The Relationship of Waitemata Formation and the Manukau Breccia, Auckland, New Zealand

By R N. Brothers,
Auckland University College

[*Read before Auckland Institute on December 8, 1952; received by Editor, February 6, 1953*]

Summary

The Manukau Breccia and the Waitemata Formation constitute the northern part of Waitakere Hills, Auckland. The former beds are composed of fragmental andesitic debris with interbedded lava flows produced from a number of small centres, some of which are now exposed in cliff sections. The coarser sedimentary facies in large part were deposited as mudflows. These volcanic beds are coeval with the feldspathic sandstones and mudstones of the Waitemata Formation, the two groups either intergrading through transitional sediments or overlying one another. Lenses of Parnell Grit in the Waitemata Formation exhibit many features characteristic of mudflows and share a common origin with the Manukau Breccias.

Introduction

An elevated and rugged mass of marine-bedded pyroclastic material with associated dykes and lava flows which forms Waitakere Hills on the west coast of Auckland is referred to the Manukau Breccia of Mid-Tertiary (Altonian) age. On its east, the range of volcanics gives way to low rolling country of softer Waitemata sandstone, also Altonian in age, while to the north it ends abruptly near Muriwai on the line of a north-south fault (Fig 1).

The Manukau Breccia

PREVIOUS WORK

Hochstetter (1867) made the first detailed statement of the presence of these fragmental volcanic rocks near Auckland, describing them (p 66) as follows:—
" North of Manukau Harbour along West Coast extensively developed andesitic and doleritic breccias . . . together with dikes of anamesite and basalt . . . Compact or fissured mountain cones without distinct craters and lava streams; thick and far extending beds of breccia, conglomerates, and tuffs." These he classed among his " Older Volcanic Formations of the Tertiary "

Hutton (1870) gave a good description of exposures of these rocks at Manukau North Head. Cox (1881) examined the " Lower Miocene " " trachydolerite breccias " of the same locality, and traced them north to Muriwai, east across to Waimauku, and then north-east to Kaukapakapa beyond the district here described. Park (1886, 1889) and Bartrum (1924) have made passing reference to the nature of the pyroclastic material in discussing the relations between Waitemata Formation and the Manukau Breccia

Fox (1902) and Mulgan (1902) both dealt with the volcanics of Waitakere Hills, but only for the purpose of finding the origin of Parnell Grit beds in the Waitemata sandstones, and gave little detail about them. Taylor (1927) described a deposit of pumiceous silts near Bethell's Beach, and later (1930) described clastic dykes near Manukau North Head which are similar to others found in the present area. Pillow lavas and columnar fan-structures at Muriwai were studied by Bartrum (1930), and Ferrar (1934) described the northerly extension of the whole volcanic series in the Kaukapakapa area. The most pertinent account is that of Searle (1944), who made a thorough examination of the volcanic rocks in an area immediately south of that about to be described.

TYPICAL SEDIMENTS OF THE MANUKAU BRECCIA

A wide range of sediments, deposited in shallow seas by erosion of volcanic rocks, is encountered in the 56 square miles of the area that are occupied by the Manukau Breccia. Fundamentally all the sediments, which vary from tuffaceous sandstones to coarse conglomerates and breccias, have been built by the accumulation of fragments from disrupted or corroded andesitic rock; variation in the beds is due mainly to distance from the parent vent and to the amount of time between succeeding periods of sedimentation.

Hard, fine-grained, often muddy, grey tuffs are ubiquitous, being partly lithic and partly crystal in nature, for they are composed of shattered crystals of plagioclase, augite, hypersthene and magnetite together with fragments of andesite. When developed alone, these tuffs usually are well-bedded as finely-laminated strata which often exhibit large-scale current bedding, and contain sparse fragments of carbonized wood, foraminifera and small molluscs. Normally the tuffs alternate with and grade into compacted lapilli-tuffs, in which larger pieces of pyroclastic debris are dominant, such as sub-round or angular fragments of pre-existing tuffs, andesitic lava, occasional scoria, and pumice shreds.

Similar fine phases provide the matrix of conglomerates, breccias and agglomerates, the only lithological difference between, for example, a tuff and a conglomerate, being the presence of large rounded boulders of andesite in the latter. Similar fine-grained volcanic debris is present also in massive well-compacted tuffaceous sandstones which by decrease in admixed igneous material may grade into normal grey sandstones resembling the harder types of Waitemata sandstone, or into indurated brittle grey-white mudstones. In stream or cliff exposures on the west coast all these fine-grained sediments appear in well-bedded layers without regular vertical alternation or have somewhat lensoid alternating stratification, where there is gradation in texture from one facies to another. Some of these beds are highly resistant to erosion, so that they form bold sea-cliffs, many offshore stacks, the lips of waterfalls (Okiritoto Stream), and storm-wave platforms (Muriwai). The boulders or blocks in the conglomerates or breccias are remarkably uniform in rock type; all are of non-vesicular andesite, which, whether fine- or coarse-grained, is usually a pyroxene variety although hornblende andesites occasionally are present. Searle (1944) found that the majority of blocks in his southern area are angular, but in this northern portion of Waitakere Hills round or sub-round boulders preponderate, for conglomerates are seen more commonly than other types of coarse pyroclastics. Locally, however, near recognizable vents, agglomerates and scoriaceous debris are typically present and not far from them breccias may be found interbedded with coarse conglomerates. As is to be expected, the angular materials of such agglomerates are often vesicular and closely packed together with only a minimum of tuffacecus matrix.

The almost entire lack of fore-set bedding and the presence of marine shells in the tuffs and in the matrices of coarser phases of the fragmental volcanic rocks point to deposition in shallow seas. The beds are not always well sorted for many small pebbles are often bedded alongside boulders up to 5ft. by 4ft. in breadth (Pl. 24, Fig. 1), but rough sub-horizontal stratification and well-developed current-bedding are often evident (Pl. 24, Fig. 2). Closely-packed gravels which occupy scoured-out trenches in underlying beds and other local minor unconformities indicate erosional breaks during deposition of the Manukau Breccia. A curious fact is that while the beds on the whole, judged by lithology and massiveness and by lack of folding, seem highly competent, yet locally they have been acutely folded. In addition, folded masses are known to rest on an undisturbed basement of apparently identical volcanic fragmental rocks. One mile south of Muriwai sub-horizontal movement of upper beds upon lower, which may be attributed to slumping, has produced a band of friction breccia with small-scale drag-folds. Fault and joint fissures alike are commonly filled with secondary calcite or opal, and sedimentary (or clastic) dykes often occupy the spaces between adjacent dislocated blocks.

In addition to fragmental rocks the volcanic series contains large numbers of dykes and flows all of augite, hypersthene, or rarely hornblende andesite that is indistinguishable from that of the pyroclastics.

The wide distribution of andesitic eruptions in the Mid-Tertiary is attested by numerous exposures of similar breccia or conglomerate masses of similar age throughout Coromandel Peninsula and North Auckland, and on outlying islands.

LATERAL AND VERTICAL VARIATIONS OF THE MANUKAU BRECCIA

As Muriwai is approached from the south, and as outcrops are followed inland from the coastline, the volcanic series includes an increasing proportion of normal sediment and rapid gradations of texture in the beds occur locally both laterally and vertically. The heterogeneous nature of the Manukau Breccia is excellently shown in the towering sea-cliffs between White's Bay and Muriwai.

White's Bay and Anawhata

At White's Bay, in the south-west corner of the district studied, there is a former eruptive vent which widens upwards from sea-level. It contains agglomerate including angular masses of andesite as much as 3ft. across and scoria in a tuffaceous matrix which cuts vertically through bedded conglomerate. At the north end of the bay a large headland is formed of three platy lava flows interbedded in breccia in which there is a large proportion of scoria and lapilli-tuff; at the top of the headland are a few feet of conglomerate with boulders up to 8in. across. Since the gradient of these flows is downwards from the northern side of the bay to its centre, they seem therefore not to have come from the White's Bay vent and probably they, like other lava flows, arose from one or more feeding dykes further inland.

Between White's Bay and Anawhata breccias are well developed, but rounded boulders become more noticeable nearer Anawhata. Complex folding is made evident in places by fine tuffs interbedded with the coarser beds, for the white-grey colour of the former makes them readily traceable in cliff sections. About three-quarters of a mile north of White's Bay, for example, the beds are sub-vertical and appear to rest at sea-level on a basement of massive andesite lava, and two hundred and fifty yards nearer Anawhata a complete overfold to the north-east is shown in conglomerates of somewhat angular material which at sea-level rest on undeformed sub-horizontally bedded conglomerates. The over-folded strata appear to be continued inland at the south end of Anawhata Beach by tilted poorly-bedded conglomerate and tuffs which dip at 40° or more to the north-east (Pl. 24, Fig. 3). The structural axis is directed N. 38° W.; it thus appears at first sight that pressure has come from the south-west and that the basal undeformed subhorizontal conglomerates have been protected from deformation by the mass of lava immediately to the south The upper surface of these basal unfolded conglomerates is dissected; evidently, therefore, these latter were formed some time before the deformed beds unconformably above them and thus had the opportunity of becoming more "cemented" than the later beds. If so, lateral pressure is not necessarily the agent of deformation, for, in common with many other structures in both the Manukau Breccia and the Waitemata Formation, this apparent thrust fold may in reality be a gravity fold due to unequal subsidence or slumping of sediments.

Anawhata Stream to Bethell's Beach

North of the mouth of Anawhata Stream, immediately behind the beach, poorly-sorted conglomerates dip at 45° to the north-east. Three hundred and fifty yards further north, at the end of the next bay, agglomerates with angular blocks of andesite and scoria bedded in lapilli-tuff outcrop close to a probably eruptive vent.

The next accessible exposure going north is at Cannibal Creek, 300 yards distant, where a mass of lava that forms the stream bed near the shore-line appears to abut against the agglomerate further south, while a quarter of a mile to the north it is replaced by a deep-red scoriaceous agglomerate which, at the top of the cliffs, is capped by 12–20 feet of tuff. The bay immediately north of Cannibal Creek is backed by high red-stained cliffs worn back into an amphitheatre and built of consolidated volcanic rubble and tuffs containing large scoriaceous blocks and angular fragments of andesite as much as 5ft. in width. At the southern end of this bay, these beds of ejecta dip south-west at 35° and a mass of conglomerate just beyond is also inclined, but only at 20°. At the northern headland the general dip of the beds is to the north-east, with the tuffs often contorted until their layers form a reversed "S". The material described, with the exception of the conglomerates, gives the impression of an eroded debris cone. On the headland between this bay and the next one to the north (i.e., the bay south of Bethell's), the beds are also deformed for well-bedded conglomerates in a block 80ft. in length and 30ft. in height rest at a steep angle on a lava-seamed andesitic breccia overlying normal conglomerates and tuffs. From this point north to the south end of Bethell's Beach, alternating beds of breccia and pillow-lavas interbedded with pillow-lava talus are exposed in the cliffs.

Bethell's Beach to Muriwai

Conglomerates persist all along Bethell's Beach and at Kauwahia Island (at the south end of O'Neill's Bay) gradually change to beds of somewhat angular current-bedded material, consisting of boulders of andesite in lapilli-tuff.

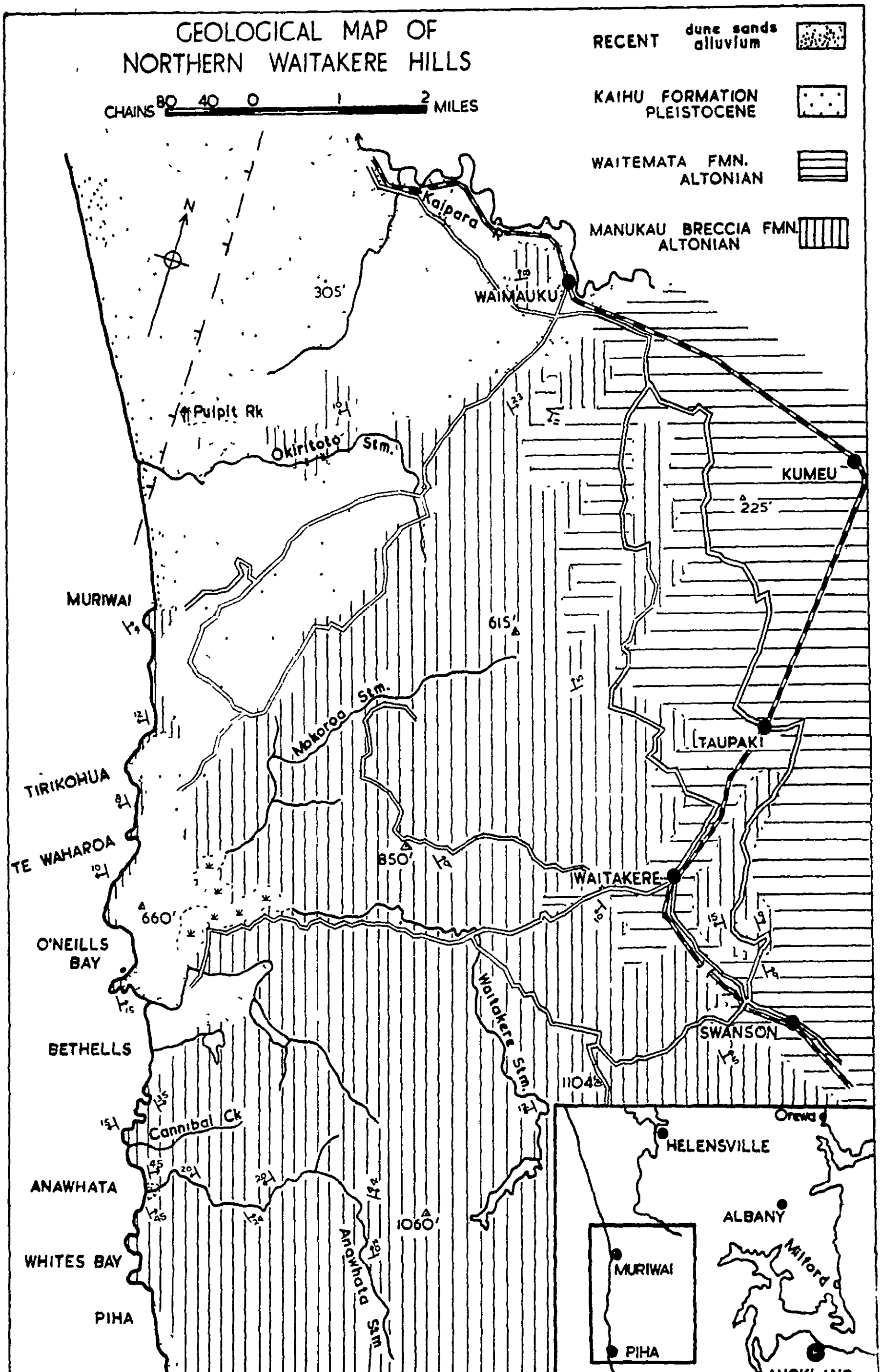
GEOLOGICAL MAP OF
NORTHERN WAITAKERE HILLS
CHAINS 80 40 0 1 2 MILES
RECENT dune sands alluvium
KAIHU FORMATION PLEISTOCENE
WAITEMATA FMN. ALTONIAN
MANUKAU BRECCIA FMN. ALTONIAN
N
Kaipara
WAIMAUKU
305'
Pulpit Rk
Okiritoto Stm.
KUMEU
225'
MURIWAI
615'
Mokoroa Stm.
TAUPAKI
TIRIKOHUA
TE WAHAROA
850'
WAITAKERE
660'
O'NEILLS BAY
BETHELLS
Waitakere Stm.
SWANSON
1104'
Cannibal Ck
ANAWHATA
1060'
Anawhata Stm.
WHITES BAY
PIHA
HELENSVILLE
Orewa
ALBANY
Milford
MURIWAI
PIHA
AUCKLAND

FIG. 1.

At the back of a boulder beach at the north end of O'Neill's Bay there is a complex series of lava flows. Some are only small "splashes" 1ft. in depth and laterally discontinuous; others are massive flows 15ft. in thickness. All are interbedded with deep-red tuff containing large blocks of non-vesicular andesite and scoria and dip gently north-west. In from the shore and a little further south, a roughly semi-circular valley 150 yards in diameter, opening to the sea, shows similar scoriaceous debris in its steep cliffs. The structure appears to be the remains of a debris cone centred on O'Neill's Bay and has many features in common with the White's Bay centre already described.

In the long stretches of coastline north and south of Te Waharoa headland, conglomerates crop out only at the base of cliffs 200ft. high, except in two places where folding along a N.W.-S.E. axis raised them to 160ft. above sea-level. Elsewhere in this stretch of coast they are overlain by horizontally-bedded tuffs and mudstones containing rare boulders of andesite and fragmental gastropod and lamellibranch shells. From Tirikohua headland northwards the tuffs are finely laminated and dip dominantly to the south-west, though locally current-bedded, and, especially where they are fine in texture, include carbonaceous layers with imperfect plant remains. Lenses of conglomerate, rarely exceeding 60ft. in length and 20ft. in depth, are interbedded mainly with tuffs at different heights in the cliffs 1½ miles south of Muriwai and in association with pillow-lavas and nearby columnar fan-structures (Bartrum, 1930). The well-known "Fishing Rocks" at Muriwai is a storm-wave platform carved in hard, thin-bedded tuffs which show gradations to lapilli-tuffs or sandstones containing fragments of pumice up to half an inch in size.

North and East of Muriwai

The Manukau Breccia continues for several miles north of Muriwai but ends abruptly in a steep bluff at Pulpit Rock, beyond which it has not been observed in coastal sections. At Pulpit Rock a conglomerate containing closely-packed unsorted boulders of pyroxene andesite up to 4ft. in diameter outcrops from sea-level to a height of 130ft.; in its upper portions there are a few feet of tuff.

East of Muriwai the pyroclastics are found at varying heights beneath a general cover of Pleistocene sandstones, and at Waimauku coarse conglomerates, at least 20 ft. thick, are overlain in the upland east of Kaipara River by finer phases of the volcanic series. One noteworthy inland occurrence is a quarter of a mile east of Black Bridge (where Waitakere-Bethell's Beach road crosses Waitakere River). Here a thin lens of black and yellow sandstone of beach origin is exposed in a road cutting. The downward succession is:

3ft. of fine tuff.
10ft. of lapilli-tuff.
2ft. of fine lapilli-tuff.
2ft. (black sandstone, yellow sandstone).
4ft. of grey tuff.

The sandstones are in horizontal laminae up to half an inch in thickness and grade up into tuffs containing small pieces of andesite, small pebbles of slightly calcareous mudstone, fragments of lamellibranch shells, and carbonized wood. Forty feet west of the outcrop exposing this succession, the lens of sandstone thins down to 3 inches before gradually pinching out. Pebbles of calcareous mudstone similar to those mentioned above have also been found in deposits on erosion

1

2

3

4

FIG. 1.—Coarse andesite conglomerate, south end of Bethell's Beach.

FIG. 2.—Roughly stratified but unsorted breccias, south end of O'Neill's Bay.

FIG. 3.—Sub-vertical beds, from right to left, of tuff, mudstone, breccia and conglomerate 350 yards south of Anawhata Beach.

FIG. 4.—Interbedded Waitemata sandstones and carbonaceous lapilli-tuffs of Manukau Breccia. Railway cutting 1 mile west of Swanson.

surfaces near Swanson, and possibly have been derived from beds of Onerahi Group (? Late Cretaceous—Early Tertiary).

ORIGIN AND MODE OF EMPLACEMENT OF THE MANUKAU BRECCIA

Park (1889) and Bartrum (1929) believed the rocks of this formation to be a result of volcanic eruptions in shallow seas. Bartrum considered that the parent volcanoes lay not far to the west of the present coastline. Searle (1944) reached a similar conclusion and, after pointing out anomalies in the evidence for deposition by streams, suggested the beds were probably beach deposits. The Manukau Breccias in the area studied by the writer, however, show greater variation in lithology and structure than the breccias and agglomerate described by Searle and thus provide evidence on origin and mode of emplacement not available to him.

Corrasion and deposition by streams does not satisfactorily explain the texture and structure of the beds of the formation. The variable form of the constituent blocks, the amazing rapidity with which conglomerates regularly give way both vertically and laterally to breccias or tuffs, and the rapid grading of tuffs into lapilli-tuffs, mudstones, etc., indicate considerable changes in the conditions of supply of material, if not in its actual source. Complete lack of sorting is common and boulders 5ft. or more in diameter may be closely intermingled with pebbles 2in. across, no doubt as a result of rapid influx of debris. Although the almost complete absence of fore-set bedding indicates that the deposition has not been by streams, layers of well-sorted cobbles and gravels occur as lenses filling contemporaneous erosional hollows and as sub-horizontal strata.

These markedly variable rocks have certain features in common. For instance, non-vesicular andesite is the universal rock type in all grades of material except at the actual sites of eruptive vents. The beds are evidently all marine for they include marine fossils, interbedded pillow-lavas and some boulders which from their size and high degree of rounding seem clearly to have been rolled on wave-lashed beaches.

Small eruptive vents containing agglomerates and scoria in the coastal cliffs have already been mentioned. Searle (1944) recorded similar vents close to the shoreline of the district south of the present one, and has described large blocks of tuff which are included in the local conglomerates and breccias as far south as Manukau North Head. One would expect agglomerates to be developed near vents and conglomerates at a distance from them, but this is not always the case. Agglomerates merge into conglomerates close to vents, and on the other hand, breccias occur far from any known vent in areas built dominantly of typical conglomerates. Neither do flow rocks always indicate the close proximity of eruptive vents, for lava has issued from a dyke fissure at O'Neill's Bay and masses of dyke-fed pillows are exposed in the cliffs near Muriwai. These facts indicate that centres of eruption or effusion were widely distributed in space and time.

Cotton (1944) has emphasized that mudflows, or lahars, are the chief makers of volcanic conglomerates. In the present area transport by volcanic mudflows offers the most satisfactory explanation for the occurrence of thick layers of unsorted conglomerate marine beds, and perhaps also for some of the sorted conglomerates and interstratified muddy tuffs. During transport by lahars the boulders would probably attain some degree of rounding, and subsequent settling in water would separate finer material from the coarser to produce tuffaceous and conglomeratic facies respectively. The phenomenon of volcanic mudflows satisfactorily explains the frequent occurrence of compact bedded accumulations of volcanic blocks and other debris at low altitudes in places some miles distant from the steeper flanks of the parent volcanoes For example, mudflows were observed by Perret (1924, p. 102) as post-eruptive features at Vesuvius in 1906: "The ash, sand and boulders were in no case . . . carried (by hot avalanches) more than 3 or 4 kilometres from the volcanic axis, and they remained consequently on the slopes of the mountain Rain or snow would then . . . soak the porous mass until a certain consistency was reached, which conferred a degree of mobility differing widely in character from that of the hot avalanche but nevertheless permitting rapid descent through gullies and other natural depressions as a torrent of liquid mud. This carried blocks and boulders of all sizes" and "the mudflows massed their heterogeneous contents into conglomerates". Fenner (1937) described a similar cold lahar at Katmai and particularly noted the resulting abrasion, for "the pounding and grinding undergone by the boulders seem to have been equivalent in their rounding effect to those produced on the ordinary boulders of river channels through hundreds of years of stream action" The larger andesite blocks exposed in the conglomerates of the Manukau Breccia are not as rounded as the smaller boulders, for usually only their corners and ridges are rounded off. Blackwelder (1928) believes from similar observations that this is due to the tendency for larger blocks more or less to float in a mudflow or even lie on its surface.

The conglomerates of the Manukau Breccia, it is believed, were formed by processes similar to those outlined above, but we have yet to consider the mode of formation of the deposits of breccia that so commonly lie interstratified in lenses with the volcanic conglomerates. Are these breccias simply the ejecta of major explosions? Are they deposits of short-lived mudflows? Or are they the farthest travelled portions of block lavas of either the block and ash type associated with weak Pelean eruptions (Perret, 1935) or with the normal type (Washington, 1926)? The latter writer has described the filling of a lagoon by flow of non-vesicular blocks lacking pumiceous or scoriaceous material, and Williams (1932) traced a similar flow, consisting of andesitic basalt, over an area of 20 square miles. The writer believes that block flow of fragments, comparable to that described by Washington. partly explains many of the breccia deposits in the volcanic fragmental accumulations along the Waitakere Coast. However, some of the breccias may have been deposited directly from explosive activity and soon covered, before they could be sorted or rounded, by lahar material, for coarser debris left on slopes, with added ash, would provide a suitable source of later bulky mudflows.

There is no clear evidence as to the type of volcanic activity which made available such vast amounts of fragmental material since details of the vents are lacking and most of the debris appears marine-bedded. The association of normal lava flows, scoriaceous debris, agglomerates, pumice shreds and accessory blocks around the vents at White's Bay, O'Neill's Bay, Anawhata, and that just south of Bethell's Beach points to eruptions of Vulcanian type There arises also, however, the possibility of mixed activity. For example there may have been phreatomagmatic explosions caused by seawater entering fissures opened by volcanic heavings; and, as already mentioned, some of the eruptions may have been of

Pelean type, for this latter type of eruption is known to produce deposits closely comparable in their material to those at present under discussion.

Severe folding of the Manukau Breccias on a minor scale is not infrequent. It does not seem, however, that movements of the Kaikoura uplift have been responsible for these minor structures, for, when the numerous structural axes within Waitakere Hills are plotted, it becomes obvious that there is no relation to a particular direction of lateral pressure. Actually, the structural picture is very similar to that derived from the " tangled skein of facts " in the Waitemata Formation on the Auckland east coast, where corrugations and faults " constantly succeed one another and trend with directions so diverse that their maze almost obliterates evidence of structural control in their creation " (Turner and Bartrum, 1929, p. 880). The widespread occurrence of small scale slumps and localised examples of intense folding in the Manukau Breccias support an hypothesis that deformation was brought about largely by gravity slides of varying magnitude and intensity, connected at least in part with the mudflow method of accumulation that has been described above. Nevertheless, in areas in Waitakere Hills where these severe folds are absent, the general structure of the beds is simple, with strikes trending E.-W. or N.W.-S.E., and this disposition is in accordance with the effect produced by a moderately intense compressional force acting from a south-western direction, that is, the post-Waitemata orogeny of Turner and Bartrum (1929).

Since this manuscript was prepared Kuenen (1950) has described a small " open-cast " slump at Muriwai, and has further discussed similar larger-scale structures in Waitemata beds at Titirangi and at Milford. He believes that the crumpling at these localities is a result of submarine slumping for " while it is hard to believe that the poorly consolidated and thin series of beds could have transmitted tectonic stress over great distances so as to cause intense compression at one point of the section only, it is even more difficult to explain how sections directly alongside could have escaped deformation " (*loc. cit.*, p. 472). The same remarks could apply to the Manukau Breccia volcanics.

As already mentioned, the volcanics become coarser and more angular as they are traced west and south-west, indicating that the rocks of the Manukau Breccia were derived from an area of volcanic activity on the western side of the shallow geosyncline in which the Waitemata sediments accumulated, and with little doubt not far from the present west coast.

THE RELATIONS BETWEEN WAITEMATA FORMATION AND THE MANUKAU BRECCIA AND DISCUSSION ON THE OCCURRENCE OF PARNELL GRIT

Hochstetter (1864) first recorded near Auckland beds which have since been found to have wide distribution north and south of Waitemata Harbour, and which have been designated Waitemata Formation. The normal beds are alternating bands, a foot or two in thickness, of sandstones and mudstones almost entirely lacking macrofossils, but often yielding abundant foraminifera; these beds are usually sub-horizontal, but locally are severely folded and faulted. Occasional fossiliferous lenses of andesitic debris containing fragments of the enclosing Waitemata sandstone occur at irregular intervals, and have been named Parnell Grit (e.g., Cox, 1882) from an exposure at Parnell, Auckland. Lens-and-pocket bedding in both the normal sediments and the Parnell Grit, and the presence of fair amounts of carbonaceous material point to deposition in shallow seas, a conclusion borne out by the occurrence of marine beach conglomerates in the formation at many places north of Auckland.

Sediments of the Waitemata Formation, which appear between Swanson and Waimauku, have been tilted in common with tuffs of the Manukau Breccia. The lithology of the Waitemata Formation has been fully described by earlier writers (e.g., Turner and Bartrum, 1929). The main points of interest in the present discussion are the relations between the Waitemata Formation and the Manukau Breccia, and their age as shown by modern determination of foraminiferal faunas. At the present time there appears to be more paleontological and structural evidence available than previously regarding the relations between the Manukau Breccia and Waitemata Formation, and this has led the writer to consider the origin of beds of Parnell Grit in the Waitemata.

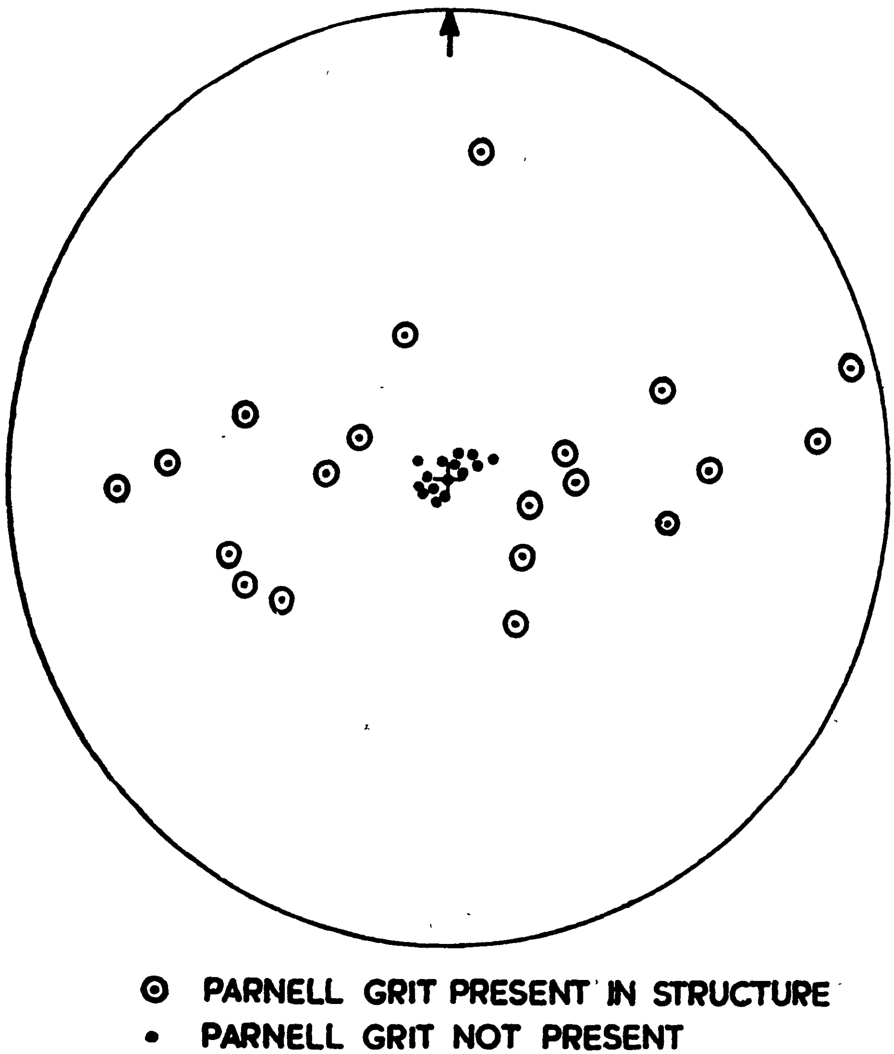

FIG. 2.—Lower hemisphere projection of dip planes in Waitemata sandstones forming the coastline between Orewa and Milford, Auckland east coast.

Hochstetter (1864), Cox (1881), Park (1889) and Marshall (1907) have agreed that the Waitemata beds and the volcanics are conformable, one with the other, near Manukau North Head, a view later confirmed by Searle (1944) in discussing the same area. All these writers have considered the Manukau Breccia to overlie the Waitemata Formation and to close the period of Waitemata sedimentation. Bartrum (1924) could find no definite evidence of unconformity between the two formations near Kaukapakapa, although Turner and Bartrum (1929) recorded tuffs resting on eroded Waitemata sediments in a water supply tunnel at Huia.

In the present study a large number of exposures have been seen in which the volcanics and sandstones indistinguishable from those of the Waitemata Formation are present together, and the facts indicate that the formations are coeval. Where the two formations are seen together either (a) there is a gradual vertical and lateral change by increasing content of volcanic material from the feldspathic sandstones of the Waitemata Formation to fine-grained tuffs of the Manukau Breccia, or (b) the beds of one formation give place vertically with an abrupt change of facies to the other. The Waitemata Formation is believed by Turner and Bartrum (1929) to have been derived from a northerly source, whereas the volcanics become coarser and attain greater height to the south-west, so these changes of facies and interdigitation of one with the other are probably the result of continuous sedimentation in an area to which material was supplied from two different sources, one to the north and the other mainly to the south-west of the area of accumulation.

Although the volcanics are found at elevations over 700ft. higher than the hills of Waitemata sandstone at Kumeu and Riverhead, this is due only to lowering of the softer Waitemata beds by the erosion of an ancient stream flowing from north to south, while the resistant beds of Manukau Breccia were much less reduced in elevation. Sandstones of the Waitemata Formation with interbedded mudstones at a height of 480ft. on the flat-topped ridge between Waitakere and Bethell's Beach are clearly remnants of a formerly more extensive sheet, for similar beds outcrop at short intervals westwards from Waitakere Station to within a quarter of a mile of Black Bridge, where the Waitakere-Bethell's road crosses Waitakere River.

At a number of places in the Waitakere Hills the Waitemata beds grade into tuffaceous sandstones or else into tuffs of the Manukau Breccia. The following are brief descriptions of some outcrops where passage from one to the other has been studied:

1. *One Mile South of Waimauku on School Road.* Here weathered red tuffs outcrop in cuttings at the base of the hill. Some 500 yards uphill from the tuffs massive yellow silty Waitemata sandstones, strongly carbonaceous in places, outcrop intermittently through a vertical distance of 95ft. and show transition to overlying red-brown tuffs. Towards the top of the hill the beds cannot be classed as either Manukau Breccia or Waitemata, for they are red to white tuffaceous sandstones containing large amounts of volcanic material in addition to the grains of feldspar that predominate in Waitemata sandstones.

2. *Mokoroa Stream.* In its lower course the stream cuts through coarse tuffs and hard brittle mudstones of Manukau Breccia. At the second fork upstream, at a height of 290ft., part of a tongue of Waitemata sandstone 8ft. thick appears

in the stream bank. This tongue pinches out westwards within a distance of 30ft. and is covered by weathered massive tuff which has a very abrupt contact with the sandstone. If less of the outcrop had been available and the lensoid nature of the sandstone not visible, the outcrop would have suggested unconformity as Turner and Bartrum (1929) interpreted a similar exposure at Huia.

3. *One Mile West of Swanson.* The two formations are clearly exposed in cuttings for a railway deviation and in excavations for the road which follows the railway at this locality. In all outcrops there are successions of tuffs, sandstones and mudstones, with Waitemata and Manukau Breccia beds intimately interbedded, as shown in Pl. 24, Fig. 4.

4. *Brickworks Quarry, Waitakere Railway Station.* In the main quarry the downwards succession is as follows:—

(iv) 5ft. of shaly fine-grained tuff deeply oxidised to a red-brown sand, each layer about half an inch thick and rich in scales of limonite.
(iii) 5ft. of brown-yellow micaceous clay.
(ii) 4ft. of typical light grey Waitemata sandstone
(i) 3ft. of coarse lapilli-tuff.

Similar beds are repeated below for another 12ft., each bed merging gradually into its neighbours.

It is clear, then, that the coeval relationship of the Manukau Breccia to the Waitemata Formation, based on structural considerations, involves their identity in age, and this is abundantly supported by the microfaunas they respectively contain. On both molluscan and foraminiferal evidence the Waitemata sandstones are classed as Altonian (Lower Miocene) and recent determinations by Finlay* of foraminifera collected by the writer from various outcrops of the Manukau Breccias indicate a facies of approximately the same age.

Beds of tuff appear in all the sections described in the Waitakere Hills east of the divide, and both Manukau volcanics and typical Waitemata beds are developed there. The question arises whether these tuffs may be facies of the Parnell Grit, so well developed elsewhere in the area of Waitemata sandstones further east, and not members of the Manukau Breccia. If this is the case, conclusions reached by the writer would be vitiated. There is little doubt, however, that the tuffs or grits in question constitute part of the Manukau Breccias, for they can with ease be traced westwards into the main mass of the Waitakere volcanics. Thus, there are two sets of similar fragmental volcanic beds, the Manukau Breccias and the Parnell Grits, interbedded with the normal sediments of the Waitemata Formation. These two volcanic deposits have previously been regarded as differing in age, and therefore in origin, but the writer believes that they were derived from the same area of igneous activity.

Turner and Bartrum (1929, p. 875) described the Parnell Grit as a variation from the normal sandstones and mudstones of the Waitemata beds that occurs as bands of fine-grained grits, tuffs, and in some places coarse-grained breccias. These materials are found in fossiliferous lenses at varying levels in Waitemata sandstones from Auckland north to Whangaparoa Peninsula. Occasional larger fragments of sandstone and andesite are set in a matrix of finer particles of the

* Personal communication, 14/4/47. See Appendix.

same material which grades into the enclosing soft normal Waitemata sandstone. The Parnell Grit corresponds with lapilli-tuffs and tuffs of the Manukau Breccia and apart from included polyzoans, it is lithologically inseparable from the latter beds. On this aspect much has been written. Cox (1882), Park (1886), and Mulgan (1902) correlate the Parnell Grit with the Manukau Breccia. Fox (1902), however, placed only a portion of the grits (his " Cheltenham Breccia ") in the Manukau Breccias, and kept the Parnell Grit separate. Turner and Bartrum (1929) considered the grits to be entirely different in origin from the Manukau Breccia, for reasons stated below. Firth (1930) closely followed the opinions of Turner and Bartrum (*op. cit.*) in discussing the origin of Parnell Grits occurring in Waitemata sandstones at Weymouth, on Manukau Harbour, and at Eastern Beach, on the Hauraki Gulf coast. Firth (*op. cit.*) noted that, as elsewhere, the volcanic materials grade through tuffaceous sediments to normal sandstones, and that they include rounded andesite pebbles as much as 4 inches in diameter, in addition to polyzoa, showing that the beds were deposited in shallow seas.

These investigators considered the Manukau Breccia and the Parnell Grits to have had no common source, but the evidence indicates that this view is not correct. As yet there is no trace of eruptive centres responsible for the Parnell Grit on the Auckland east coast or on the southern shores of Manukau Harbour (Day, 1948), so that it is of interest to examine the possibility that such centres lie in the Manukau Breccia volcanic area. Turner and Bartrum (1929) note an objection to such belief—the apparent unconformity of tuffs of the Manukau Breccia on Waitemata sandstone in a water-supply tunnel at Huia, in the Waitakere Ranges Bartrum (1937; *fide* Searle, 1944) later doubted his earlier interpretation, and the writer regards such breaks as diastems interrupting the contemporaneous accumulation of two rock groups which otherwise intergrade or interdigitate, although lithologically dissimilar. Turner and Bartrum (*op. cit.*) also accepted the views of Cox (*op. cit.*), Park (*op. cit*), and Marshall (1907), that the Manukau Breccia lies at the top and closes the Waitemata period of sedimentation. Facts set forth on preceding pages conflict with this view. Turner and Bartrum urge as a second objection to correlating the two sets of volcanic beds that the rapid variation of texture and lensoid nature of the Parnell Grits suggest that they originated from a number of small explosion centres with a common magmatic source rather than from a single major one. Such changes in texture are also characteristic of finer phases of Manukau Breccia away from eruptive centres, as is well shown between Bethell's Beach and Muriwai, for these volcanics have arisen from a number of small centres. Moreover, because Parnell Grits closely overlie Onerahi limestones (early Tertiary and earlier) near Mahurangi Heads (Fox, 1902) and because several hundred feet of sandstone overlie the tuffaceous beds at Parnell Point, Turner and Bartrum (*op. cit.*) concluded that the eruptions responsible for the grits were not limited to the final stages of Waitemata sedimentation. On the other hand, they believed that the Manukau Breccias belonged at the top of the Waitemata succession and therefore could not be correlated with the Parnell Grit.

It is no longer possible to accept the sequence of events assumed by these earlier writers for undoubted Waitemata sandstones conformably overlie tuffs at a height of 480ft. on the Waitakere-Bethell's road, and Firth (1930) recorded an occurrence of Parnell Grit at 400ft. above sea-level about 4 miles east of Otahuhu; these heights are at least one-third of the highest known elevation of Waitemata sandstone—i.e., 1,200ft. in the Kaipara district (Ferrar, 1934).

The widely distributed Parnell Grits extend to within 6 miles of areas of undoubted Manukau Breccia sediments, while those found on the southern shores of Manukau Harbour may have been quite close to eruptive centres located in a former southern extension of the Manukau volcanics that was depressed by block-faulting relatively to adjacent blocks during Late Tertiary uplift (Bartrum, 1937). Transport of the andesite debris for many miles from its source and its incorporation in finer fragmental material is feasible when one recalls that the subsidence that gave continued shallow water conditions for the Waitemata sedimentation was interrupted by occasional negative movements of sea-level (Firth, 1930). During the breaks due to such movements, mudflows transferring material from the parent sources of the Waitakere volcanics may well have flowed far to the east or north-east. Marine organisms which colonized the more favourable non-depositional environments would have been included in the Parnell Grit mudflows along with fragments of sandstone provided by contemporaneous erosion of Waitemata beds.

In a recent paper Kuenen (1950) has discussed the Parnell Grit at Milford beach. He states (p. 474), "Each individual detail (of the grit) is hard to account for, but at any rate the entire composition is chaotic. The great irregularity of the lower and internal contacts, and the poorly consolidated nature of the large fragments exclude the possibility that the grit is a beach formation. Neither can direct deposition on the sea floor by eruptions be assumed, because in that case the beds should have come to lie on a smooth bedding plane while the inclusions would be difficult to explain. Hence the writer ventures to suggest that the grits were brought along by mud flows from a distance. These mud flows are thought to have originated subaerially as "lahars" on the slopes of the volcano(es?) producing the andesite material and to have travelled onwards along the sea floor after reaching the coast."

Thus the evidence is very strong that the Parnell Grit had its origin in the volcanic activity and subsequent sedimentation that formed the Manukau Breccia. If this origin for the Parnell Grit be accepted, then it is quite probable that the influx of the mudflows caused overloading on graded subaqueous slopes in the area of Waitemata sediments and thereby initiated gravity slides. This would explain one of the most noteworthy characteristics of local exposures of intensely deformed Waitemata beds; that is, that they are almost always best developed in association with coarse or moderately-coarse beds of the Parnell Grit. The correlation between steeply inclined beds and the presence of Parnell Grit is clearly shown by stereographic projection of dip surfaces as given in Fig. 2. When bands of Parnell Grit are present strike lines apparently have no common trend but their distribution is significant in that more than 87 per cent. are contained within an arc of 95°, roughly 45° either side of north. This is the type of corrugation that could be expected when an eastward-flowing lahar plunged down a subaqueous slope and caused buckling.

SUMMARY OF CONCLUSIONS

The Manukau Breccia and the Waitemata Formation were formed from separate sources by coeval sedimentation in shallow seas during the Altonian stage of the Lower Miocene. The Manukau Breccia is composed of andesite lavas and volcanic detritus which grades laterally into feldspathic sandstones and mudstones of the Waitemata Formation. The Parnell Grits of the Waitemata Formation were derived as mudflows from the same sources as gave rise to the Manukau Breccia.

ACKNOWLEDGMENTS

The work published here formed part of a thesis prepared under the instructive supervision of the late Professor J. A. Bartrum.

APPENDIX

Lists of Foraminifera and Mollusca collected from the Manukau Breccia and the Waitemata Formation in the Waitakere area.

Identifications of the Foraminifera and comments were kindly made by the late Dr. H. J. Finlay.

Foraminifera

(a) Volcanic tuffs of Manukau Breccia, southern tributary of Mokoroa Stream, a little south-east of Muriwai, Auckland West Coast.

Anomalina n.sp. aff. *aotea* Finlay.
Chilostomelloides sp., probably new; not uncommon in the Altonian of Ihungia and Waitemata elsewhere.
Cibicides sp.
Cyclammina incisa Stache.
Globigerina aff. *bulloides* d'Orb.
?*Globoquadrina subdehiscens* Finlay.
Globorotalia aff. *canariensis* (d'Orb).
Nonion sp. probably new; well known from Waitemata beds.
Robulus antipodus (Stache).
Robulus whaingaroicus (Stache).
Saracenaria sp. aff. *schencki* Cush. and Hobson.
Stilostomella verneuili (d'Orb).
Vaginulina legumen (Batsch.)
Vulvulina pennatula (Batsch.)

(b) Waitemata sandstones, railway tunnel between Swanson and Waitakere.

Chilostomelloides sp.
Cyclammina sp. or *Flabellammina*.
Globigerina aff. *triloba* Reuss.
Globoquadrina subdehiscens Finlay.

(c) Tuffs of Manukau Breccia at Swanson-Waitakere railway tunnel.

Bulimina pupula Stache.
Chrysalogonium striatissimum (Stache).
Chilostomelloides n.sp.
Dentalina sp.
Globigerina n.sp.
G. subcretacea Lornn.
Globoquadrina subdehiscens Fin.
Karreriella aff. *chapapotensis* (Cole).
Lagenonodosaria cf. *separans* (Brady).

Nodosaria aff. *fistuca* Schwag.
Plectofrondicularia aff. *awamoana* Fin.
Pleurostomella alternans Schwag.
Pyrgo depressa (d'Orb).
Parrella bengalensis (Schwag.)
Stilostomella aff. *lepidula* (Schwag.)
Stilostomella several spp.
Uvigerina miozea Fin.

(d) Tuffs of Manukau Breccia, Swanson Stream, opposite University hut.

Amphistegina "campbelli Karrer".
Bolivinopsis sp. prob. aff. *cubensis* of Cush. & Berm.
Chilostomelloides n.sp.
Cibicides prob. n.sp.
Elphidium ornatissimum (Karrer).
Globigerina bulloides d'Orb.
G. subcretacea Lornn.
Globoquadrina subdehiscens Finlay.
Gyroidina zelandica Finlay.
Haeuslerella sp. prob. *pukeuriensis.*
Nodosaria longiscata d'Orb.
Plectofrondicularia aff *awamoana* Finlay.
Robulus sp.
Stilostomella aff. *jarvisi* (Cush.)

(e) Tuffs of Manukau Breccia, Swanson Stream, 50 yards downstream from University hut.

Ammodiscus incertus Stache.
Bolivina n.sp.
Dentalina sp.
Epistomina elegans d'Orb.
Globigerina n.sp.
G. subcretacea Lornn.
Globoquadrina subdehiscens.
Nodosaria cf. *fistuca* Schwag.
N longiscata d'Orb.
Pleurostomella brevis Schwager.

Mollusca

Powell (1935, p. 328) records fossil mollusca from five localities in the tuffs of the Manukau Breccia exposed in the sea cliffs south of Muriwai.

Dr. C. R. Laws has informed the writer that in addition to the molluscs described by Powell the following fossils have since been found at Muriwai.

PHYLUM MOLLUSCA

Class Pelecypoda

Nucula n.sp
Nuculana (Saccella) n.sp.

Class GASTROPODA

Cabestana cf. *tetleyi* (Pow. & Bart.)
Coluzea n.sp. aff. *dentata* (Hutton).
Eubela monile Marwick.
Globisinum sp.
Nerita sp.

Class CEPHALOPODA

Aturia sp.

In fine-grained tuffs at the first fork upstream in Mokoroa Stream, the writer found fairly abundant remains of two of the pelecypods recorded by Powell (1935):

Myrtea (Lucinoma) taylori Pow.
Thyasira (Prothyasira) motutaraensis Pow.

REFERENCES

BARTRUM, J. A., 1924. The Geology of the Riverhead—Kaukapakapa District, Waitemata County, Auckland. *Trans. N.Z. Inst.*, 55, 139–153.

——— 1929. Notes on the Geology of Auckland *Municipal Record*, Auckland, January, 1929, 2–5

——— 1930 Pillow-lavas and Columnar Fan-structures at Muriwai, Auckland, New Zealand *Journ Geol*, 38, 447–455

——— 1937. Geography and Geology of Auckland and Environs *Auckland*—a handbook for Aust. & N.Z. Ass Adv Sci., Auckland Meeting, 1937, 7–13

BLACKWELDER, E., 1928. Mudflow as a Geologic Agent in Semi-arid Mountains. *Bull. Geol. Soc. Amer*, 39, 465–484

COTTON, C A, 1944. *Volcanoes as Landscape Forms.* Whitcombe and Tombs Ltd.

COX, S. H., 1881. Geology of the Rodney and Marsden Counties *Rep Geol Explor. during 1879–80*, 13–39.

——— 1882. North Auckland district including Thames, Coromandel, Island of Kawau, and Drury Coal Field. *Rep. Geol. Explor. during 1881*, 17–41

DAY, J. R., 1948. Geology of the area between Waikato Heads and Manukau Harbour. Unpublished thesis, Auckland University College Library.

FENNER, C N., 1937 Tuffs and other Volcanic Deposits of Katmai and Yellowstone Park *Trans Am. Geophys Union*, 18, 236–239.

FERRAR, H. T., 1934. The Geology of the Dargaville—Rodney Subdivision *N Z Geol. Surv Bull. n.s. 34.*

FIRTH, C W., 1930 The Geology of the North-west Portion of Manukau County, Auckland. *Trans. N.Z. Inst.*, 61, 85–137.

FOX, C. E., 1902. The Volcanic Beds of the Waitemata Series. *Ibid*, 34, 452–493.

HOCHSTETTER, F. VON, 1864. Geologie von Neu-Seeland *Reise der Oster Freg. Novara*, Geol. Theil, Bd. 1, Ab. 1.

——— 1867. *New Zealand.* Stuttgart.

HUTTON, F. W., 1870 Geology of the North Head of Manukau Harbour. *Trans N Z Inst.*, 2, 161.

KUENEN, PH. H., 1950. Slump Structures in the Waitemata Beds around Auckland. *Trans. Roy. Soc. N Z.*, 78, 467–475.

MARSHALL, P., 1907. Geology of Centre and North of North Island. *Trans N.Z. Inst.*, 40, 79–98.

MULGAN, E. K., 1902. On the Volcanic and Ash Beds of the Waitemata Series. *Ibid.*, 34, 414–435.

PARK, J, 1886. Waitemata, Eden and Manukau Counties. *Rep. Geol. Explor. during 1885*, 147–164.

PARK, J., 1889. On the Waitemata Series. *Trans. N.Z. Inst.*, 22, 391–399.

PERRET, F. A., 1924. *The Vesuvius Eruption of 1906.* Carnegie Institute of Washington.

——— 1935. *The Eruption of Mt. Pelee, 1929–32.* Carnegie Institute of Washington.

POWELL, A. W. B., 1935. Tertiary Mollusca from Motutara, West Coast, Auckland. *Rec. Auck. Mus.*, i, 327–340.

SEARLE, E. J., 1944. Geology of the Southern Waitakere Hills Region, West of Auckland City. *Trans. Roy. Soc. N.Z.*, 74, 49–70.

TAYLOR, N. H., 1927. Pumiceous Silts in the Waitakere Ranges, Auckland. *N.Z. Journ. Sci. & Tech.*, 9, 166–167.

——— 1930. Clastic Dykes in Volcanic Breccia, Manukau North Head. *Ibid.*, 11, 305–309.

TURNER, F. J. and BARTRUM, J. A., 1929. The Geology of the Takapuna-Silverdale District, Waitemata County, Auckland. *Trans. N.Z. Inst.*, 59, 864–902.

WASHINGTON, H. S., 1926. Santorini Eruption of 1925. *Bull. Geol. Soc. Am.*, 37, 349–384.

WILLIAMS, H., 1932. Mount Shasta, a Cascade Volcano. *Journ. Geol.*, 40, 417–429.