limestone strata, but this mineral is more common in the calcareous sandstones interbedded with the limestones. Specimen 9005 is typical of these sandstones; angular to subangular quartz up to 0.3mm diameter constitutes 40 percent of the sediment, and the minor lithic detritus consists of aggregates of sutured quartz grains, sometimes associated with colourless mica; intermediate plagioclase is found in accessory amounts and authigenic pyrite, rare zircon, and very rare epidote are the only heavy minerals. Foraminifera are scattered throughout the section, as also are bright green glauconite pellets. Calcite cement that has partially replaced some detrital grains makes up 35 percent of the rock.

Thin section 9006 is of a laminated green sandstone found interbedded with the limestone. Although glauconite grains are present, most of the colouration comes from unidentified matrix material that appears a turbid brown under the microscope. Abundant quartz and infrequent feldspar occur along with common calcite patches and authigenic pyrite. Rare lithic fragments are siliceous, and detrital heavy grains are absent.

In the arenaceous sediments the dominance of quartzose material, together with the paucity of the heavy mineral suite, indicates derivation from a sedimentary or low-grade metasedimentary landmass. The plagioclase may have been derived from lavas interstratified with such rocks; altered igneous material would provide a possible source for the rare epidote.

Age and Correlation

A considerable lithologic difference exists between the rocks now included in the Porotu Limestone and those of Cretaceous age with which they were previously considered to be allied (Bartrum and Turner, 1928; Kear and Hay, 1961). Examination of the abundant Foraminifera in section 9006 allowed Dr N. de B. Hornibrook to confirm the suspected Tertiary age of the sediment and to suggest it might be of Arnold age because of the tentative identification of *Globigerapsis index* (pers. comm. 13/11/64).

Correlation of the limestone with other North Auckland rocks cannot be made with certainty. In the Arnold strata of the Mangakahia Subdivision (Hay, 1960) both the Tangowahine Formation (Runangan–Whaingaroan) and the Pa Greensand (Bortonian) are glauconitic, while argillaceous limestone has been reported from the Aponga Shale (Bortonian). The Runangan Ruatangata Sandstone of the Kamo district also contains glauconitic horizons (Kear, 1959). On a purely lithologic basis, the Porotu rocks are similar to the Whaingaroan–Duntroonian Otai Greensand of Hay (1960).

WAITEMATA GROUP

The name Waitemata Group is applied to a thick sequence of clastic sediments ranging from claystone to conglomerate that occur in the North Cape district. Deposition, which spanned at least Waitakian to Awamoan times, took place in a variety of environments, but the rocks are characterised by their high content of volcanic-derived detritus.

Stratigraphic Subdivision

The stratigraphic terms applied to the lithologic units than can be mapped in the group are given in Table I; all are new, although the major divisions are essentially those recognised by Bartrum and Turner (1928) and subsequent workers. The only name previously proposed for these sediments, Coal Point Series (Bell and Clarke, 1910) or Formation (Kear and Hay, 1961) has been found unsatisfactory and is hence abandoned. No type section or area was given for this term, named from a feature that is more correctly referred to as Ohao Point, and which is wrongly located on Bell and Clarke's map. Several distinct formations can be mapped in the rocks referred to by this name; to change the status of the term to that of a group would cause added confusion, while to restrict it to only a portion of the rocks which it previously covered appears even less desirable. The rocks are in large part clastic marine sediments, with coal occurring as a rare and atypical variant, in contrast with the connotations of the term.

Correlation

In the Auckland–North Auckland region an extensive marine transgression was initiated by the tectonic movements of the Upper Oligocene which also provided conditions conducive to the accumulation of thick sedimentary sequences in a complex fast-subsiding basin. This lay west of a probably continuous landmass and was bounded to the west, at least in part, by a volcanic chain possibly of island-arc type, activity from which occasionally encroached into the depositional area.

The sequence in the Auckland–Kaipara district has not been fully elucidated. Hornibrook and Schofield (1963) reported a succession from Pareora to Southland Series west of Auckland City, and Otaian rocks are widespread (Hopgood, 1961; Hornibrook, *in* Fleming, 1959; Fleming, 1962). The relative importance of the Hutchinsonian, Awamoan, and Altonian stages is not known.

In the Hokianga district little data are yet available but both Kear and Hay (1961) and Thompson (1961) map these rocks as of Pareora to Altonian age, and Hornibrook and Scott (*in* Squires, 1962) regard the coral-bearing beds at Hokianga as Otaian. At Parengarenga the bulk of the strata are Otaian, but a sequence from Waitakian to Awamoan and possibly to Altonian is present.

TOM BOWLING FORMATION

The Tom Bowling Formation includes all those rocks of the Waitemata Group that unconformably overlie the Whangakea Volcanics and rest in broad conformity below the thick andesitic Kaurahoupo Conglomerate. Fine- and medium-grained detrital sediments form the bulk of the unit, but breccias and grits are also present. The type section of the formation lies along the western half of Tom Bowling Bay, between 422514 and 437516, where both the overlying and underlying rocks are also exposed.

Distribution, Stratigraphy, and Thickness

Distribution of the formation is outlined on the geological map (Fig. 2). Apart from a triangular wedge of these rocks converging westward from near Wharekawa and a block of similar sediment associated with a major fault immediately west of Porotu Stream the Tom Bowling Formation is found in stratigraphic contact with the underlying Whangakea Volcanics.

Stratigraphic columns for four sections within the formation (Fig. 3) indicate a considerable variation in thickness despite the incomplete nature of some of the data. Unfortunately above the basal breccia no intraformational correlations are possible so that it is not apparent whether the variations are primary depositional features or arise from erosion attendant upon uplift of the basin prior to deposition of the overlying conglomerate. The thin sequence at Hooper Point comprises predominantly fine-grained sediments that accumulated under quiet conditions in an environment into which only the finest detritus was transported, but the much thicker sequence along western Tom Bowling Bay includes coarse sandstones of turbidite type.

Content

The four distinct types of deposits found in the Tom Bowling Formation, a calcareous basal breccia, alternating sandstone-siltstone sequences, fine-grained

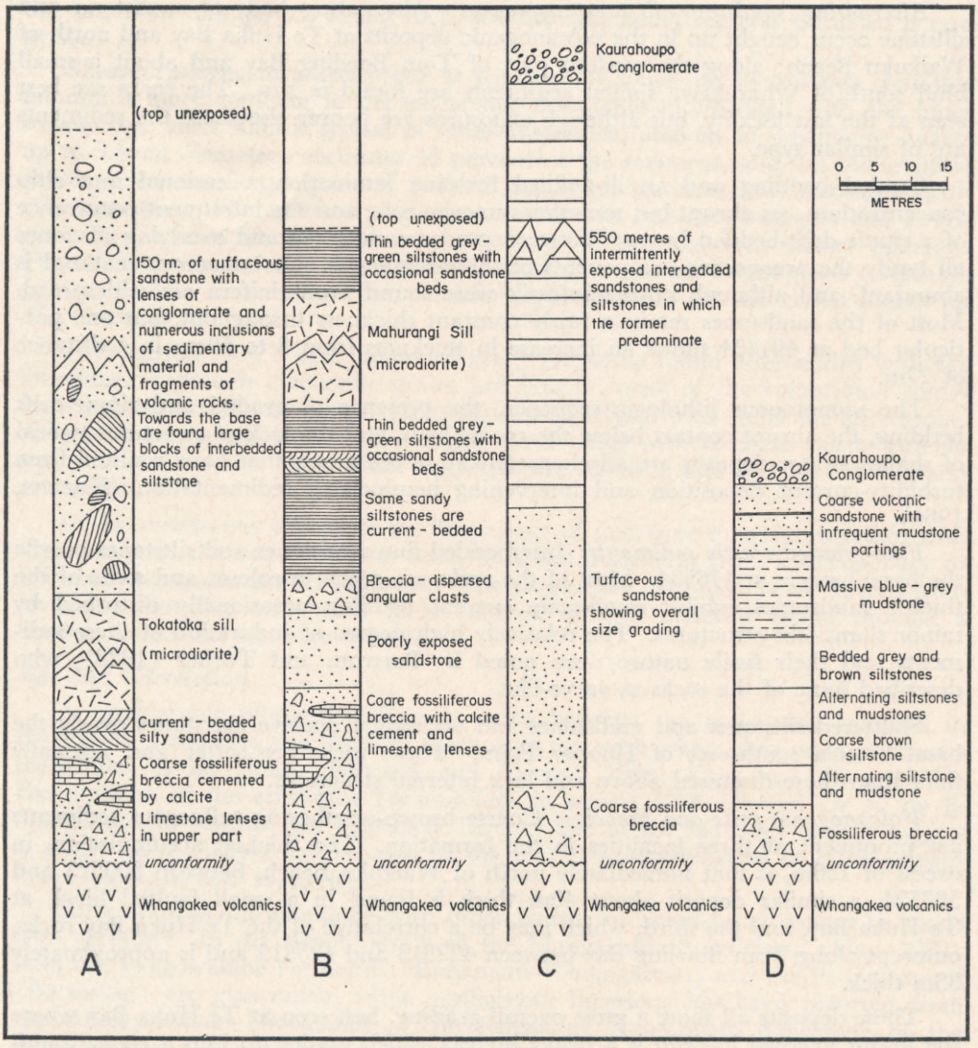

FIG. 3.—Stratigraphic columns in the Tom Bowling Formation. A: Southeast corner of North Cape Headland (508526–498503). B: Southwest corner of North Cape Headland (476535–476530). C: Western Tom Bowling Bay (422514–437516). D: Southeast of Hooper Point (344524).

clastic sediments, and thick volcanogenic grits and breccias, are each discussed below.

Basal breccia: The lowermost horizon of the formation is a fossiliferous breccia 3 to 25m thick. Everywhere the clasts, which range from small pebbles to poorly rounded boulders 65cm in diameter have been derived from the underlying Whangakea Volcanics, but the nature of the matrix is somewhat variable. On the North Cape Headland little fine detritus is present, and at both 507526 and 476534 the fragments are cemented by a dense pink limestone which also penetrates cracks and joints in the basement. The boulder-to-matrix ratio is high at both these localities except near the top of the breccia, where lenses of pebbly limestone up to 2m thick occur. East of Te Huka Stream and about Hooper Point the breccia is thinner and the matrix, although still highly calcareous, is less pure and not crystalline.

Alternating sandstone-siltstone sequences: Alternating beds of sandstone and siltstone occur caught up in the volcanogenic deposits at Te Huka Bay and north of Waikuku Beach; along the western part of Tom Bowling Bay and about a small bluff south of Wharekawa similar sediments are found *in situ*. The rocks are best seen at the last locality, but although exposures are poorer elsewhere the sediments are of similar type.

Graded bedding and an ill-defined bedding lamination, occasional mud-chip concentrations, an abrupt but sometimes uneven sole, and the infrequent occurrence of a ripple-drift-bedded interval between graded sandstones and overlying siltstones all typify the arenaceous components of these sequences. Carbonaceous material is abundant, and although no macrofossils were found Foraminifera are widespread. Most of the sandstones retain a fairly constant thickness throughout, but one particular bed at 491484 shows an increase in thickness from 8 to 60cm in a distance of 27m.

The monotonous lithologic sequence, the presence of graded and ripple-drift bedding, the abrupt contact below the coarse beds, and the lack of structures typical of shallow-water deposits are all characteristic of sediments that have resulted from turbidity-current deposition and intervening hemipelagic sedimentation (Kuenen, 1964).

Fine-grained clastic sediments: Interbedded fine sandstones and siltstones overlie the basal breccia at 476534. Most of the rocks are green in colour, and some of the thicker sandstones exhibit small-scale current bedding occasionally disturbed by minor slump-like structures. The relatively high degree of induration of these sediments and their fissile nature were noted by Bartrum and Turner (1928), who described some of the rocks as varve-like.

Shattered siltstones and mudstones and occasional massive claystones overly the basal breccia south-east of Hooper Point. These rocks are softer and normally finer than those discussed above and lack internal structures.

Volcanogenic grits and breccias: Coarse brown-weathering tuffaceous sediments are prominent at three localities in the formation. The thickest accumulation, in excess of 150m, is that immediately north of Waikuku Beach, between 500523 and 503524, a similar deposit about 40m thick is found in a small faulted block at Te Huka Bay, and the third, which may be a correlative of the Te Huka Bay rocks, outcrops along Tom Bowling Bay between 422513 and 425515 and is approximately 33m thick.

These deposits all show a gross overall grading, best seen at Te Huka Bay where the lowest exposed horizon is a heavy breccia which grades up into a coarse sandstone. Crude stratification is sometimes discernible, but mudstone partings are absent. Small boulders and numerous subangular cobbles of andesite that are often highly vesicular are present in the rocks at the first two localities; these rudaceous fragments are quite distinct from Whangakea debris, which occurs rarely. Angular sedimentary blocks are ubiquitously distributed throughout the tuffaceous material, and large rafts of sediment may float in its lower levels. At both Te Huka Bay and north of Waikuku Beach, the tuffaceous deposits are intimately associated with masses of slumped and disrupted strata of alternating sandstone-siltstone type.

The base of the grit at Tom Bowling Bay lies sharply but irregularly on the basal breccia, and it is in turn overlain by normal marine strata.

Thin sections show the tuffaceous material to be rich in volcanic glass and fresh andesite debris. The glass is often vesicular, with the vesicles showing a marked elongation in many instances. The direction of elongation varies between individual fragments, and there is no sign of welding. Very rare Foraminifera and glauconite pellets are found in the rocks. All the allogenic constituents are poorly rounded and the degree of sorting is low.

From the foregoing description it appears that these rocks represent the rapid accumulation of large volumes of material in a marine environment. The crude grading and poor sorting suggest deposition from a highly turbid medium, with disturbances attendant on the emplacement of the deposits causing large-scale disruption of moderately deep-water sediments forming the sea bed at the time.

The little abraded nature of the debris and the presence of fresh volcanic-glass fragments argues for a pyroclastic rather than an epiclastic origin for the volcanogenic materials, and the high glass content suggests aqueous quenching. The vesicular nature of much of the igneous material indicates a high content of volatiles in the magma at the time of eruption.

The writer considers that the deposits result from submarine phreatic eruptions caused by a relatively small volume of andesitic lava coming into contact with large amounts of connate water a short distance below the sea floor. This type of highly explosive eruption could disrupt large masses of recently deposited sediment and mix smaller sedimentary blocks, along with ash, glass, and volcanic boulders, into a dense, turbid aqueous cloud. Depending on the gradient of the sea bottom and the directional component of the blast, the eruption might produce a turbidity current immediately, or one might arise subsequently to the erupted material settling in an unstable position. At North Cape no evidence of definite flowage was found, and it is possible that the observed features are solely the result of settling. This mechanism is similar to that postulated by Fiske (1963) for the most widespread type of subaqueous pyroclastic flow he has recognised, characterised by the presence of a great variety of lithic fragments. No associated lava flows and no submarine volcanic edifices have been recognised in the Tom Bowling Formation, but neither would necessarily result from an eruption of the type suggested.

Age

Although macrofossils were observed only in the basal breccia, a large number of foraminiferal samples have yielded information pertaining to the age of the formation (Table II); determinations have been made by the Micropaleontology

TABLE II.—Microfaunal ages for samples from the Tom Bowling Formation.

Sheet fossil number	Grid reference	Age	Height above Whangakea basement (metres)
N2/504	341527	Lwh-d	1.6
505	341527	?Lw	unknown
515	507527	Lw	3
517	490484	Lw	unknown
520	341527	Lw	6
522	341527	Lw	12
523	341527	Lw	21
525	341527	Lw	39
526	341527	Lw	15
529	424514	Lw	c.45
542	490488	Lw-Po	unknown
543	490488	Lw-Po	unknown
556	457433	Lw	unknown
565	372509	Lw-Po	c.33
568	507526	Lw-Po	13.5

Branch of the New Zealand Geological Survey on collections made by a number of workers. These data indicate that the bulk of the formation is Waitakian, although its basal part may be made up of rocks as old as Duntroonian, and it possibly ranges up into the Otaian in its upper horizons.

Petrography, Provenance, and Diagenesis

Thin-section study of the sandstones and finer grits has yielded information on both the provenance and diagenetic alteration of the rocks. These sediments consist of angular to subrounded grains set in a relatively high proportion of fine matrix; sorting is generally poor and the rocks are often uncemented. Petrographically they are all wackes but include representatives of the volcanic, arkosic, and feldspathic subdivisions as defined by Williams *et al.* (1958).

Detrital quartz usually occurs as clear, unstrained, subangular grains lacking prominent inclusions although sometimes containing tiny dust particles. In some samples (9008, 9013, 9014) it is the predominant allogenic constituent but in others, especially the volcanogenic grits (9017, 9016, 9015) plagioclase and volcanic rock fragments are both more abundant; and quartz is an infrequent or rare phase. Intermediate and calcic plagioclase seldom showing any sign of predepositional alteration is common in all specimens; the crystals are complexly twinned, are zoned, and may contain glassy inclusions. Fresh grains of augite are widely distributed throughout the samples, as are a variety of amphibole types, the chief of which is a weakly pleochroic pale-green hornblende that occurs as prismatic fragments. A brown pleochroic variety is of more restricted distribution, being most plentiful in 9011; a dark red oxyhornblende is present in 9015 and 9011. Pale-green fibres of tremolite-actinolite occur in 9013, chlorite and biotite are widespread minor constituents, hypersthene and epidote rare ones, and glauconite, calcite, and pyrite are present in several of the rocks.

Rock fragments form an important part of many of the sediments. Fresh fragments of augite andesite are especially common in 9015, and volcanic glass is the most abundant constituent of 9016 and 9017. Clasts of silty rock are present in most sections, but quartzitic material is of much less importance.

The contribution of debris from an intermediate or basic volcanic source is readily recognisable. Some of the rocks of the formation are considered to be largely the result of pyroclastic activity, but in others the igneous detritus is epiclastic and much of this was probably derived from material recently erupted on the borderlands of the basin. The fresh plagioclase, pyroxene, and hornblende in the sediments contrast with the altered nature of the pyrogenic phases in the Whangakea Volcanics, and it is unlikely that these detrital minerals were derived from them, although such rocks could have supplied the detrital epidote, chlorite, and tremolite-actinolite. Lithologies of the type already considered would not have been capable of providing the abundant quartz found in many of the Tom Bowling rocks, and this was probably derived from older sedimentary units.

Several sporadically developed diagenetic processes have affected the formation. Most of the sandstones are fairly soft and uncemented, but some show partial development of a calcite cement. This process is never complete, but several stages can be recognised; in the earliest irregular patches of calcite occur in haphazard arrangement; as these grow they unite, and in rare cases numerous detrital grains float in a calcareous matrix that has invaded much of the rock. As well as occupying pore spaces the carbonate partially supplants silty matrix, quartz, plagioclase, glass, and augite.

Siliceous concretions have formed around mudstone fragments contained in a volcanic sandstone at 372509. A thin section (9011) of part of one of the concretions shows fresh plagioclase and ferromagnesian minerals but lacks detrital quartz grains. Pyritic nodules, up to 3cm in diameter, are present in the formation at Waitanoni Stream and near Hooper Point. In section 9010 pyrite partially supplants the original matrix, enclosing detrital grains in a pseudopoikolitic texture. According to Dapples (1962), pyrite is an authigenic product during the earliest or redoxomorphic stage of authigenesis and the replacement of both quartz and feldspar by carbonate occurs in the later locomorphic stage. The freshness of the grains contained within the pyrite, as compared with their much calcitised nature in the body of the rock, and the lack of calcite inclusions in the pyrite, indicate that the sequence postulated by Dapples has been followed. However, the presence of fresh glass fragments together with the extensive diagenetic calcite (for example in section 9010), indicates that under certain conditions volcanic glass may persist unaltered in rocks in which reactions characteristic of the locomorphic stage have taken place.

KAURAHOUPO CONGLOMERATE

A thick sequence of volcanic conglomerates, associated with subordinate finer detrital sediments and rare coal seams forms a prominent horizon in the Waitemata Group, here termed the Kaurahoupo Conglomerate. The name is taken from Kaurahoupo Rocks (440518) which lies in the type section, defined as that exposed along Tom Bowling Bay between 437516 and 448516.

Distribution and Interformational Relations

The extent of the unit is outlined in Fig. 2. Evidence of minor erosion of Tom Bowling strata prior to deposition of the Kaurahoupo Conglomerate is found at the contacts of these formations at 435500 and 372511. This may indicate temporary emergence of the Waitemata Group above sea level at the end of Tom Bowling sedimentation, for considerable uplift must have occurred at this time; alternatively, the increased current competency indicated by the coarse detritus of the conglomerates may have caused local scouring of the underlying rocks. No angular unconformity was detected between these two formations.

In the western and central parts of the North Cape district Paratoetoe rocks conformably overlie the Kaurahoupo Conglomerate; in the east the uppermost horizon of the Kaurahoupo interdigitates with the lower beds of the Paratoetoe Formation and a tongue of volcanic conglomerate extends into the Paratoetoe for at least 3km.

Thickness and Stratigraphy

The only complete section through the formation is that south of Tom Bowling Bay, where calculations indicate the presence of approximately 1,000m of strata. The sequence south-west of Ohao Point is incomplete; computations suggest that at least 1,400m of Kaurahoupo rocks is present here, although exaggeration owing to normal faulting cannot be completely discounted.

Little stratigraphic subdivision of the conglomerates is possible, for marked lithologic variations are of local development only. Distinctive coal-bearing strata exposed on the northern side of the entrance to the Parengarenga Harbour are referred to as the Karerewaka Coal Measures Member; this occupies a position at the top of the Kaurahoupo Formation here, but has not been recognised elsewhere in the North Cape district.

Even in those exposures composed almost entirely of conglomerate bedding is usually discernible, although near the base of the formation more massive exposures are found. Individual conglomerate strata vary between 0.3 and 5m in thickness, are often lensoid, and may be split laterally by beds of finer grade. In the rudaceous rocks every gradation exists between orthoconglomerates with closely packed boulders and cobbles with little matrix and open-framework rocks, best termed bouldery sandstones, in which infrequent rudaceous fragments are scattered throughout an essentially arenaceous sediment. All cobbles and boulders are fairly well rounded, the larger better so than the smaller; most are between 8 and 30cm in diameter, but a boulder of 3m diameter was found in the conglomerates on the north side of Rangiora Bay.

The conglomerate grade material is poorly sorted but the matrix, a coarse sandstone, contains little finer detritus. When the supply of rudaceous fragments was temporarily curtailed lenses of sandstone accumulated. Occasionally, as at Pananehe Island, these deposits occur only as small pockets, but elsewhere they are continuous throughout exposures several tens of metres long. Such lenses average about 0.2m in thickness, but larger units that are internally stratified and may show cross-bedding are up to 5m thick.

Rare thin grey mudstones are interbedded with the conglomerates particularly in the section south-west of Ohao Point, where they sometimes contain well-preserved leaf impressions; petrified wood, including logs 2m long, is scattered throughout the formation.

In Peterahema Stream between 398488 and 400484 some 150m of poorly exposed alternating sandstones and siltstones are both overlain and underlain by volcanic conglomerates. These beds lack shallow-water structures, and some of the siltstones contain abundant planktonic Foraminifera.

Karerewaka Coal Measures Member. This name is given to about 124m of strata characterised by the presence of minor coal seams which occurs at the top of the Kaurahoupo Conglomerate between 470405 and 466405. Hector (1872) first described the succession in this area, but comparison of his section with that measured by the writer (Table III) indicates that he recorded only the lower three horizons at present exposed, although in addition he was able to examine rocks now masked by sand and vegetation.

Table III.—Stratigraphic section through the Karerewaka Coal Measures between 470405 and 466405.

	Metres
Grey carbonaceous mudstone, at least	7
Polymictic conglomerate	4
Coarse structureless sandstone	10
Conglomerate with mudstone matrix containing fragments of muddy carbonaceous sandstone up to 1m long	16
Mudstone with plant remains and occasional coarse sandstone lenses	9
Polymictic conglomerate	4
Sandstone, coarse at base, with infrequent concretions and lenses of carbonaceous mudstone and conglomerate	11
Conglomerate	3
Rhythmically repeated current-bedded sandstones, laminated sandstones, coal seams and mudstone	35
Coarse concretionary sandstone, at least	25

Most of the coal occurs in a 35m sequence of rhythmically repeated beds (asymmetric cycles in the terminology of Weller, 1960) in which a complete rhythm consists of:

(top)
(d) Coarse, grey, current-bedded sandstone 15–60cm.
(c) Laminated fine-grained muddy sandstones, occasionally current bedded 15–30cm.
(b) Coal 0–12cm.
(a) Chocolate to grey mudstone, sometimes arenaceous 15–30cm.

The most common omission from this sequence is the coal unit (b) which is found in comparatively few cycles, but in spite of this, where it is developed it may alternate several times with unit (a) and increase the thickness of the complete cycle considerably; the other members of the cycle are nearly always present. Each cycle is abruptly terminated at the top of (d) and the contact of this with (a) is not gradational.

Plant remains are a characteristic feature of the rhythmically repeated strata, but differences in content exist between the various units: unit (d) contains occasional scattered and comminuted plant debris; in (c), which is often rich in plant fossils, large palmaceous fronds are preserved, especially near the (d)–(c) interface.

Broad leaves are associated with these but become more plentiful at a slightly lower level. Unit (a) contains small delicate vegetal remains as well as larger fragments.

Apart from the presence of the rhythmically repeated beds the member differs from typical Kaurahoupo rocks in the increased content of non-volcanic material in the conglomerates, which have a muddy rather than a sandy matrix.

Intraformational Disturbances

In the northern part of the section between 461422 and 460418 well stratified sandstones and conglomerates of the Kaurahoupo Formation dip at moderate angles to the south-west. However, from 461419 to 460418 the arrangement of the beds becomes chaotic, the strata are broken into irregular packets rarely continuous over distances exceeding 2m and the entire mass lacks any sensible structural pattern.

This is believed to have resulted from slumping soon after deposition of the affected beds, for welded contacts between adjacent packets, the lithification of the whole mass to a degree comparable with that of the uncomplicated rocks immediately to the north, and the undisturbed nature of these overlying rocks indicate this is not a recent slump feature.

Age

Three foraminiferal samples from this formation have yielded diagnostic faunas, identified by Dr N. de B. Hornibrook, who supplied the following information (pers. comm. 3/7/64): Sheet fossil No. N2/569, from the bed of a tributary of Te Huka Stream at 414493, *Globigerina apertura woodi* Jenkins, *Globorotalia kugleri* Balli, *Globoquadrina dehiscens* (Chapman, Parr, and Collins)—age Otaian.

Sheet fossil No. N2/573, from a tributary of Peterahema Stream at 400486, *Globoquadrina dehiscens, Globigerina dissimilis* Cushman and Stainforth, *Globigerinoides altiapertura* Balli—age about mid-Pareora, probably Upper Otaian.

Sheet fossil No. N2/574, from the eastern face of the Pinnacle at 376501, *Globigerina dissimilis, G.* aff. *altiapertura, Globorotaloides*—age Otaian.

Provenance

The essentially andesitic derivation of this formation is indicated by the great predominance of andesite boulders in all conglomerate exposures; microdiorite clasts, though less common, are also widespread, but sedimentary material is of restricted occurrence. Lithologies recognised in thin section include altered basalt (Whangakea type), basaltic andesite, augite andesite, two-pyroxene andesite, quartz-bearing augite-microdiorite, uralite gabbro (Kerr Pluton type) and quartz sandstone.

No andesite flows are known in the North Cape district or its immediate environs, but the petrography of the conglomerate boulders indicates that they are similar to flows and shallow intrusives that were emplaced in the Auckland–Northland region during Lower Miocene times (Searle, 1944; Brothers, 1948; Hay, 1960; Black, 1967). There is no difficulty in regarding the andesite boulders as having been derived from a northern extension of this province in which activity was probably in part contemporaneous with the deposition of the Kaurahoupo Formation. The microdiorite clasts closely resemble those of the Tawakewake Intrusives and were probably eroded from the intrusive equivalents of the andesites emplaced in the lava pile. Most of the boulders of sedimentary type in the conglomerates are identical with the finer phases interbedded with the conglomerates, and are probably the result of local erosion.

PARATOETOE FORMATION

On the northern shore of the Parengarenga Harbour, sandstones, siltstones and conglomerates form a distinct mappable unit within the Waitemata Group, to which the name Paratoetoe Formation is given. The type section is that exposed from 455433 to 418423, including strata at Paratoetoe Point, the source of the name.

Distribution, Intraformational Stratigraphy, and Thickness

The formation outcrops in an arcuate band trending south-east from Spirits Bay to Ngatehe Point and in a small, poorly exposed area immediately south-west of Waikuku Flat.

Exposures are not sufficiently complete to allow the erection of a detailed stratigraphy through the whole of the formation. The type section along the northern shore of the Parengarenga Harbour is outlined in Table IV; it commences approximately 375m above the highest horizon of the Kaurahoupo Conglomerate and together with unseen rocks totals some 934m, indicating a thickness of at least 1,309m of Paratoetoe sediments.

TABLE IV.—Type section through the Paratoetoe Formation along the Parengarenga Harbour from 455433 to 418423.

	Metres
Alternating sandstones and siltstones often rich in fossil material	55
Highly fossiliferous massive grey mudstone	22
Carbonaceous sandstones and siltstones with minor conglomerates in the lower part	37
Massive conglomerate	22
Unexposed	c.145
Massive conglomerates with infrequent finer lenses that are often carbonaceous. Boulders up to 70cm diameter are well rounded	25
Graded sandstones and conglomerates interbedded with occasional carbonaceous siltstones	155
Distinctive thin bedded alternating grey sandstones and siltstones. The sandstones, which may be laminated or graded often have coarse fossiliferous lenses at their bases	125
Unexposed	c.70
Alternating sandstones and siltstones in which fossils become more common towards the top of the unit where some extremely shelly beds occur	85
Siltstones, overlain by conglomerates and then by alternating sandstones and siltstones some of which show minor slump folds. Near the top conglomerates containing worn fossils are interbedded with the finer strata	60
Unexposed	c.125
Disturbed interbedded conglomerates, graded sandstones and siltstones	c.30

Content

Bedded clastic sediments that range in grade from siltstone to conglomerate constitute the bulk of the Paratoetoe Formation. Individual strata rarely exceed 2m in thickness, although infrequently the thickness of siltstone and conglomerate units is much greater than this.

The siltstones are grey and slightly calcareous; they are normally soft and uncemented although rare silicified beds and siliceous concretions attest to local cementation. The rocks may be massive or show a laminated structure, the latter due to minor changes in grain size or the presence of thin carbonaceous partings.

Sandstones of the formation are blue-grey when fresh and weather to a green or rusty-yellow. They are little lithified, often contain carbonaceous fragments, and are sometimes richly fossiliferous. Their internal features vary; some strata are characterised by well-developed grading, occasionally repeated several times, others are laminated, but many are quite massive and devoid of obvious structures. The base of the sandstones may be irregular due to minor scour features and to the local development of load features, but sole markings are not widely developed. Exotic boulders up to 70cm in diameter occur in some of the strata and others contain numerous cobbles.

Thin conglomerate beds are found interbedded with the finer rocks of the formation; they contain well-rounded cobbles which rarely exceed 15cm in diameter, have a highly variable matrix content, and at times grade up into sandstones. The thicker conglomerates encountered in the section outlined above contain much larger rudaceous material, up to 80cm in diameter, and are distinguished from similar rocks in the Kaurahoupo Formation by the variety of rock types they contain and by a much increased matrix content; these conglomerates nearly always have a matrix to boulder ratio that exceeds unity.

Age

Foraminiferal studies by Jenkins (1965) and Scott (pers. comm.) indicate that the age of the Paratoetoe Formation varies from Otaian to Upper Pareora or Altonian.

Provenance

The wide range of lithologies present in the conglomerates indicates derivation of the rocks from a landmass of considerable diversity. The nature of some of the material is apparent in hand specimen, but identification has in most cases been confirmed by thin-section study. Rock types recognised and their possible sources are summarised below.

Andesites similar to those found in the Kaurahoupo Conglomerate occur throughout the Paratoetoe Formation; varieties include pilotaxitic andesine andesite (9034) and quartz hornblende andesite (9035). These rocks undoubtedly come from the same source as those in the Kaurahoupo.

Altered basic lavas (9037) that are often mineralised and veined by zeolite and calcite can be matched petrographically with the lavas of the Whangakea Volcanics. Clasts of this type are widely distributed although not as common as those of little-altered andesite.

Grey flow-banded volcanics, not separated in the field, were found subsequently to be of two types; keratophyres (9038) similar to those described by Bartrum (1929) and Battey (1955) from the Cretaceous Mt Camel Volcanics, and dacites (9041) of the type found by Black (1967) in the Tokatoka district.

Gabbroic rocks (9039) indistinguishable from certain phases of the Kerr Pluton are of only rare occurrence, as are granitic types, including a graphic microcline granite (9040). The latter may have been derived from the reworking of Cretaceous conglomerates similar to those recorded farther south (Bell and Clarke, 1909; Battey, 1950), for the boulders are exceptionally well rounded.

A porphyrite (9042) in which most of the plagioclase has been pseudomorphed by prehnite could not be confidently ascribed to any known Northland rock unit.

Soft sandstone and siltstone fragments that closely resemble those of the Waitemata Group in this area are probably the result of submarine erosion during the emplacement of the conglomerates or of the erosion of material exposed on the margins of the trough following local upflexing.

Diverse calcareous sediments, including argillaceous and crystalline limestones and highly siliceous mudstones, quartzose sandstones, and cherts are found throughout the conglomerates; they have probably been derived in the main from Cretaceous or Lower Tertiary lithologies of similar type that are found throughout Northland.

WAIKUKU LIMESTONE

This unit, a highly fossiliferous calcarenite of Upper Lillburnian or Waiauan age which forms small outcrops along Waikuku Beach, has recently been described by Leitch *et al.* (1969). The relationship of these rocks to older strata is unknown.

Tawakewake Intrusives

The term Tawakewake Intrusives is proposed for several hypabyssal igneous bodies, the emplacement of which postdated the commencement of Waitemata Group sedimentation. The commonest rock type is a quartz-bearing augite microdiorite that contains rare aplitic segregations. A single small augite-dolerite dyke is also included in this formation. The sill exposed on either side of Tawakewake Stream at 475530 may be regarded as the " type intrusion ".

The distribution of the various bodies is indicated on the geological map (Fig. 2); a detailed account of their field relations, petrography, and associated contact rocks is at present in preparation.

Age

No accurate assessment of the age of the intrusions is possible at present. They are younger than the Waitakian–Otaian Tom Bowling Formation and are tentatively considered to be mid-Miocene. This age is based mainly on field relations at Te Huka Bay, where a large dyke has been emplaced along a fault separating Tom Bowling rocks from lavas of the Whangakea Volcanics. There was renewed minor movement on the fault after intrusion of the dyke, which was probably emplaced towards the end of diastrophism in this region. Leitch *et al.* (1969) have shown that some tectonic movements postdated the Waikuku Limestone.

Correlation

Although chemical analyses of these rocks are not yet available, inferences drawn from their mineralogy suggest little difficulty in regarding them as part of the mid-Tertiary calc-alkaline association which is widespread throughout the North Auckland Peninsula. No obvious petrographic correlatives of the microdiorites have been described from this area, for although numerous intermediate intrusive rocks of comparable age are known (e.g., Black, 1967) most show a volcanic texture. The porphyrites of Whangarei Heads (Bartrum, *in* Ferrar, 1925; Allen, 1951), the Miocene Paritu quartz-diorite of northern Coromandel Peninsula and the diorites of Coppermine Island (Brothers and Hopkins, 1967) all differ from the North Cape rocks in mineralogy.

Quaternary Deposits

Scattered deposits of quartzose sands mantle old erosion surfaces up to an altitude of 185m. Talus, with an initial inclination reaching 35° has formed around the North Cape Headland, and Waikuku Flat is underlain by Quaternary peat. The more mature valleys are extensively alluviated in their lower reaches, and low, elongate tongues of sandy and muddy strata extending out into the Parengarenga Harbour are remnants of the harbour floor that developed during the maximum incursion of the Flandrian transgression.

Of particular interest is a 20m section exposed at 461407 which shows a sequence of dune-bedded and structureless sands intercalated in which are old soil horizons that contain root impressions, and are overlain by highly carbonaceous beds. A pollen preparation from one of these highly carbonaceous beds yielded a flora in which beech was dominant and which lacked warm or coastal species, suggesting a climate cooler than at present (Dr W. F. Harris, pers. comm. 27/7/65). This indicates that even in northernmost New Zealand a marked climatic deterioration accompanied at least one of the Pleistocene coolings. Unfortunately the age of the rocks here is not accurately known; a terrace is cut in them 6m above sea level, suggesting that they are older than late Monastirian and possibly accumulated during the regression that accompanied the Penultimate Glaciation.

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E. C. Leitch,
Geology Department,
University of New England,
Armidale, N.S.W.,
Australia.

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