GEOLOGY OF THE ALDERMEN ISLANDS

by B.W. Hayward* and P.R. Moore*

SUMMARY

The Aldermen Islands are the much eroded remnants of a once far larger complex of rhyolite domes, associated ignimbrites and pyroclastic sediments. The majority of rocks present are rhyolitic lavas and pyroclastic sediments of the Whitianga Group (Pliocene in age) which unconformably overlie (Miocene – lower Pliocene) andesitic Beesons Island Volcanics.

Whitianga rocks comprise five intrusive and extrusive domes of the Minden Rhyolite Subgroup, intruded along an east-west trending line from Ruamahua-nui to Hongiora. Remains of coulées that are inferred to have been derived from these domes are exposed on islands to the north and south of this line. Pyroclastic flows, tephra showers and breccia flows of this rhyolitic eruptive period have formed the widely varied deposits of the Coroglen Subgroup exposed on most islands.

INTRODUCTION

This island group, situated 18 km east of Tairua, off the east coast of the Coromandel Peninsula consists of four main islands and six smaller ones, and scores of rocky islets (Hayward, 1973).

A geological survey of the Aldermen Islands was carried out by the authors during the seven day Auckland University Field Club Scientific Camp in May 1972.

Rock specimen numbers referred to are those of the petrology collections of the Geology Department, University of Auckland, and fossil record numbers are those allotted in the archival N.Z. Fossil Record File.

PREVIOUS WORK

Prior to this study, very little was known of the geology of these islands. Sladden and Falla (1927) presented a short report by J.A. Bartrum based on samples brought back from the four main islands. They briefly noted, as did Cochrane (1962), that Ruamahua-iti appeared to be composed of breccia, Hongiora was totally lava and that Middle Island contained columnar jointed lava. Bartrum (in Sladden and Falla, 1927) noted that all samples appeared to be a distinctly acidic rhyolite.

Cochrane (1962) believed Ruamahua-nui to consist of grey rhyolitic breccia, and Hongiora to be a lava flow. Based on the diagnosis of Bartrum, Schofield (1967) included the rocks of these islands within the Minden Rhyolites.

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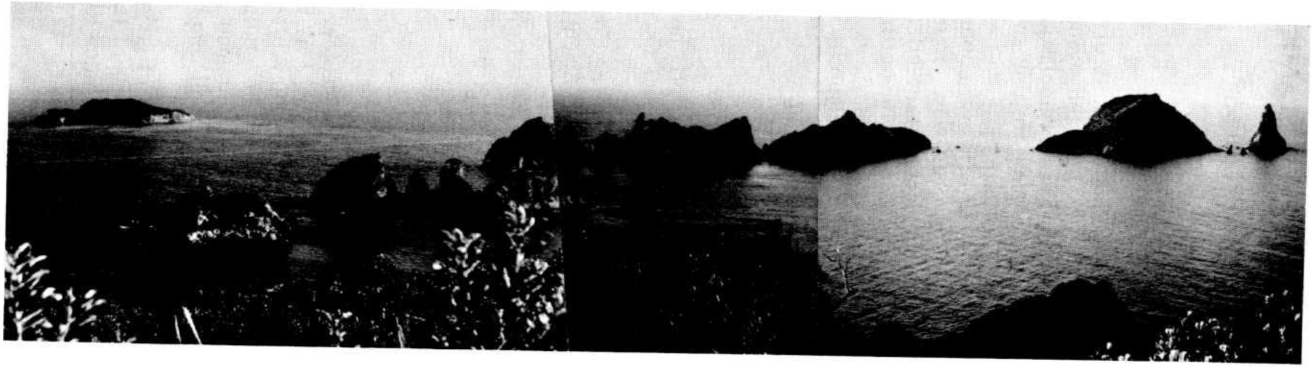

Fig: 1 View from top of Ruamahua-iti northwards to (from left) Hongiora, Half Island, Hernia Island, Middle Island, Ruamahua-nui and The Spire.

PHYSIOGRAPHY

The islands of the Aldermen Group are the only exposed portions of a submarine plateau, covering an area of 14 sq. km. above a depth of 40 m, which rises steeply from the continental shelf (average depth 100 m in this vicinity).

Present erosion of the Aldermen Islands is controlled almost entirely by wave action and nature of the rock. However, erosion by running water has probably been important at times of former low sea level, as suggested from submarine contours (Fig. 2), and it is this erosion that has largely controlled the present distribution of the islands. Hence the islands are merely small remnants of a once more extensive landmass.

Steep cliffs of rhyolite lava or breccia up to 180 m in height (Ruamahua-iti) are a conspicuous feature of the islands, and only on the uppermost bush-clad slopes is the geology obscured (Fig. 1). The pronounced topography on the western half of Middle Island results from the prominent columnar joints in the rock, which yields easily to wave action. However, the more resistant poorly-jointed, flow-banded rhyolite of Hongiora has responded entirely differently to erosion, and its subdued topography is in marked contrast to the remainder of the islands.

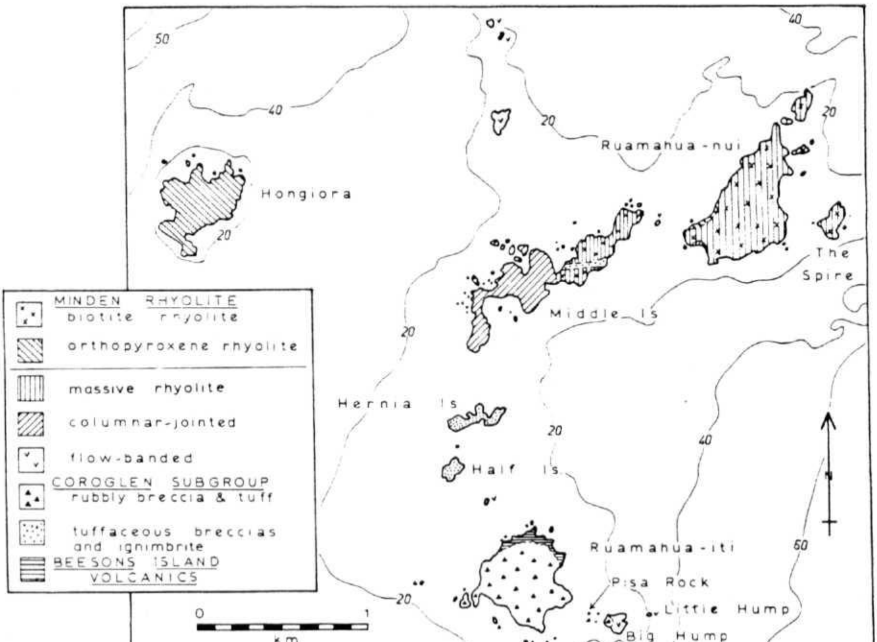

Fig. 2: Geological map of the Aldermen Island Group.

(Submarine contours in metres.)

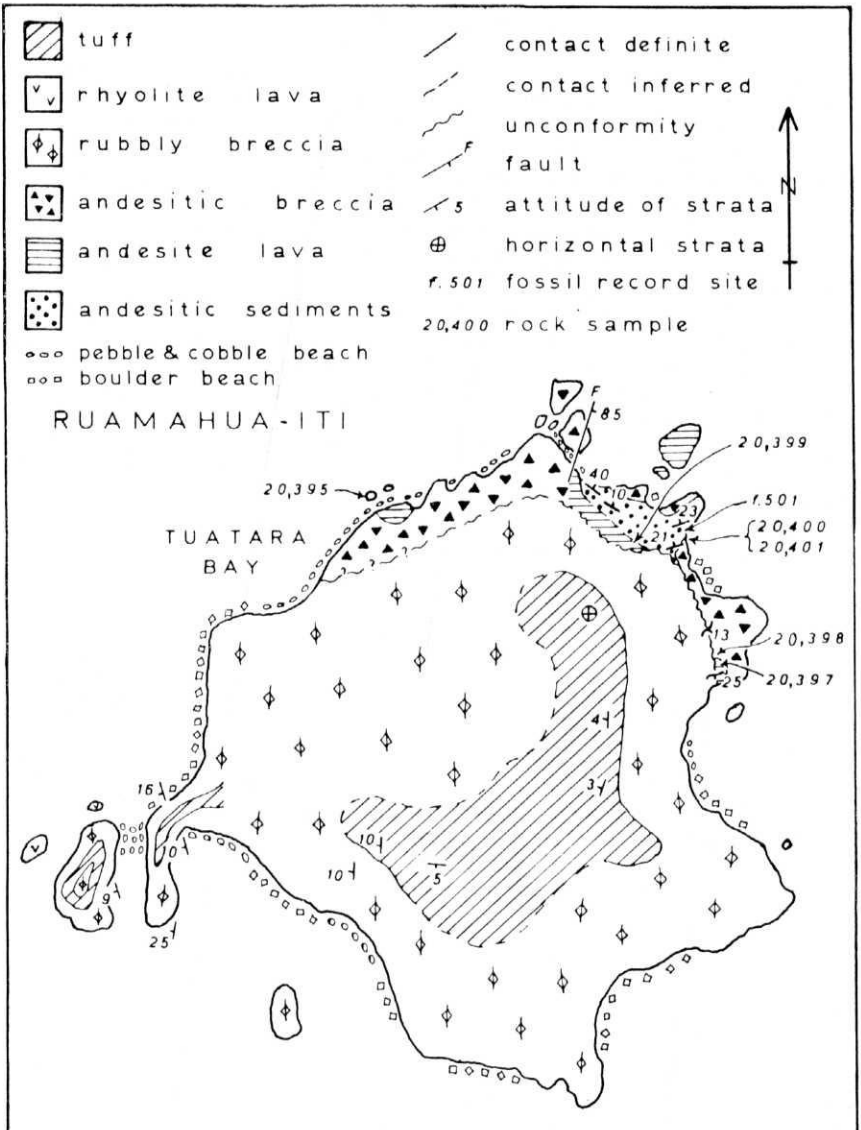

Fig. 3: Detailed lithostratigraphic and structural map of Ruamahua-iti.

Caving of cliffs is a common feature and has given rise to numerous stacks, particularly on the north-western side of Middle Island, and also surrounding Ruamahua-nui and Ruamahua-iti. Collapse of caves has produced the prominent isthmus of central Middle Island, and provides the name for Hernia Island.

More detailed descriptions of individual islands are given in Hayward (1973).

STRATIGRAPHY

1. Beesons Island Volcanics

Rocks of this andesitic volcanic group are exposed only around the base of the cliffs and in the shore platforms of northern Ruamahua-iti (Fig. 2). These rocks consist of hydrothermally altered, subrounded to angular, cobble and pebble andesite breccias, lava flows and sediments lying beneath an irregular unconformity, (Figs. 3,4) and overlain by rhyolitic rubbly breccias.

Petrography

(a) Lava flows

In hand specimen fresh samples of the least altered lava are medium grey porphyritic rocks containing abundant phenocrysts of plagioclase with fewer and smaller dark phenocrysts of pyroxene set in a light to medium-grey encrystalline groundmass.

Four samples were thin sectioned, three from flows (20395, 20398, 20399) and one a breccia clast (20397). Sections 20395 and 20398 were too highly altered for worthwhile study. Modal analyses of the two least altered samples are presented in Table 1. A chemical analysis of the freshest sample (20397) is given in Appendix 2.

Table 1: Modal analyses of Beesons Island Volcanics lavas.*

	20397	**20399**
PHENOCRYSTS (>0.3 mm)		
Total	32.0	32.8
Plagioclase	27.1	23.2
Orthopyroxene	4.9	9.6
GROUNDMASS (<0.3 mm)		
Total	68.0	67.2
Plagioclase	33.0	19.5
Orthopyroxene	2.6	1.8
Opaques	1.8	0.1
Indeterminate	30.6	45.8

*1000 points per count.

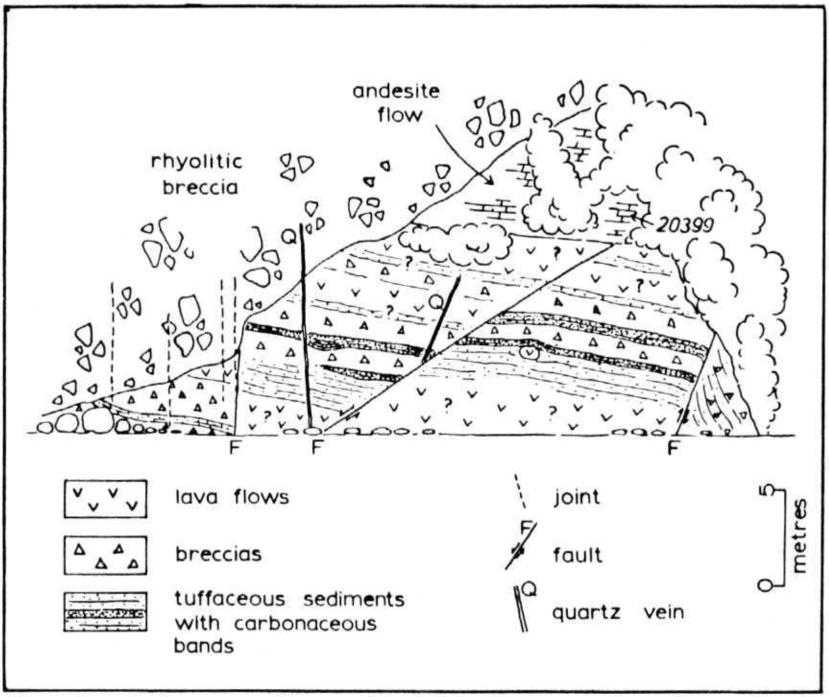

Fig. 4: Sketch of exposure of Beesons Island Volcanics sequence beneath unconformity; base of cliffs, north Ruamahua-iti.

In thin section these lavas are composed of phenocrysts (32% of total rock composition) of plagioclase (0.3 – 3.0 mm) and weakly pleochroic hypersthene (0.3 – 2.5 mm) in a hypocrystalline groundmass composed of plagioclase microlites, pyroxene and opaque grains with altered interstitial glass. Glomerophenocrysts of orthopyroxene and plagioclase crystals occur throughout.

It is concluded that the lavas here are hypersthene andesites similar to those found commonly elsewhere in the Beesons Island Volcanics Group.

(b)Sediments

Interbedded lava flows and sediments of the Beesons Island Volcanics are well – exposed in a cliff section on the northern side of Ruamahua-iti (Fig. 4). The sediments are grey to black, fine to coarse breccias, tuffs, and fine carbonaceous tuffs, locally silicified and pyritised. Study of three thin sections (20400(2), 20401) showed the sediments to consist largely of angular to subrounded tuffaceous rock fragments (0.05 – 2 mm) with plagioclase and orthopyroxene crystals in lesser amounts, and accessory apatite and opaques. Pleochroic green chlorite may replace both plagioclase and orthopyroxene, and is also found as a cavity filling, along with quartz and zeolites. Veining by fluorite and zeolite is present in some sections (20400).

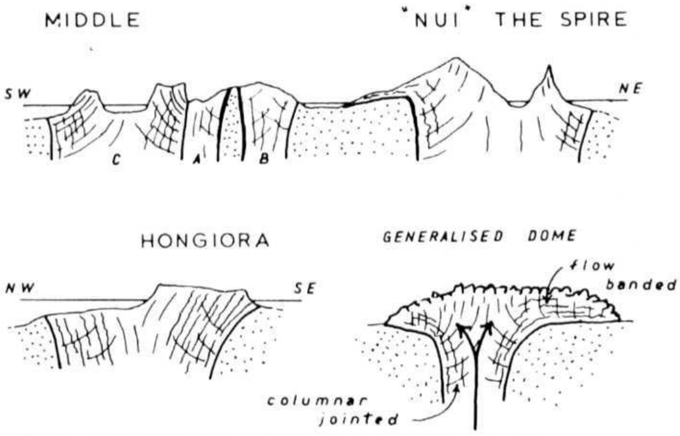

Fig. 5: Sketched cross-sections of a generalised rhyolite dome and of Hongiora, Middle Island, and Ruamahua-nui showing inferred resemblence and structure.

2. Whitianga Group

The Whitianga Group as used here includes all the rocks of the Pliocene rhyolitic eruptive period of the Coromandel volcanic province. Two subgroups are recognised within this group, Minden Rhyolite and Coroglen Subgroup (Hayward, in prep a) though it appears that both are closely related, often with the Coroglen pyroclastics having been erupted contemporaneously with, and from the same vent or centre as the Minden Rhyolite lavas.

(a)Minden Rhyolite

This unit is separated from the Coroglen Subgroup on lithologic differences alone and contains all the rhyolite lavas of the Whitianga Group.

(i) Structure

Before attempting to describe the structure of these islands, the structure of a generalised rhyolite dome is outlined here for later comparison. Such a dome consists of an intrusive neck with extrusive pile above and possibly lava flows (coulées) extending outwards from it (Fig. 5). Due to rapid chilling of the lava, the intrusive contacts of the neck are generally glassy (perlitic), and up to 30 m thick. Within the dome itself, flow-banding parallel to the direction of flow may be well or poorly developed. In the neck region flow-banding is generally steep and parallel to the intrusive contacts whilst in the extrusive pile and flows it is often subhorizontal. Columnar joints often form during cooling, and are generally oriented perpendicular to the intrusive cooling surfaces in the neck and subvertical in the extrusive portion.

Five rhyolite domes are recognised on the Aldermen Islands and are here referred to as Hongiora Dome, Nui Dome, and Middle Domes A, B, and C (Fig. 6).

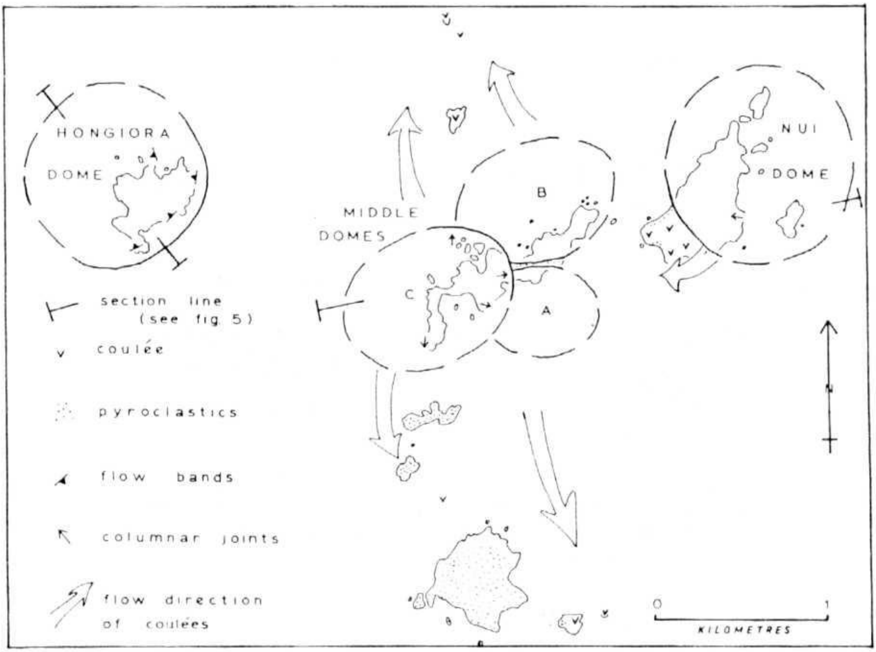

Fig. 6: Interpretation of the geology of Aldermen Islands showing inferred position of five original domes and direction of couleé flow away from them.

Exposures on low-lying Hongiora (75 m high) indicate that it is the south-east remnant of a formerly circular dome (Fig. 6.). Flow-banding arcs around the south and east sides of the island and is steeper in the centre and shallower in the south (Fig. 7). The north-west of the island is massive rhyolite with steeply dipping columnar joints and is inferred to be near the centre of the dome, whilst the south-east point is inferred to be close to where the intrusive lava extruded outwards over the surface (Fig. 5).

Although the structural picture of Ruamahua-nui and The Spire is not as clear as Hongiora, the Nui Dome is inferred to be centred just north of The Spire with couleés forming the south-eastern part of Ruamahua-nui (Fig. 6). In the central parts of the dome, The Spire consists of 150 m of massive rhyolite having vertical columnar joints in the upper parts, and the bulk of the northern and central part of Ruamahua-nui is massive rhyolite with occasional planar joints, columnar joints and flow-banding (Fig. 7).A 15 m wide vertical perlite band, exposed on the north-west coastline, marks the western intrusive contact of the neck of the Nui Dome with Coroglen pyroclastics. The contact is not exposed on the south coastline but perlitic cooling surfaces occur between lava flows high in the southern cliffs. The south-west of the island is capped by thick Nui Dome couleés which conformably overlie Coroglen pyroclastics on the south-west point.

Table 2: Modal analyses of Minden Rhyolite thin sections*

	20391	20392	20387	20389	20384	20386	20388	20380	20376	20382	20381	20383
PHENOCRYSTS (>0.3mm)												
Total	6.6	7.2	25.9	16.5	24.0	11.1	22.8	19.0	26.4	26.1	25.7	20.7
Plagioclase	4.8	5.5	23.5	15.6	23.8	9.8	22.0	15.7	23.5	21.6	24.6	19.9
Quartz	-	-	0.5	0.5	-	1.1	0.1	0.2	1.6	3.2	0.3	0.3
Biotite	-	-	1.2	0.3	0.2	0.1	0.6	0.9	1.1	0.8	0.8	0.5
Orthopyroxene	1.6	1.5	-	-	-	-	-	-	-	-	-	-
Hornblende	-	-	-	-	-	-	-	1.0	-	-	-	-
Opaques	0.2	0.2	0.7	0.1	-	0.1	0.1	1.2	0.2	0.5	-	-
GROUNDMASS (<0.3mm)												
Total	93.4	92.8	74.1	83.5	76.0	88.9	77.2	81.0	73.6	73.9	74.3	79.3
Plagioclase	-	-	0.1	0.7	9.4	3.2	0.4	1.1	2.6	0.8	0.5	0.7
Glassy & Indet.	93.4	92.8	74.0	82.8	66.6	85.7	76.8	79.9	71.0	73.1	73.8	78.6
	HONGIORA		A	A	B	B	B	RUAMAHUA-NUI				THE SPIRE
*1000 points per count	DOME		MIDDLE DOMES					NUI DOME				

The remnants of three domes are exposed on Middle Island. The western dome (C) consists entirely of columnar jointed and occasionally flow-banded rhyolite, the attitude of which (Fig. 8) suggests a slightly elongate dome centred off the north-west corner of the island (Fig. 6). A 100 m high knob just inside the eastern margin of Dome C is columnar jointed throughout with flat-lying columnar joints near the base becoming steeper upwards and towards the west (Fig. 5). It is deduced from this that the lower parts are within the vertical neck of the dome and upper parts are in the extrusive portion. In the east, Dome C appears to have intersected the two earlier domes, A and B, which form the east part of Middle Island. Dome B consists of massive rhyolite with a 10 m wide vertical perlitic intrusive contact exposed on the north-west side of the island (Fig. 8) but buried beneath a slip on the east. A narrow 60-100 m wide band of Coroglen pyroclastics occurs between this perlite and another 20 m thick perlitic intrusive contact of Middle Dome A exposed on both coasts of the island. The small remnant of Dome A exposed on Middle Island consists of massive rhyolite.

Besides the domes exposed on these four islands, Minden Rhyolite also occurs on several others. The three small northernmost and unnamed islands of the Aldermen Group consist of subhorizontally flow-banded rhyolite, probably remnants of a coulée that flowed north from the line of domes. Subhorizontally flow-banded Minden Rhyolite occurs in the reef between Ruamahua-iti and Half Island, and flow-banded rhyolite is also exposed in Little and Big Humps, east of Ruamahua-iti. These exposures are also inferred to be remnants of lava sheets that flowed from the north (Fig. 5).

(ii)Petrography

In hand specimen the Minden Rhyolites of the Aldermen Islands are hypocrystalline to holocrystalline, massive to finely or coarsely flow-banded rhyolites in varying shades of buff, grey, black, pink and purple. Modal analyses of 12 thin sections, together with total crystal content are given in Table 2. Chemical analyses of two samples are given in Appendix 2.

In thin section these rhyolites have a felsophyric, cryptophyric, vitrophyric, microfelsophyric or spherulospheric texture. The phenocrystal content varies from 6.6 to 26.4% of the rock and the plagioclase/quartz ratio is always greater than 7. All sections contain corroded poikilitic plagioclase (0.1-3 mm) phenocrysts whilst most contain rounded quartz (0.3-2 mm) and euhedral magnetite (0.1-0.5 mm) phenocrysts. Strongly pleochroic, euhedral plates of biotite (0.2-1.5 mm) are present in most samples, though often in very minor amounts. No biotite is present in Hongiora Dome samples but instead phenocrysts of altered orthopyroxene (0.3-1 mm) comprise approximately 1.5% of the rock. Strongly pleochroic euhedral hornblende occurs in only one section (20380), being from a Nui Dome coulée. No definite potash feldspar or clinopyroxene phenocrysts were recognised in any sections.

The groundmass consists of intergrown encrystalline cristobalite, sanidine and minor opaques, together with variable amounts of brown glass, often concentrated in bands or even making up the entire groundmass, as in the perlites (20387, 20389, 20377, 20378) from the intrusive contacts. Spherulites occur commonly in the groundmass of a number of sections and in flow-banded samples are often concentrated in bands alternating with glassy bands.

The five rhyolite domes have been distinguished as far as possible on their characteristic ferromagnesian mineral content (Fig. 2) according to the classification used by Ewart (1967). The biotite (± hornblende) rhyolite of the Nui Dome and Middle Domes (especially A) has a higher crystal content and

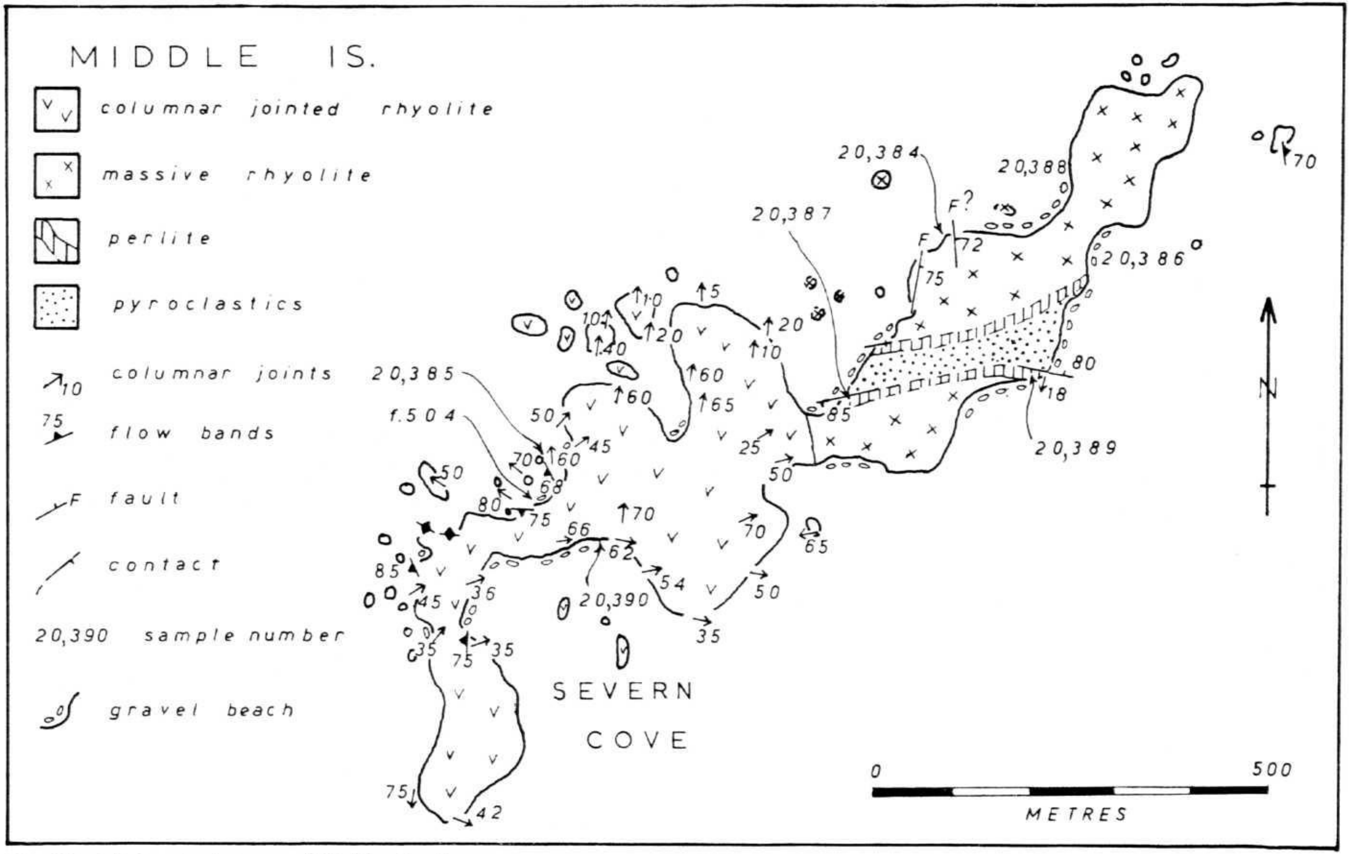

Fig. 8 Detailed geological map of Middle Island.

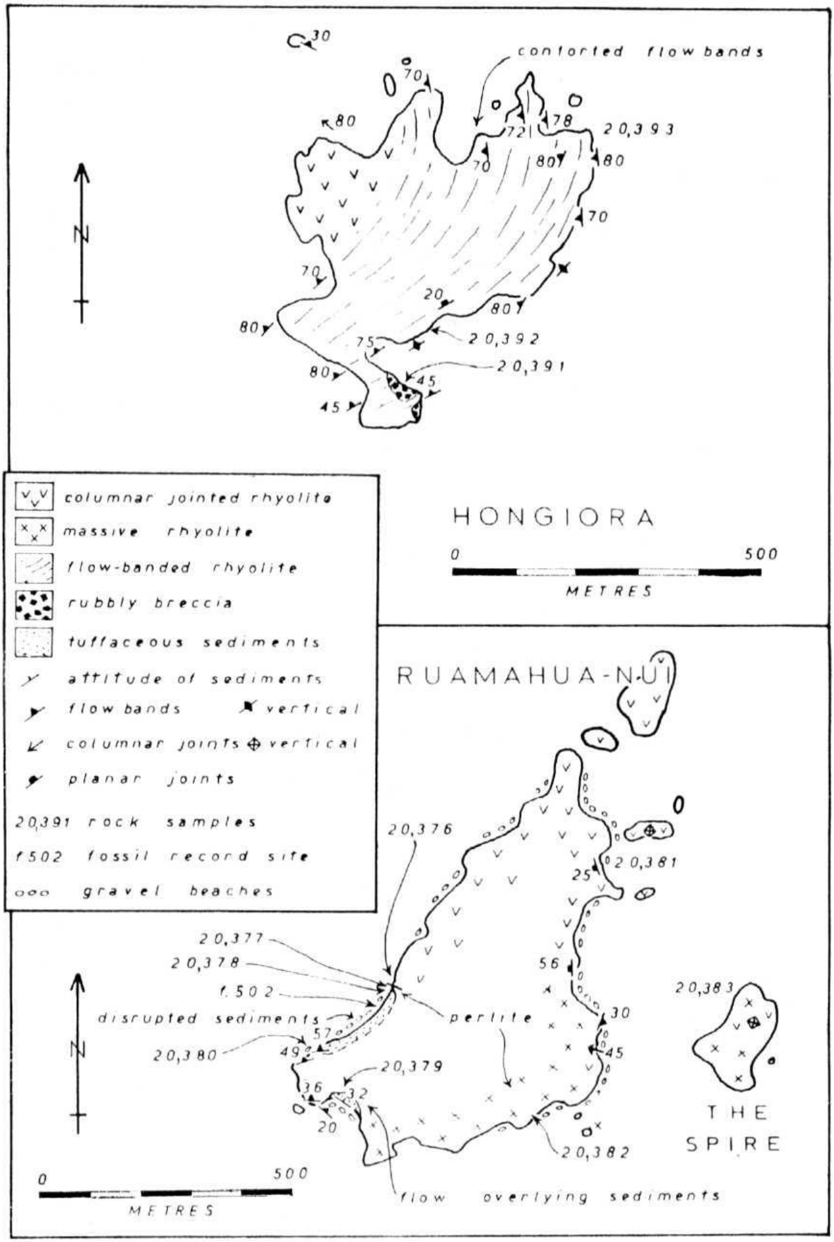

Fig . 7: Detailed geological maps of Hongiora and Ruamahua-nui.

lower plagioclase/quartz ratio than the hypersthene rhyolite of Hongiora Dome. The absence of biotite from this latter type and of hypersthene from the former is consistent with observations made by Cole (1970) within the Tarawera rhyolite dome complex, and Hayward (in prep b) in the Minden Rhyolite domes of part of the central Coromandel Peninsula.

Comparison with previous petrographic descriptions of Minden Rhyolite around the Peninsula (Rabone, 1971; Main, 1971; Hayward, in prep b; Rutherford in prep) shows no major differences. Petrographically the Minden Rhyolite of the Coromandel Volcanic province typically contains plagioclase + magnetite ± biotite ± hypersthene ± hornblende phenocrysts, sometimes with quartz and more rarely with potash feldspar phenocrysts.

(b) Coroglen Subgroup

Rocks of this subgroup, which includes all sediments and ignimbrites of the Whitianga Group, occur on six of the eleven largest islands of the Aldermen. They are not exposed on Hongiora, The Spire or the three northern islands.

Hernia and Half Islands consist entirely of poorly stratified tuffaceous breccias and partly welded ignimbrites of the Coroglen Subgroup. Alignment of coarser angular lava clasts enables an attitude for these deposits to be measured (Fig. 9). Generally these deposits contain angular to subrounded clasts of flow-banded and massive rhyolite (up to 1.5 m diameter), chert, tuff (up to 60 cm diam.), silicified fine breccia, and rarer lapillistone and wood (up to 50 cm long) (N45/f503), set in a tuffaceous matrix of glass shards, crystals and rock fragments.

Small exposures of Coroglen rocks occur on Middle Island and Ruamahua-nui. They form a thin band wedged between the perlitic intrusive contacts of domes A and B on the north-eastern end of Middle Island (Fig. 8). They are exposed only in the south-west of Ruamahua-nui where they conformably underlie a rhyolitic coulée and are adjacent to a perlitic contact in the north-east. On both islands the bedding of these deposits has been highly contorted near the intrusive contacts, and only beneath the coulée on Ruamahua-nui is bedding regular (Fig. 7). The Coroglen rocks of these two islands consist of interbedded angular tuffaceous breccia (clasts of perlite, massive and flow-banded rhyolite, jasper and tuff), pumiceous fine breccias, tuffs, carbonaceous laminae (N45/f502) and massive pumiceous lapilli tuff.

The Coroglen rocks of Ruamahua-iti are divisible into two distinct units (Fig. 3). The basal unit, overlying the irregular unconformity cut in the Beesons Island Volcanics (Fig. 4), is a massive rubbly rhyolitic breccia. It consists of angular to subangular clasts of massive rhyolite (up to 4 m; 60%), flow-banded rhyolite (up to 2 m; 15%), spherulitic rhyolite, (up to 80 cm; 10%), and rarer lapilli tuff, bedded tuff, lapilli breccia (up to 5 m; 5%) and occasional wood, set in a coarse tuffaceous matrix of quartz crystals, glass and rhyolite fragments (5-10%). All clasts are randomnly oriented with an average size of 2 to 20 cm; maximum size decreases upwards. This rubbly breccia, having a maximum thickness of 150 metres, is exposed on Pisa Rock, at the west end of Big Hump, and in the cliffs around most of Ruamahua-iti (Fig. 3). Above the rubbly breccia and exposed in the upper parts of the cliffs of Ruamahua-iti is a well-bedded tuff unit having a maximum exposed thickness of 20 m. A 3 m thick bedded tuff and lapilli tuff

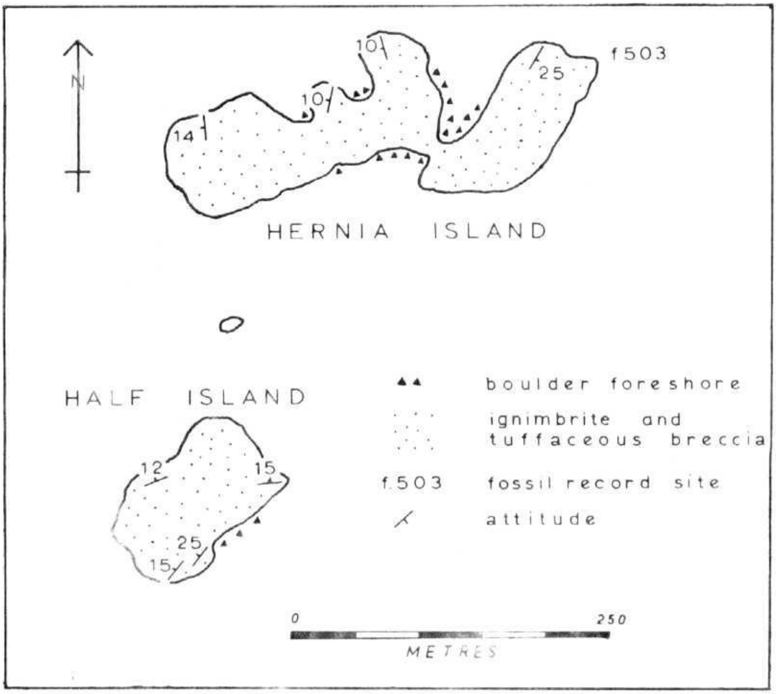

Fig. 9: Geological structure of Half and Hernia Islands.

unit occurs within the rubbly breccia on a small islet and narrow peninsula in the south-west of Ruamahua-iti.

DISCUSSION

1. Eruptive history

Andesitic lavas of the Beesons Island Volcanics were erupted sometime during the Miocene to lower Pliocene, with periods of relative quiescence in which fine pyroclastics and volcanogenic sediments accumulated in depressions. As was the case on Coromandel Peninsula this volcanic episode was followed by a period of erosion, and the nature of the exposed unconformity suggests that the landscape was still youthful when buried beneath the products of the rhyolitic Whitianga Group eruptions (Pliocene).

The lack of continuous exposure between islands prevents determination of a sequence of deposition and intrusion of the Coroglen sediments and Minden domes throughout the islands. It appears, however, that the character of Whitianga eruptions on the Aldermen was very similar to that on the mainland. Firstly, pyroclastics were erupted over the landscape as (i) hot pyroclastic flows that formed ignimbrites and tuffaceous breccias, (ii) tephra showers that were deposited as well-bedded tuffs and lapilli tuffs, and (iii) breccia flows that produced the massive rubbly breccias (Parsons, 1969) on Ruamahua-iti. Conclusive evidence indicating environment of deposition is lacking, but a terrestrial environment, possibly with occasional fresh-water deposits, is favoured by the authors.

These pyroclastic deposits of the Coroglen Subgroup were then intruded by viscous lava, forming domes along an east-west trending line. Of the five domes exposed, Middle Domes A and B are older than Middle Dome C, which has pierced Dome A as it was intruded. Most, if not all, of these domes breached the surface and coulées flowed both north and south over the Coroglen deposits (Fig. 6).

The age of the Whitianga Group in the Aldermen Islands was not determined, but it is assumed to be of similar age to the Whitianga Group of the Coromandel Peninsula, which recently has been dated by microflora as Pliocene (Mildenhall in Hayward, in prep a).

2. Evidence for post-volcanic tilting

The perlitic rhyolite chill-zone of Dome B on Middle Island contains geode-like cavities partially infilled with parallel-layered chalcedony. Since this layering must originally have been deposited horizontally, measurements of attitude of layering should provide good evidence of post-volcanic tilting. Several measurements were made which give an average strike of 015^{o} and dip of $5\text{-}6^{o}$ west.

The rhyolitic breccias and bedded tuffs of Ruamahua-iti show dips generally up to 10^{o} west, and tuffaceous breccias on Hernia and Half Islands mostly dip $10\text{-}15^{o}$ west to north-west. Although these could be primary dips, they may also indicate low angle ($5\text{-}15^{o}$) tilting to the west.

3. Hydrothermal alteration

Both lava flows and sediments of the Beeson's Island Volcanics show considerable localised alteration. Patches and small veinlets of zeolites (mainly stilbite and chabazite), chlorite, and fluorite are common; pyritisation is widespread, and sediments are locally silicified. Larger veins (2-5 cm) of quartz and zeolite cut both the Beeson's Island rocks and lower parts of the overlying rubbly breccias (Fig. 4), indicating hydrothermal activity either continued, or was renewed, during the early eruptions of the Whitianga Group. Quartz druses and veinlets, with minor calcite, are common in the breccias to the west of Tuatara Bay.

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APPENDIX 1 – FOSSIL RECORD SITES

N45/f501 Beesons Island Volcanics; carbonaceous siltstone; Microfloral sample – non-fossiliferous. Ruamahua-iti.

N45/f502 Coroglen Subgroup; carbonaceous, tuffaceous siltstone; Microfloral sample – non-fossiliferous. Ruamahua-nui.

N45/f503 Carbonised wood (20 cm long) from tuffaceous breccia of Coroglen Subgroup. Hernia Island.

N45/f504 Silicified reeds and organic material. Not in place; on beach, north side of Middle Island.

APPENDIX 2 – CHEMICAL ANALYSES

Analyst: T.H. Wilson

	20397	20381	20391
SiO_2	59.0	73.2	70.1
TiO_2	0.15	–	0.02
Al_2O_3	16.4	17.2	15.2
Fe_2O_3	1.3	1.0	2.0
FeO	6.4	0.1	1.1
MnO	0.09	–	0.08
MgO	3.0	0.2	0.23
CaO	5.1	1.1	1.3
Na_2O	2.8	3.0	3.0
K_2O	1.1	3.0	2.8
P_2O_5	0.15	–	0.02
H_2O+	2.1	0.6	0.8
H_2O^-	2.0	0.1	0.1
Total	99.59	99.5	99.75

20397: Beesons Island Volcanics' andesite, Ruamahua-iti

20381: Minden Rhyolite – biotite rhyolite, Ruamahua-nui

20391: Minden Rhyolite – hypersthene rhyolite, Hongiora