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FIELD TRIP GUIDES

Edited by
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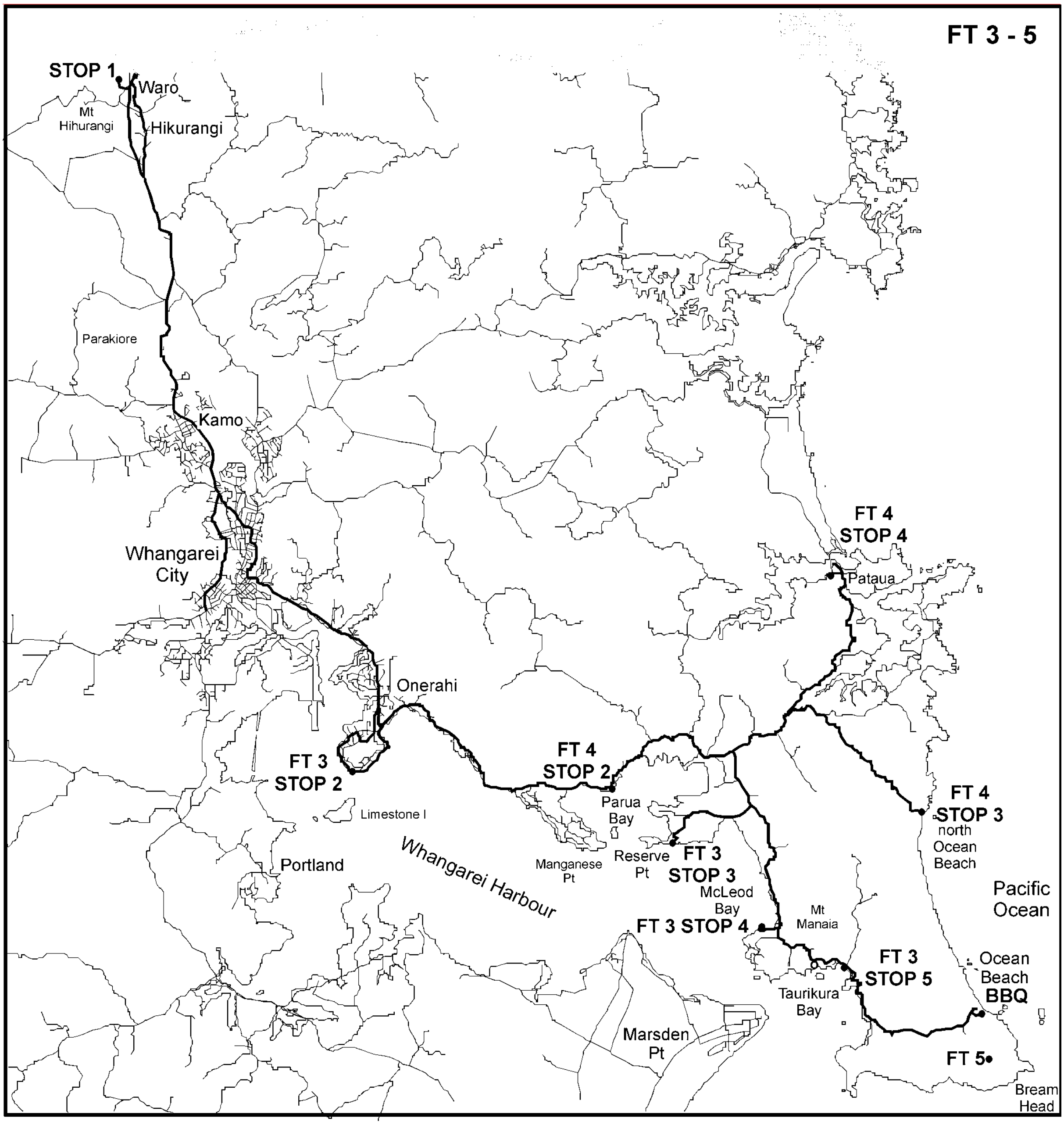


Route map for Field Trips 3, 4 and 5 (FT 3, 4, 5)

Part one of Field trips 3, 4 and 5

Introduction to Whangarei geology

Bruce Hayward, Mike Isaac, Keith Miller and Bernhard Spörli

Whangarei geology

The city of Whangarei is spread through the valleys and hills around the head of the Whangarei Harbour. This area has some of the most varied and complex geological origins of anywhere in New Zealand. Hills to the west are hard greywacke (Waipapa Terrane) that accumulated several hundred millions ago (Permian-Jurassic) off the coast of Gondwanaland. Small pockets of coal measures (Kamo Coal Measures), greensand (Ruatangata Sandstone), and crystalline limestone (Whangarei Limestone) are scattered throughout the suburbs. These late Eocene and Oligocene (Te Kuiti Group) sediments accumulated in small down-faulted half-grabens on top of the eroding greywacke.

Low lying hills in various parts of the city are underlain by claystone, muddy limestone and minor micaceous sandstone and greensand that accumulated on the floor of the adjacent Pacific Ocean 80-25 million years ago (Cretaceous-Oligocene). About 25 million years ago these deep-sea sediments were uplifted and pushed/slid onto Northland as the Northland Allochthon.

Whangarei's landscape is dominated however by the products of later volcanism. The most prominent natural landmark is bush-clad Parahaki, just across the river from downtown Whangarei. This is the southernmost of three large volcanic domes (Parahaki Dacite) that lie in a straight line along an ancient geological fracture, known as the Harbour Fault. The other two domes are Parakiore, which looks down over the northern suburb of Kamo, and 6 km further north, Hikurangi which rises high above the town of the same name. K-Ar dating indicates that Parahaki was squeezed out about 20 million years ago and is considerably older than its two northern cousins which are only about a million years old.

The greatest changes to the area were brought about by two periods of basalt volcanism (4-2 Ma, 0.5-0.3 Ma). Fire fountaining built scoria cones and large volumes of fluid lava flowed out and down existing valleys. All scoria cones from the earlier period have been eroded away and the older flows have deeply weathered red soils with fresh rock seen in the deeply incised Whangarei Falls. Ten young scoria cones and a small shield volcano (Whatitiri) form prominent hills. Seven of these younger cones form an east-west line through Kamo.

All three mid conference field trips share the same initial route and stops.

0 km	**11 AM Leave Forum North** and head north through Kamo to Hikurangi. Enroute the high forested hill on the right skyline is the early Miocene Parahaki Dacite Dome and the hills on your left are an uplifted greywacke block. The western bypass road initially runs along in a valley eroded by a stream displaced from its previous course by a 300 000 year old basalt flow from Hurupaki (see Fig. I.6 in intro). Note basalt boulders on right. The road crosses the stream and rises up onto the flat-top of the flow.
8 km	Passing through Kamo, you may get glimpses of the high scoria cone Hurupaki on your left, with the lower Kupenui scoria cone closer to the road. Look for these on the way south later.
10 km	Forming the impressive barrier on your left at Kamo Springs flat is the Quaternary dacite dome of Parakiore.
12 km	We climb the hill and over the top of the weathered and eroded remains of basaltic flows of Apotu basaltic volcano (4.2 +/- 1.1 Ma). Descending the hill, greywacke hills are present in front and to the right of the road on the uplifted side of the Harbour Fault (Fig. 3-5.1).
16 km	Hikurangi town is passed on the right and the high Mt Hikurangi dacite dome (1.2 Ma) on the left.
18 km	11.30 AM Wilsonville Quarry.

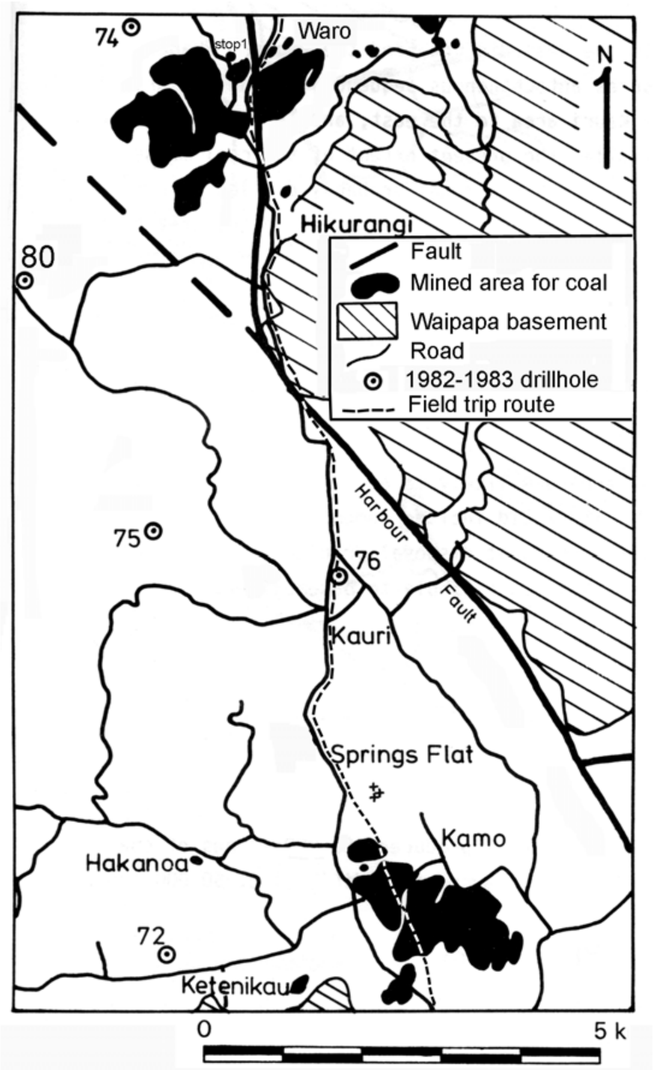


Fig. 3-5.1: Simplified coalfield geology and drill hole sites in the Kamo-Hikurangi area (from Isaac 1985).

STOP 1: Wilsonville Quarry, Hikurangi (Q06/266229)
Concrete structures in the paddock on the left near the foot of Hikurangi Mt. are the old entrances for the Hikurangi Shaft Coal Mine that extracted coal from beneath the level of the limestone. This mine was closed in 1947 following flooding. Coal mining in and around Hikurangi (Fig. 3-5.1) between 1890 and 1971 yielded 4.2 million tonnes of coal of marginally bituminous rank. The stratigraphic sequence in the vicinity of the quarry is best shown by the log of coal exploration drill hole d74 (Fig. 3-5.2) which was drilled 1.5 km northwest of the present quarry in 1983 and a west-east cross-section (Fig. 3-5.3).
Hikurangi Swamp is further away to the west (left).

Whangarei Limestone, Te Kuiti Group
The Whangarei limestone from this quarry is transported by road to Portland, south of Whangarei, where it is mixed with local argillaceous limestone (Mahurangi Limestone, Northland Allochthon) and used in cement manufacture. The limestone is around 100 m thick here, with all but the upper 13 m being consistently high grade limestone with a $CaCO_3$ content of 94-98%. The upper part of the sequence is exposed in the north-western part of the quarry and consists of sandy glauconitic limestone with bands of granular lithic fragments. The lowest quarry floor is currently at 63 m above m.s.l., and 26 m below the level of the nearby Hikurangi Swamp. The underlying Kamo Coal Measures and abandoned coal workings are a minimum of 20 m below the quarry floor.

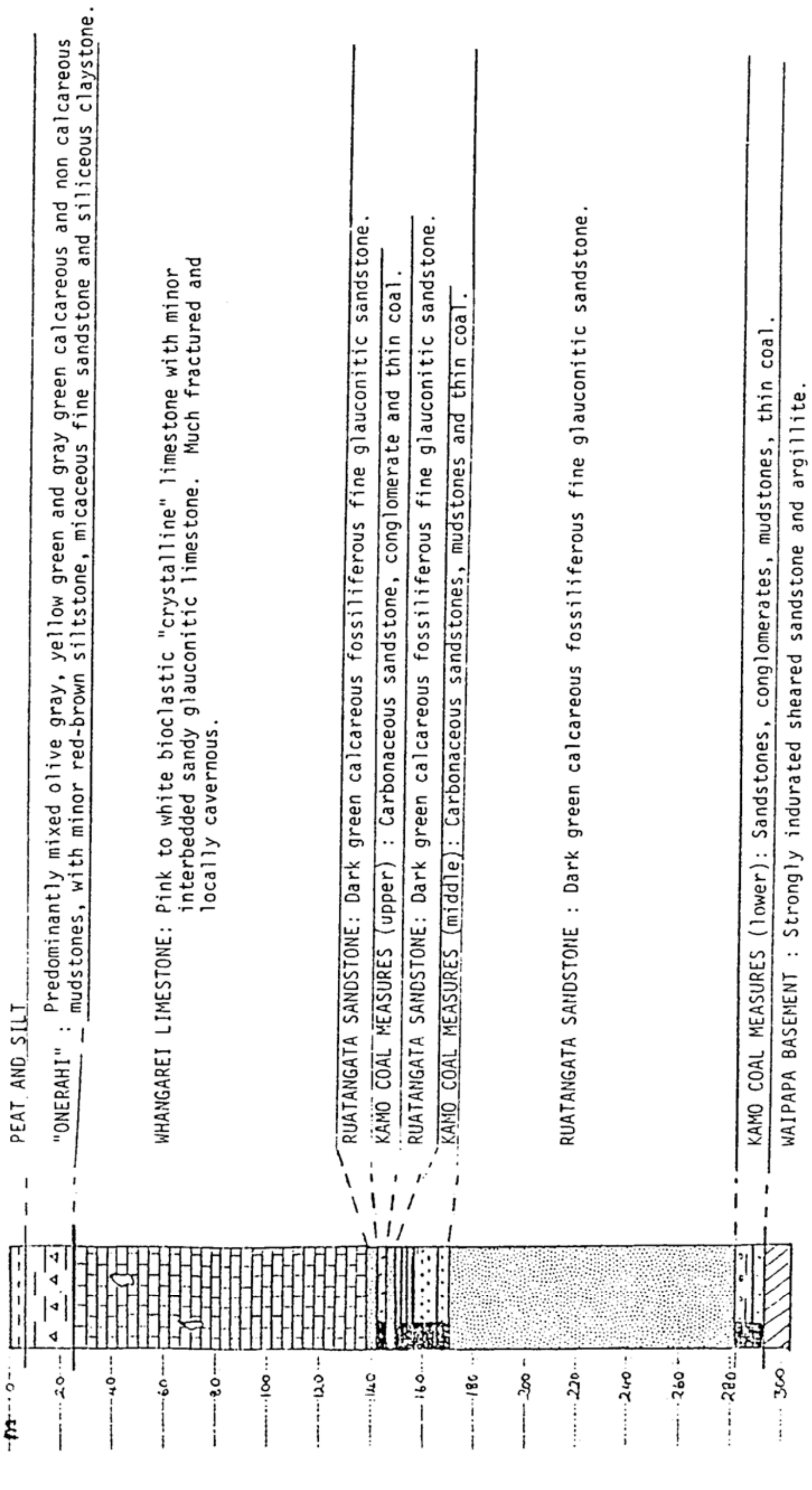


Fig. 3-5.2: Summary log of coal exploration drill hole d74, 1.5 km northwest of Wilsonville Quarry (Isaac 1985).

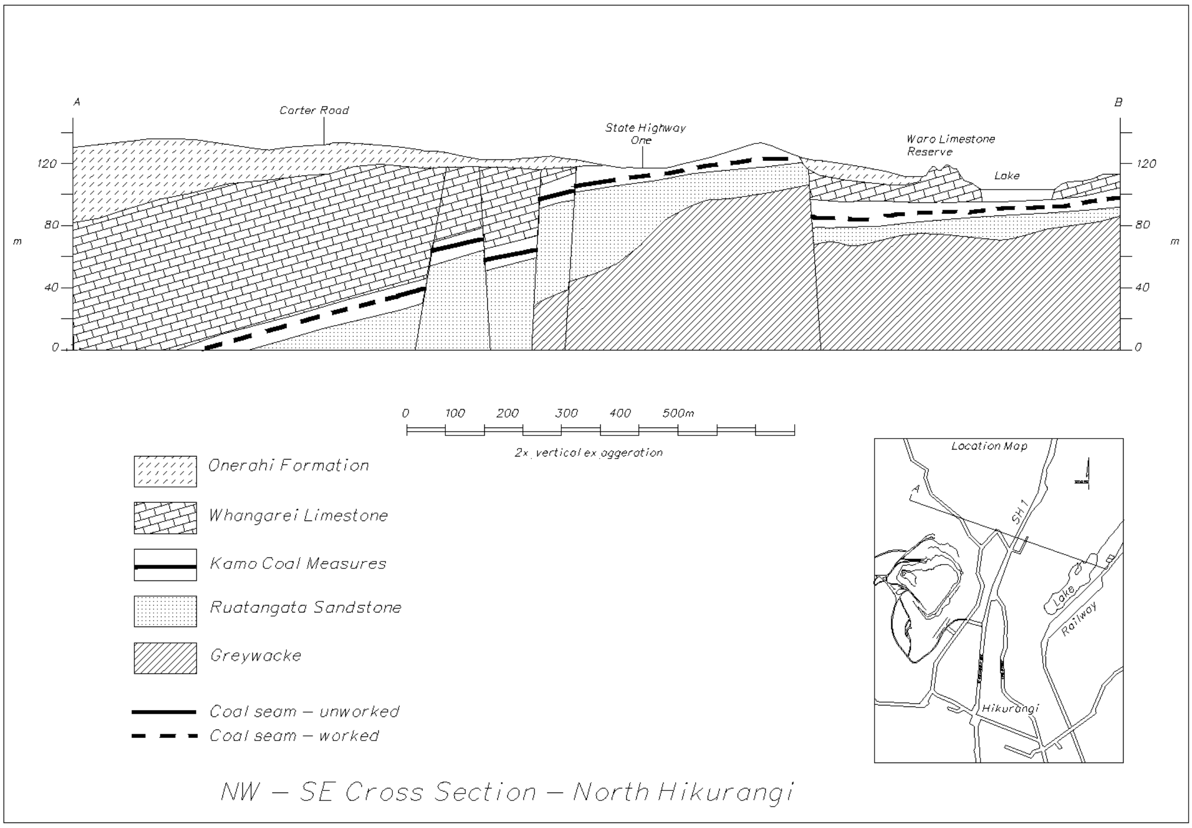


Fig. 3-5.3: West-east geological cross-section through the Wilsonville Quarry – Waro Rocks area (STOP 1). Wilsonville Quarry is located just west of Carter Rd (from K. Miller unpubl.).

Oligocene Whangarei Limestone is a stylolitic, bioclastic, so-called "crystalline" limestone. Here it is mostly a bryozoan calcarenite grainstone with 50% bryozoan fragments, 20% echinoid and 20% benthic foraminifera (Smaill 1985). It is considered to be autochthonous inner shelf deposit within an in-situ late Eocene – Oligocene sedimentary sequence sitting on an irregular Waipapa Terrane greywacke basement. In some nearby drill holes Whangarei Limestone is overlain by latest Oligocene calcareous sandstone (Fig. 3-5.4).

Northland Allochthon

Here in Wilsonville Quarry, Whangarei Limestone is overlain by Northland Allochthon containing a variety of multicoloured units, including pale and dark grey siliceous claystone (Whangai), red brown siltstone, micaceous fine sandstone and flint (all late Cretaceous-Paleocene), and rarer argillaceous Mahurangi Limestone (Oligocene). Hole d74 drilled 20 m of similar lithologies above Whangarei Limestone (Fig. 3-5.2). In the uppermost level of the north-west corner of the quarry, grey, green and red sedimentary rocks are folded into series of west-verging folds, implying transport from an easterly or north-easterly direction. Elsewhere the beds are relatively straight, but there is local development of broken formation. Further to the east along the north face of the quarry there is a slice of yellow white calcareous mudstone.

McKay (1894) had the sequence correct (Fig. 3-5.5) although he did not know of the age inversions within the sequence. Wilsonville Quarry is adjacent to Carter's Hill shown in McKay's section.

Nature of the Allochthon-autochthon contact

The widespread occurrence in outcrop and drill holes in the local area (Figs. 3-5.4) and throughout eastern Northland, of Cretaceous-Oligocene, deformed, deep-water sedimentary rocks over a late Eocene-Oligocene, less deformed, shallow-water, sedimentary sequence (Te Kuiti Group), proves the regional extent of allochthonous rocks. The youngest rocks within the Northland Allochthon are latest Oligocene (early Lw); the youngest rocks beneath the Allochthon are latest Oligocene (eLw) in Northland and earliest Miocene (Po) in Auckland. The oldest rocks intruding and overlying the Allochthon are early Miocene (Otaian, c.22-19 Ma). Thus the allochthonous rocks were emplaced close to the Oligocene-Miocene boundary (c.24-22 Ma), slightly later in the south.

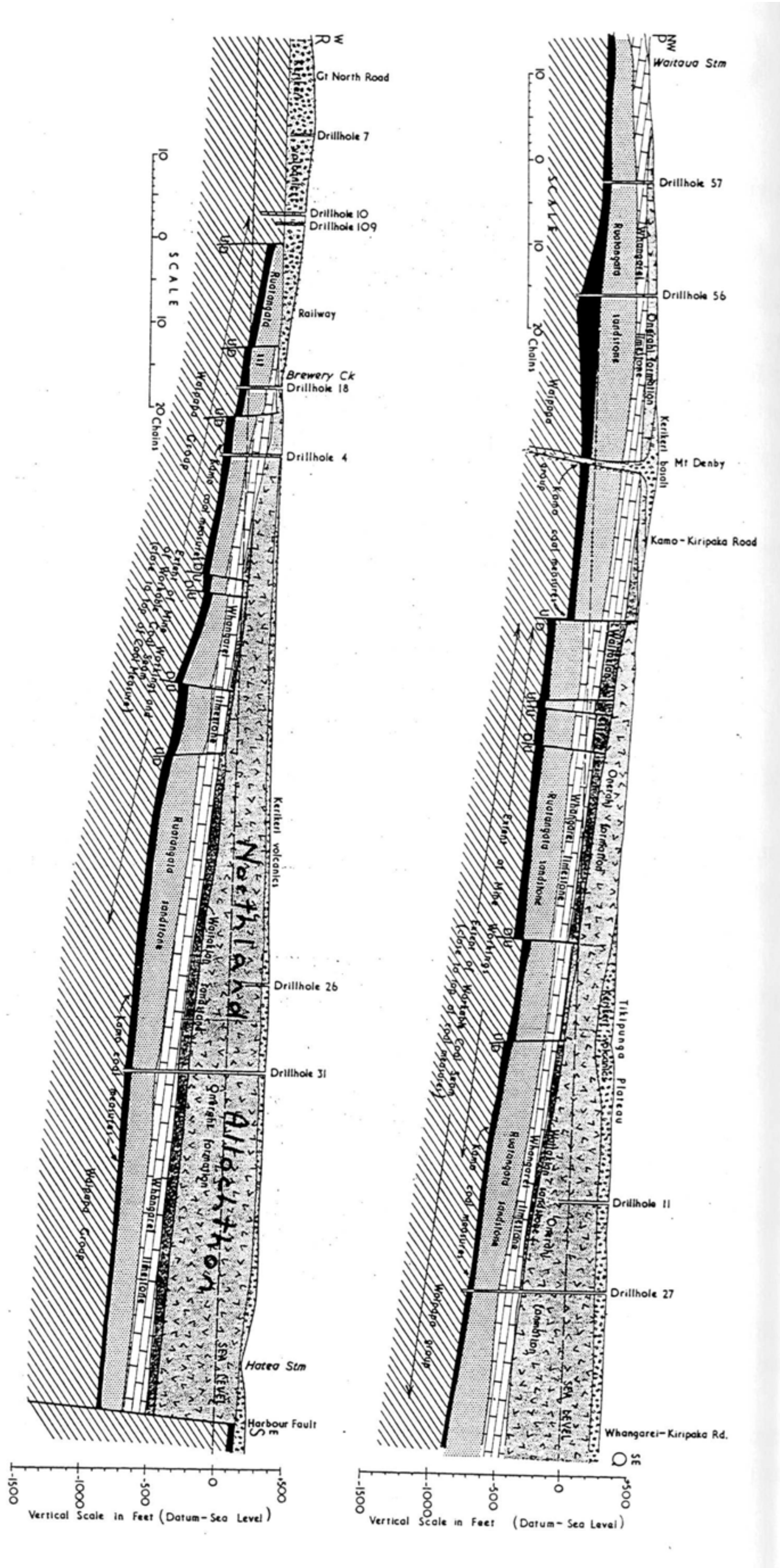


Fig. 3-5.4: West-east cross-sections through the Kamo coal field area, just south of Whangarei, illustrating the relationships between the autochthonous Te Kuiti Group rocks and the overlying Northland Allochthon (= Onerahi Formation). (from Kear 1959).

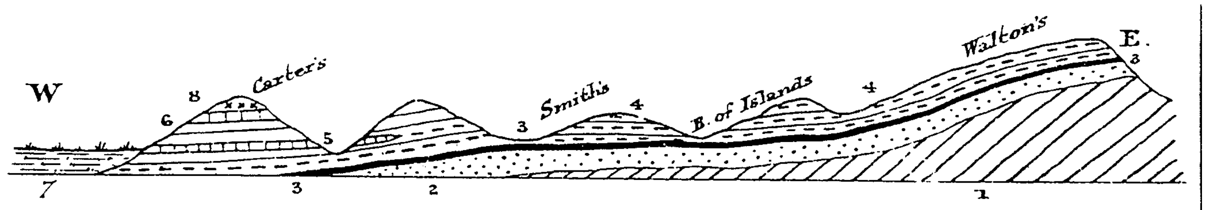


Fig. 3-5.5: Geological section at Hikurangi (from McKay 1894). Wilsonville Quarry is located in units 6 and 5 on the west side of Carter's Hill.

The karstose nature of the contact here is highly unusual and the subject of considerable debate about its origin and significance.
Some of the possible explanations are:

1. Karst was formed during a previously unrecognised late Oligocene period of terrestrial erosion; followed by rapid subsidence and Allochthon emplacement.
2. Karst was formed in Pliocene or Pleistocene following local removal of Allochthon cover; Quaternary remobilisation of clay-rich allochthon lithologies has resulted in secondary slope failure emplacement of allochthon over karst.
3. The Allochthon was emplaced over a non-karstose limestone surface; subsurface karst has subsequently formed along the contact within the sequence.

Key factors to consider include:

a. rounded (subterranean) rather than sharply pinnacled (subaerial) character of karst.
b. nature of sediment filling karst depressions.
c. lack of evidence of allochthon structures collapsing into the karst.

12.30 PM Leave Wilsonville Quarry.
Drive out to HWY 1, turn left and drive past Waro Rocks Scenic Reserve (a small karrenfield = outcrop of limestone showing solution features; developed in the Oligocene Whangarei Limestone).

Kamo Coal Measures
Drive through pull-off gravel road and drive slowly to view exposures of late Eocene Kamo Coal Measures in road cutting and drains on west side of HWY 1 opposite (Fig. 3-5.3). Kamo Coal Measures are palynologically dated as late Eocene, Kaiatan (Ak), in the same zone as the lower Waikato Coal Measures (Isaac et al 1994, p. 38). Kamo Coal Measures have intermittent outcrop for over 100 km between Kerikeri and Brynderwyn Hills. The occurrence of the thickest sequences suggests that they accumulated mainly in WSW-ENE oriented half-grabens (Isaac 1985).

Turn back to south on HWY 1, past Waro Rocks and through Hikurangi Township.

Waro Marble
The lake on left, east of Waro Rocks is a flooded quarry, where building and facing stone of Whangarei Limestone (called Waro Marble) was extracted in the1920s-1940s and freighted on the adjacent railway line around New Zealand. Examples of its use are to be seen in many government buildings of that vintage around the North Island, including the foyer of Wellington Railway Station. The quarry was then used by Wilson's Cement (later Golden Bay Cement) as a source of high grade limestone before Wilsonville Quarry, over the road, was opened in 1974. The site was subsequently gifted to Whangarei District Council as a reserve.

Beside the entrance road to Waro Lake (Fig. 3-5.3) is the tip head (spoil heaps) from the New Phoenix Incline Coal Mine, Hikurangi. This mine extended beneath Waro Rocks. It has been suggested that the tilting of some of the limestone blocks in Waro Rocks may be a result of subsidence into the old workings underneath.

On the return journey to Whangarei there are excellent views of Hurupaki scoria cone at Kamo and of forested Parahaki Dome as we wend our way around its base and out towards Whangarei Heads.

42 km The road climbs the hill onto the top of the c. 4 Ma basalt flow that caps Onerahi Peninsula. Note basalt boulders on hillside on left.

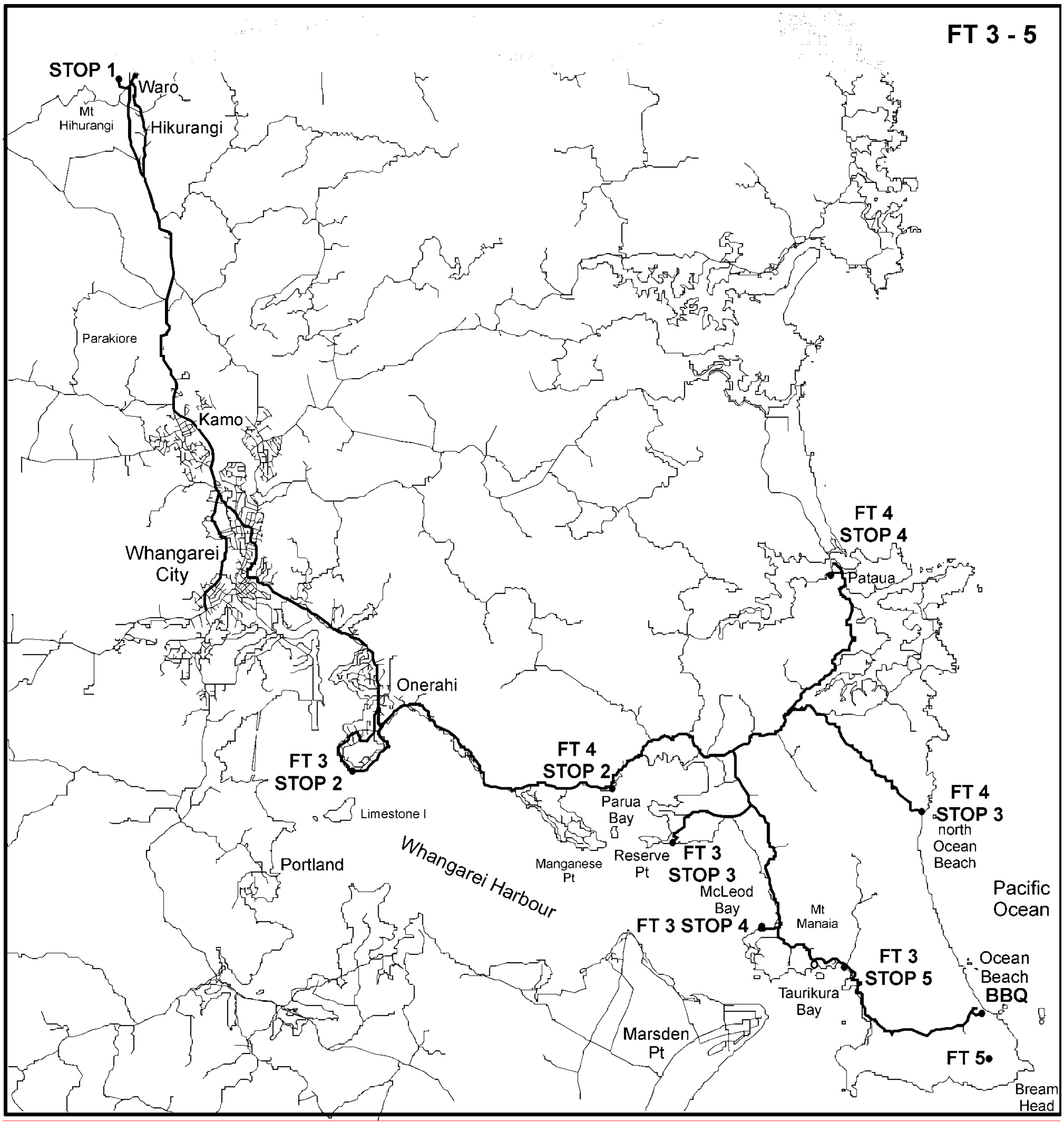
From here, field trips 3, 4 and 5 go their separate ways.
All come together again at Ocean Beach surf club for the BBQ, from 5.30 PM till dusk. (wet weather BBQ venue: Manaia Baptist Camp, end of McDonald Rd, west end Taurikura Bay).

Field Trip 3

Whangarei Heads Geology

Petra Bach, Philippa Black, Bruce Hayward,

Mike Isaac and Ian Smith



Route map for Field Trip 3 (FT 3)

Field Trip 3

Whangarei Heads Geology

Petra Bach, Philippa Black, Bruce Hayward, Mike Isaac and Ian Smith

Part 1: See previous section – Introduction to Whangarei geology.

Part 2: Below

Drive straight ahead along the top of basalt flow surface through Onerahi. Views of Tangihua Range to the south and high Maunu scoria cone to the west.

Onerahi Peninsula (Q07/342020)
Name-bearer of Onerahi Series and Onerahi Chaos Breccia, fore-runners of the Northland Allochthon. (Fig. 3.1)

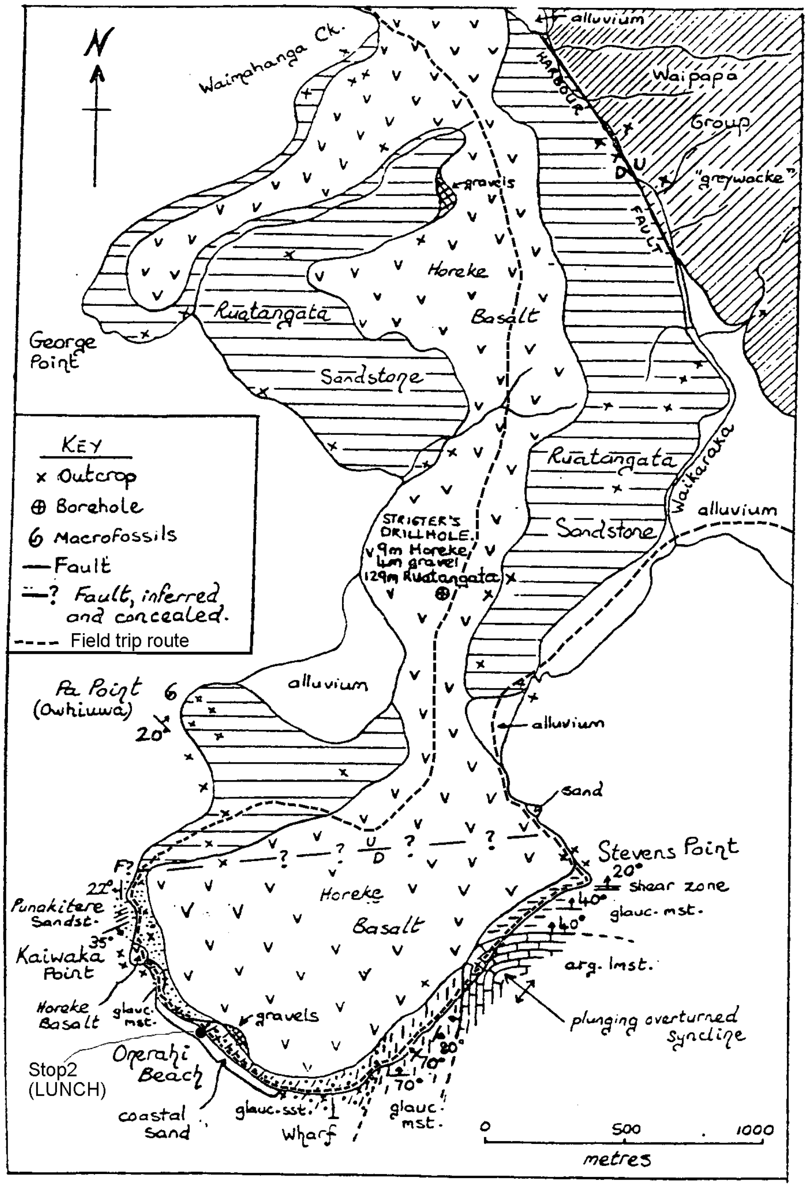


Fig. 3.1: Geological map of Onerahi Peninsula (from Evans and Hayward 1989).

Onerahi Peninsula is a low ridge of sedimentary rocks unconformably overlain by Pliocene flow basalt (c.4 Ma). The northern three quarters of the peninsula is underlain by undeformed, north-east-dipping, massive to crudely bedded glauconitic sandstone (Ruatangata Sandstone, Te Kuiti Group, Ar-eLwh). This lithology is assumed to be autochthonous here upon Waipapa greywacke.

At the southern end of the peninsula, deformed late Cretaceous and Paleogene rocks of the Northland Allochthon, outcrop beneath the basalt. North-west of Onerahi Beach lunch stop, a steeply dipping sequence of carbonaceous and micaceous siltstone and quartzose concretionary sandstone (Punakitere Sandstone, Mh, late Cretaceous), is exposed in the shore platform. East of Onerahi Beach, the shore platform comprises deformed, massive, glauconitic sandstone and mudstone of middle Eocene (Dh) age, containing lenses of pebble conglomerate (one of the few places in Northland where this rare unit is seen). Beyond Onerahi Wharf, the mid Eocene sediment passes gradationally upwards over a 5-8 m interval through late Eocene and early Oligocene greensand (Ak, Ar and early Lwh), into massive glauconitic argillaceous Mahurangi Limestone of late Oligocene (Lwh-Ld) age. This unique condensed sequence is preserved in a small overturned syncline (=antiform).

44 km 1 PM **STOP 2 - LUNCH** by boat ramp, parking, toilets.

View of Limestone Island in Whangarei Harbour (Oligocene deep-water Mahurangi Limestone, Northland Allochthon). Site of early quarries for cement industry and now wildlife refuge with community revegetation project.

Leave 1.40 PM. Drive around south and east sides of Onerahi Peninsula shoreline (Fig. 3.1).

Drive around Waipapa Terrane greywacke coastline past Manganese Pt and Parua Bay.

<u>**EARLY MIOCENE TAURIKURA VOLCANICS**</u> (Figs. 1.1, 3.2)

Taurikura volcanic centre rocks outcrop around Whangarei Heads and to the southeast on the Hen and Chickens Islands. Offshore seismic and marine magnetic studies (Thrasher 1986) suggest that the seafloor between these areas is underlain by igneous rocks and that present day outcrops are the greatly eroded remnants of a 50 km diameter stratovolcano complex (Fig. 1.1)

Whangarei Heads Volcanic Centre (Taurikura Subgroup)

Early Miocene igneous and volcaniclastic rocks in the Whangarei Heads area consist of a diorite pluton, numerous andesitic and dacitic subvolcanic stocks and dikes intruding greywacke and Northland Allochthon rocks (Allen 1951, Elliot 1966; Middleton 1983; Weigel 1971), all overlain by weakly stratified to massive, rubbly breccia with rare andesite flows. The volcaniclastics outcrop in three parts of the Whangarei Heads area (Fig. 3.2) and are inferred to be the basal remains of a subaerial andesitic cone sourced from at least two vent areas (Hayward 1993). The intrusions are interpreted to be the high-level subvolcanic plumbing beneath the stratovolcano.

The Northland Allochthon sedimentary rocks, that these igneous rocks intrude and overlie, were emplaced into this area in the earliest Miocene (late Waitakian) c. 23-22 Ma (Hayward et al. 1989; Hayward 1993). This was followed by block faulting, uplift, and considerable erosion to produce a planar surface upon which the Whangarei Heads stratovolcano was built. There is no evidence of any igneous activity at this centre during or prior to Allochthon emplacement. Stratigraphically acceptable K-Ar ages indicate that the Whangarei Heads Volcanic Centre was active during the period 21-16 Ma (Hayward et al. 2001).

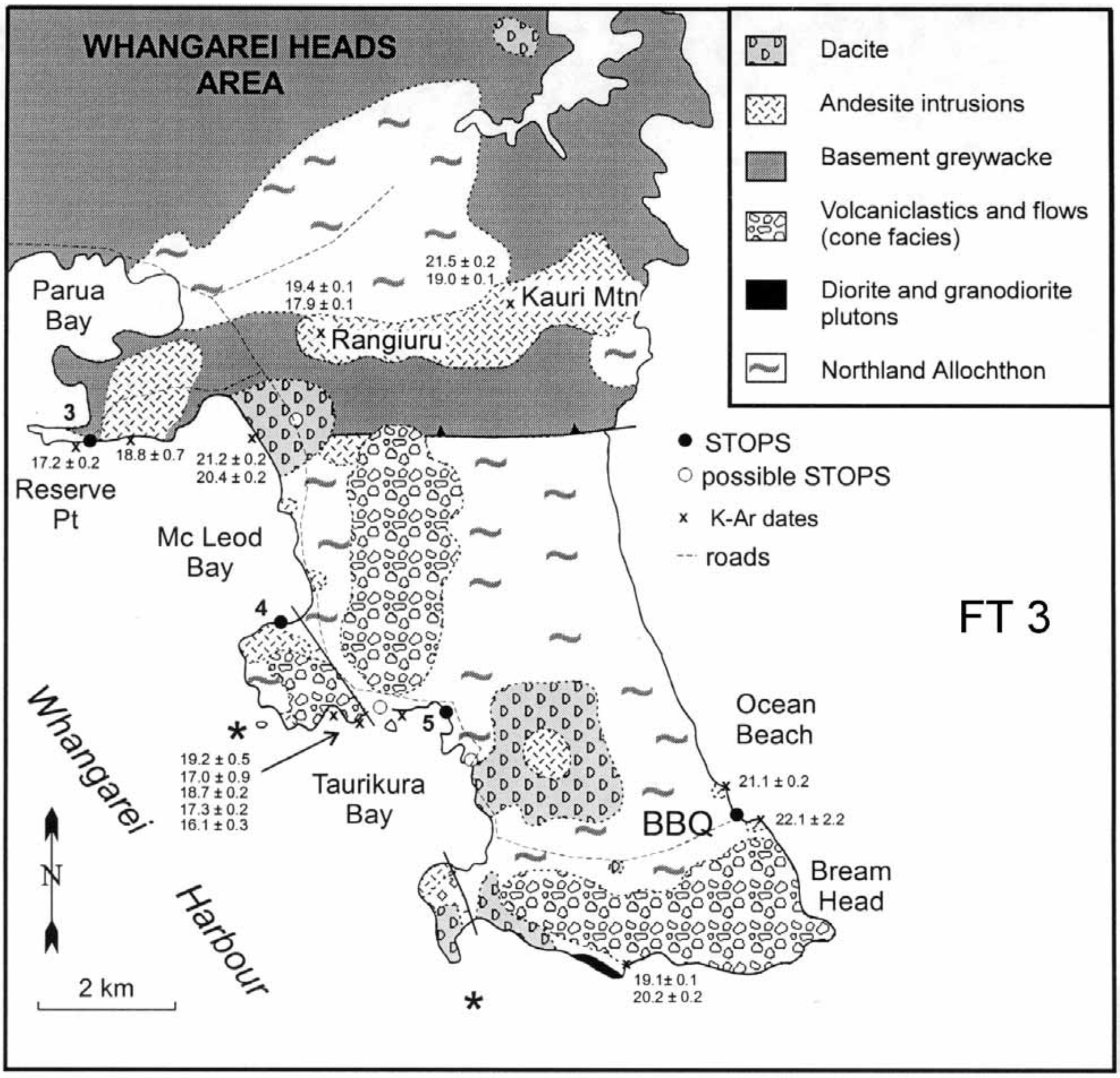


Fig. 3.2: Distribution of early Miocene Whangarei Heads Volcanic Centre rocks (from Hayward et al. 2001).

65.5 km 2 PM Bus stops at junction of Nook Road with road off to right (last turning point). Vans continue straight ahead for 1.5 km and return to pick up walking bus passengers.

67 km **STOP 3 <u>Reserve Point</u>** (Q07/423997)

Late Eocene (Ar), glauconitic, calcareous sandstone, that sits unconformably on greywacke around the point, here includes a thin nephelinite lava flow, dated at 38 Ma (Smith et al. 1986). The flow contains olivine with minor clinopyroxene phenocrysts in a groundmass of clinopyroxene, plagioclase and nepheline (Taylor 1980). The nephelinite is one of several occurrences of alkaline rocks in the area which represent an older and quite separate association from the adjacent early Miocene Whangarei Heads Centre.

Nearby is a dike-like intrusive body of early Miocene hornblende-bearing garnet andesite (Day et al. 1982). This rock has been dated as 17.2 +/-0.2 Ma (Hansen 1978). An unusual feature is the abundance and variety of inclusions. There are two types (Smith et al. 1986):

1. Strongly foliated basalt with a mineral assemblage of green hornblende, feldspar and quartz with minor epidote and sphene. Their chemical composition is comparable to oceanic basalt.

2. Hornblendite and gabbro, with brown hornblende and plagioclase, with or without orthopyroxene and clinopyroxene; some of these also contain garnet. These have variable chemistry but appear to be consanguineous with the host garnet andesite. In detail the inclusion suite comprises calc-alkaline high-MgO pyroxene- and hornblende-pyroxene andesites (HMA), low-MgO hornblende and biotite-hornblende andesites (LMA), and dacites. These rocks carry tholeiitic gabbroic xenoliths of high-MgO pyroxenite, hornblendite and pyroxene-hornblende gabbro (HMG) as well as of high-Al_2O_3 hornblende-, garnet-hornblende gabbro, garnetite lenses and anorthosite (HAG). Garnet and gabbroic xenoliths reveal a P-T environment of 10 kbar and 700-1000ºC, and thus provide an unique window into deep magmatic processes in a subduction setting. These xenoliths provide an exceptional opportunity to study deep arc processes in an add-on approach from the bottom to the top of a subduction zone revealing sequential petrogenetic processes that took place in the mantle wedge during the initiation of subduction.

Leave c. 4.10 PM.

72 km Drive slowly past road cuttings on right through deeply weathered, white, early Miocene dacite intrusion with bleached micas in a ceramic clay. Fresher rock from this dome has been dated at 21.8 +/-2.1 Ma (Middleton 1983).

75 km Turn right and drive c. 200 m along Stuart Rd. Bus stops at corner and passengers walk.
4.20 PM **STOP 4. Foreshore McLeod Bay wharf** (Q07/463972)

In the foreshore we see a steeply-tilted block (autochthonous or allochthonous autochthon) that preserves an interesting sequence of Whangarei Limestone faulted against and overlain by early Miocene Waitemata Group and then by sheared mudstone and other lithologies of the basal Northland Allochthon. Similar sequences to this are present around the shores of Whangarei Harbour. They all indicate rapid post-Whangarei Limestone subsidence, accumulation of a thin sequence of deep water 'Waitemata' sediments followed by the incoming of the Northland Allochthon in this area in the early Miocene (late Waitakian-early Otaian).

Leave by 4.55 PM.
Drive up hill between Mt Manaia (left) and Mt Aubrey (right), both erosional remnants of early Miocene andesitic stratovolcanic cone breccia and minor flows.

79 km 5PM **STOP 5. Taurikura Bay natural jetty** (Q07/487959), and toilet stop.

Walk along roadside to view and photograph New Zealand's best example of a natural jetty. NO HAMMERS PLEASE. It is formed by an early Miocene dike of resistant augite andesite (with chilled margins) intrusive into less resistant argillaceous limestone of the Northland Allochthon.

Leave by 5.20 PM.

80 km Road cuts and shore line of white Mahurangi Limestone.

81 km Black rock in road cut on left is limestone baked by early Miocene dacite intrusion.

83 km Take road over hills of Northland Allochthon (Mahurangi Limestone) with hill on left composed of early Miocene dacite and andesite, and forested Bream Head ridge on right of early Miocene andesite stratovolcano breccia.

87 km 5.30 PM **STOP 6. Ocean Beach** (Q07/528947) BBQ.

Turn right down access road to beach carpark and surf club.
Toilets by carpark. High tide 7 PM.
Rocks at both ends of beach are early Miocene andesite intrusions into Northland Allochthon limestones.
At the southern end, multiple dikes of pyroxene andesite form the point. For those with sharply honed observational skills rare garnet crystals can be seen in the andesite.

Drive home after the BBQ will take about 1 hour (45 km) and return you to Whangarei and accommodation precinct.