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FIELD TRIP GUIDES

Edited by
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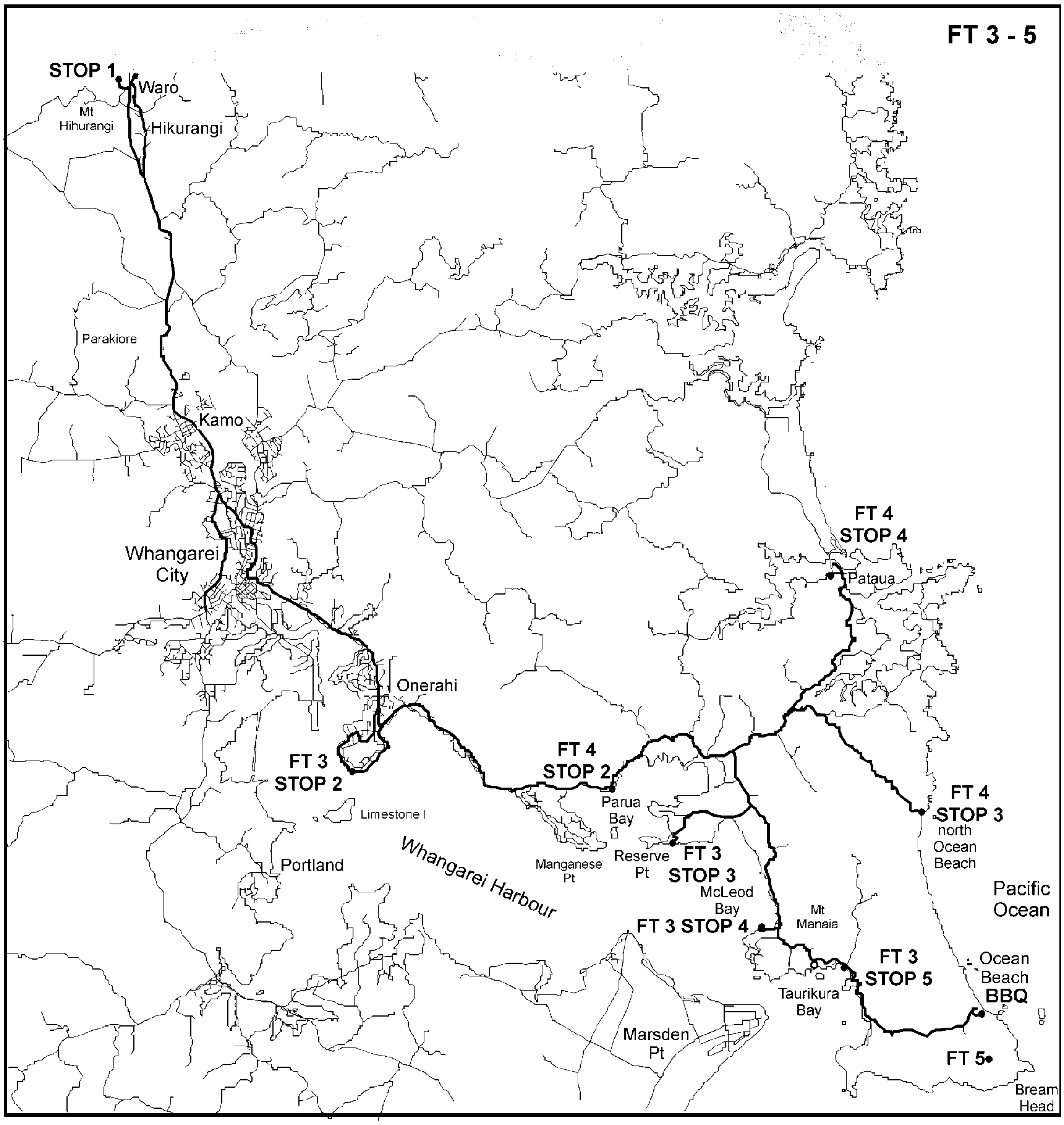


Route map for Field Trips 3, 4 and 5 (FT 3, 4, 5)

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.

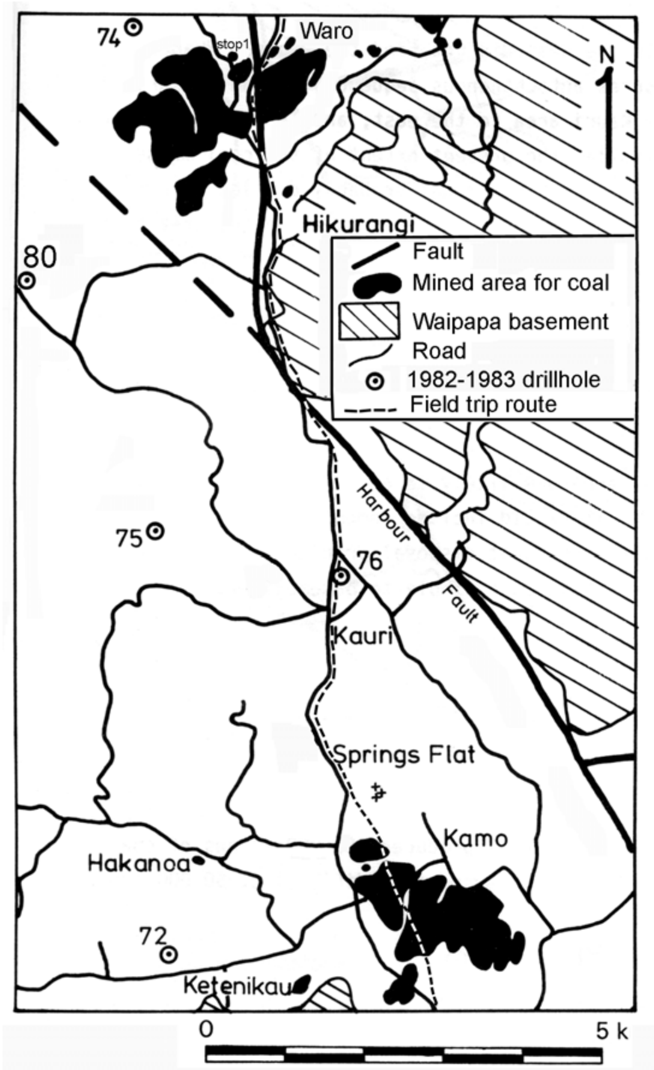


Fig. 3-5.1: Simplified coalfield geology and drill hole sites in the Kamo-Hikurangi area (from Isaac 1985).

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.

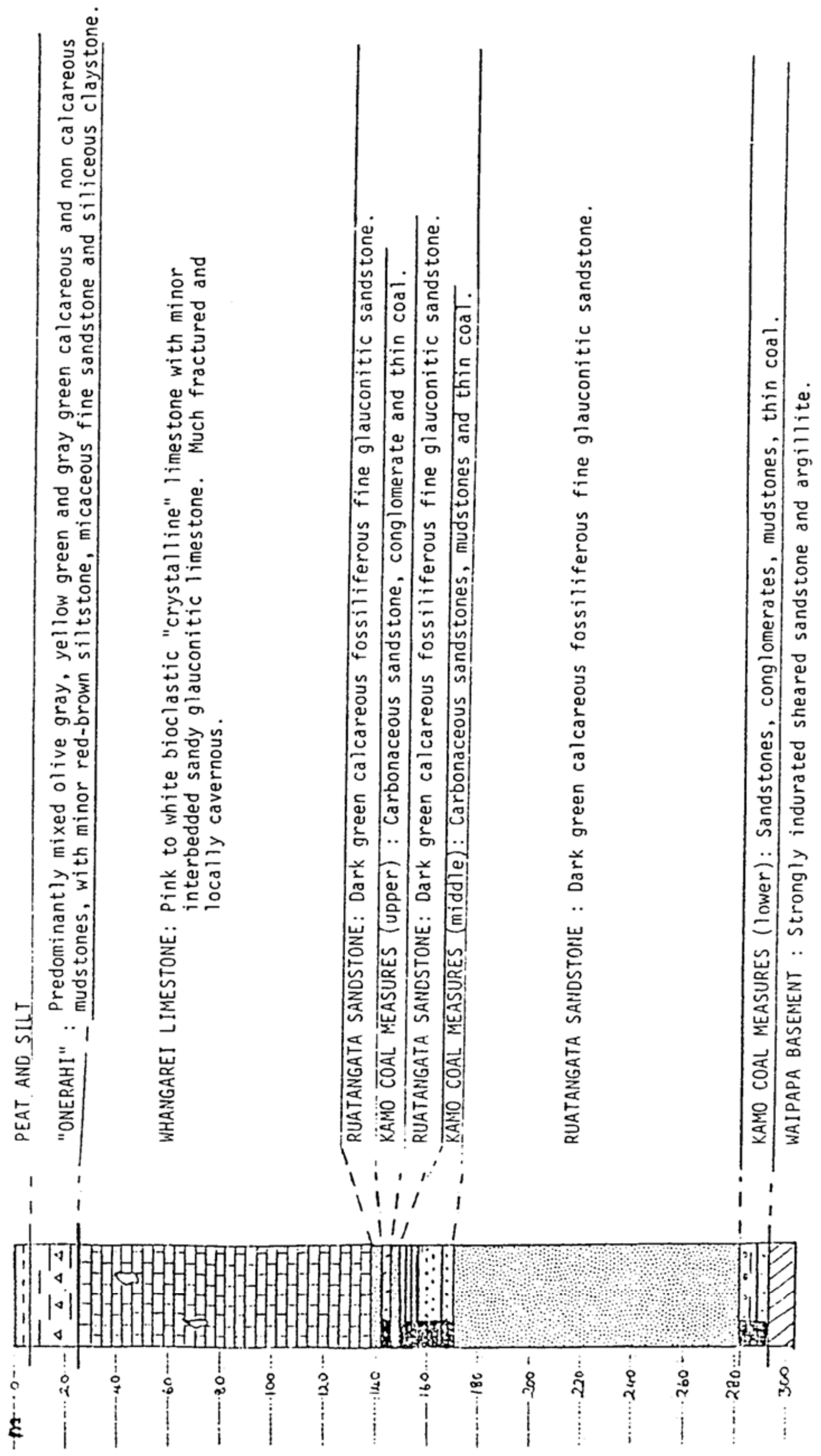


Fig. 3-5.2: Summary log of coal exploration drill hole d74, 1.5 km northwest of Wilsonville Quarry (Isaac 1985).

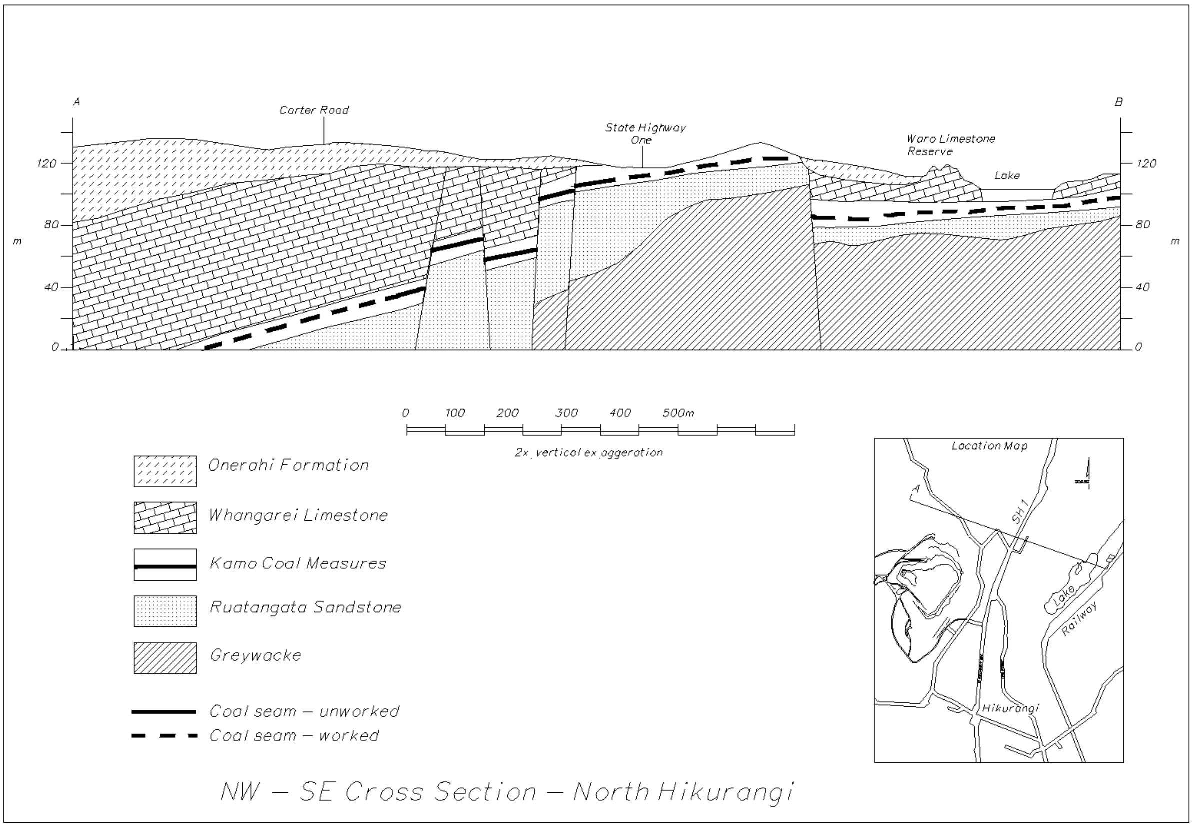


Fig. 3-5.3: West-east geological cross-section through the Wilsonville Quarry – Waro Rocks area (STOP 1). Wilsonville Quarry is located just west of Carter Rd (from K. Miller unpubl.).

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.

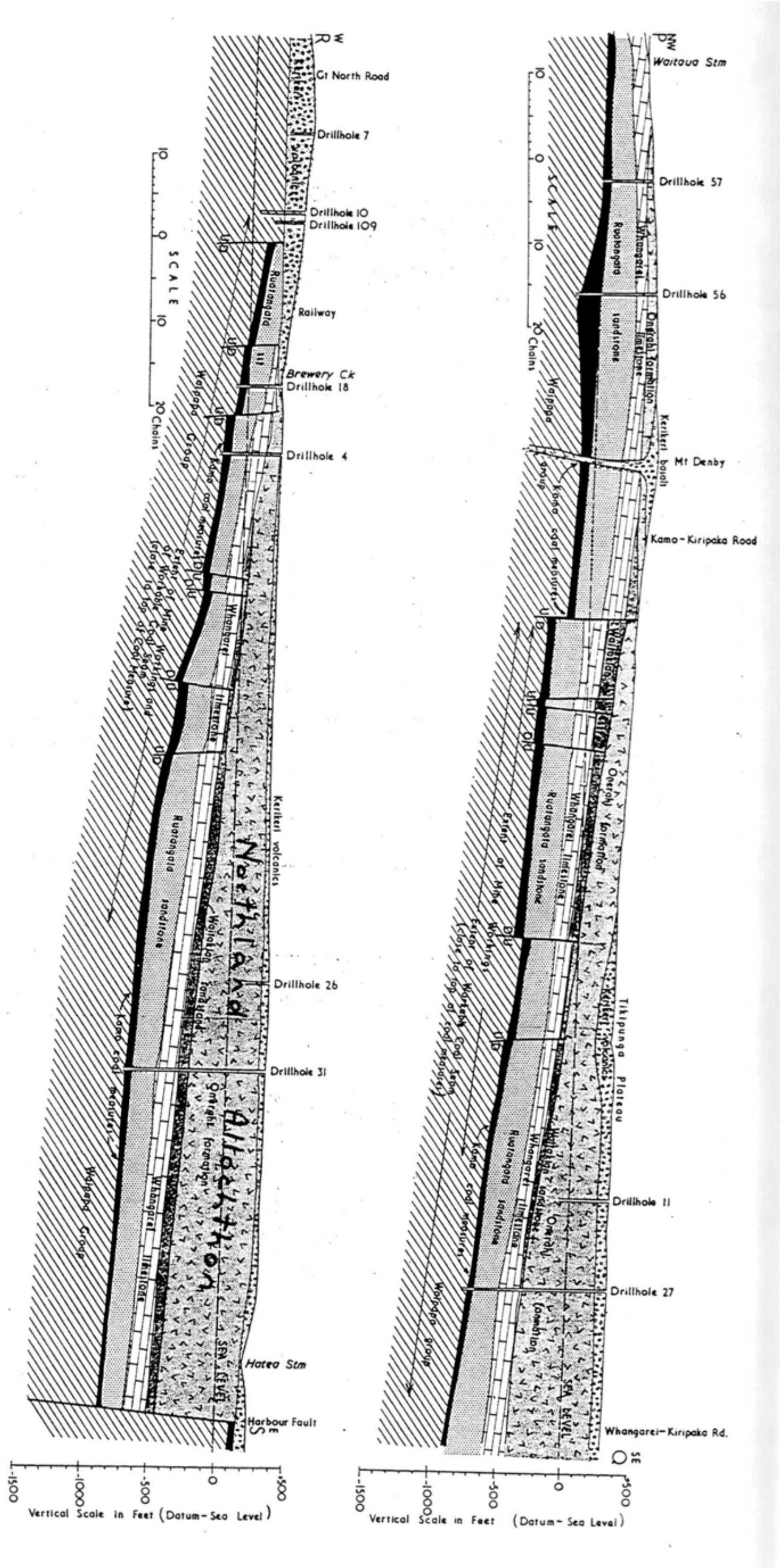


Fig. 3-5.4: West-east cross-sections through the Kamo coal field area, just south of Whangarei, illustrating the relationships between the autochthonous Te Kuiti Group rocks and the overlying Northland Allochthon (= Onerahi Formation). (from Kear 1959).

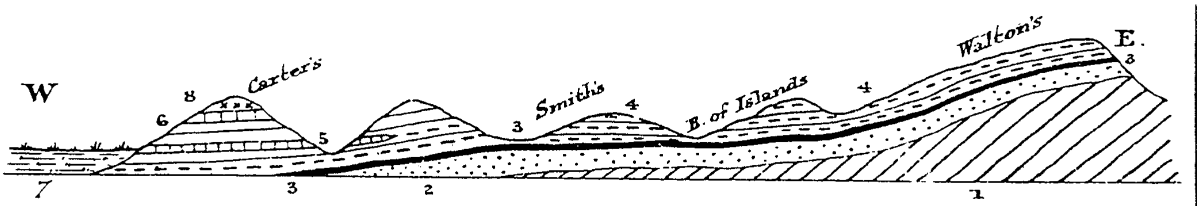


Fig. 3-5.5: Geological section at Hikurangi (from McKay 1894). Wilsonville Quarry is located in units 6 and 5 on the west side of Carter's Hill.

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.

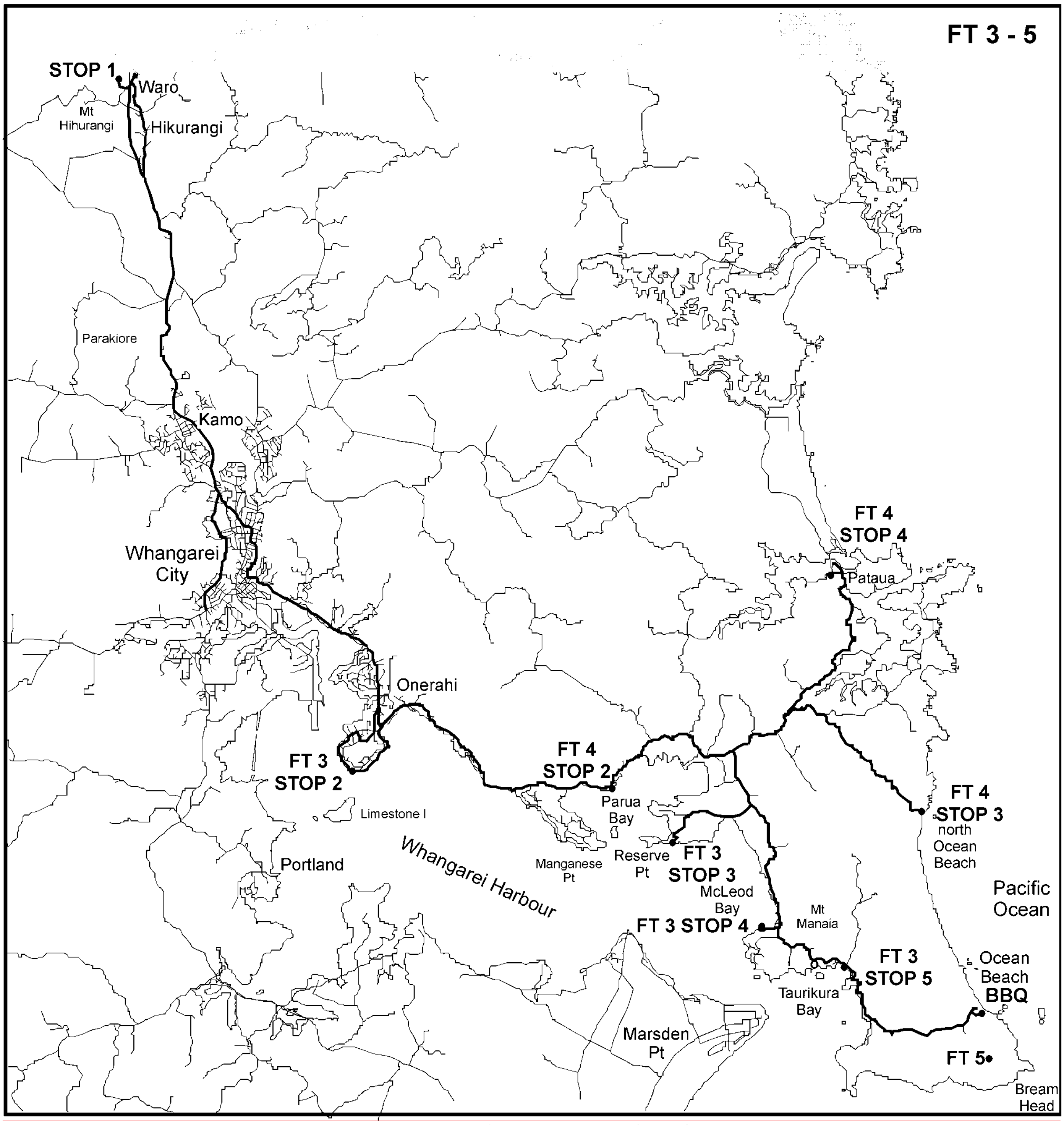
42 km The road climbs the hill onto the top of the c. 4 Ma basalt flow that caps Onerahi Peninsula. Note basalt boulders on hillside on left.

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 4

Basement/Tertiary cover/Allochthon interactions (Ocean Beach)

Bernhard Spörli



Route map for Field Trip 4 (FT 4)

Field Trip 4

Basement/Tertiary cover/Allochthon interactions (Ocean Beach)

Bernhard Spörli

Part 1: See previous section between field trips 2 and 3 – Introduction to Whangarei geology.

Part 2: Below

Onerahi to Parua Bay domain
Descend from the high basalt surface of Onerahi township.
Then 5km along the road skirting the harbour. Waipapa terrane greywacke hills to the left. The road runs parallel to the postulated "Harbour Fault". However the existence of the fault is somewhat in doubt today.

Parua Bay (Marina and Domain) (3.5km)
At the Parua Bay Hotel (just past the Domain), rusty red weathering outcrops of **Waipapa radiolarian chert** are exposed in shore platform and road cuts. These strike NW-SE, across the bay (rocky islets). On the other side of the bay there are associated pillow basalts. This volcanics/cherts/green argillite association represents a typical **ocean floor sequence** at the base of one of many thrust slices in Mesozoic Waipapa terrane **accretionary prism** (eg. Aita and Spörli 1992). Unfortunately we have no ages from these radiolarian cherts yet. Similar cherts are Triassic/Early Jurassic in the Auckland area (Spörli *et al.* 1989) and Permian/Triassic at Arrow Rocks in Northland (Takemura et al. 2002, also see field trip FT8).

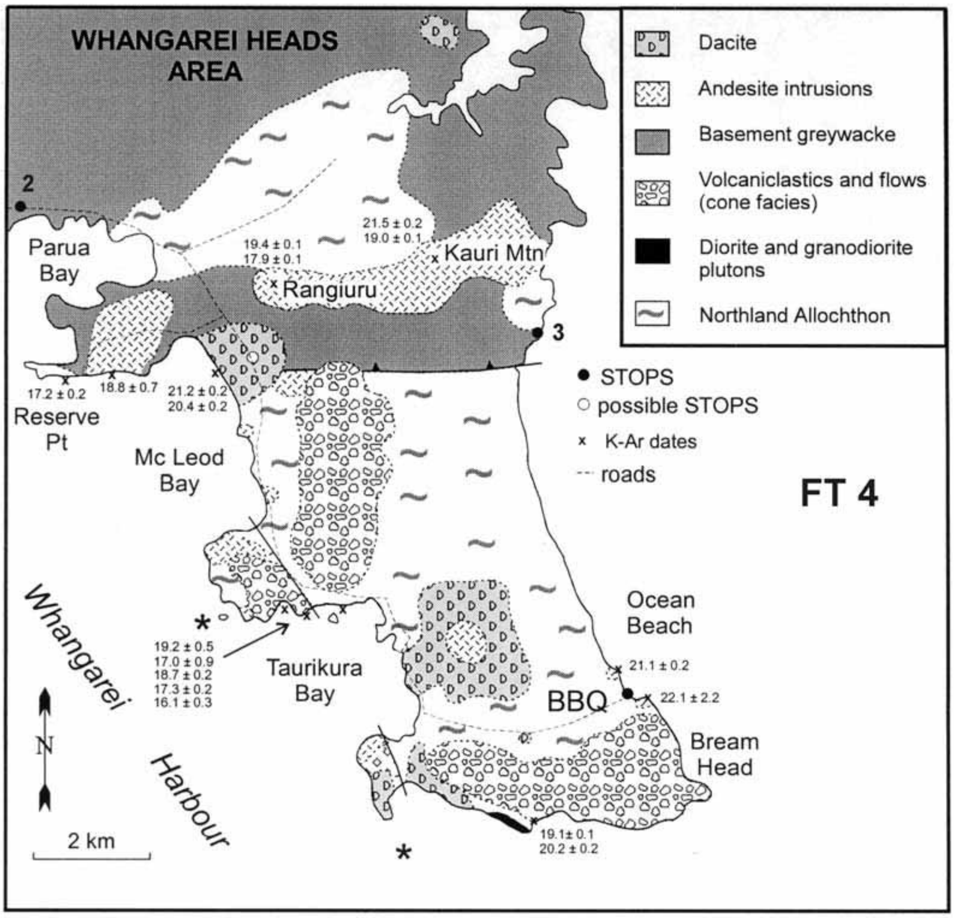


Fig. 4.2: Geological map of the Parua Bay- Whangarei heads -Ocean Beach area. Modified from Hayward *et al.* (2001)

STOP 2: Parua Bay domain (Lunch, Toilets) A liitle before Parua Bay Hotel.

View across bay
The low-lying, smooth slopes at the eastern end of Parua Bay are underlain by Northland Allochthon. This is well exposed along the southern shores (K.B. Spörli, p.25 in O'Connor and Ballance 1995 and Harrison, 2000).

Northland Allochthon (a complex array of slivers of Cretaceous and lower Tertiary deep water rocks) **structurally overlies** Whangarei limestone **and basal Waitemata Group,** which sit on Waipapa greywackes (the latter extending to the pillow lava/chert outcrop mentioned above). The entire stack is positioned on the **north limb of a northward verging, +/- E-W trending fold,** which is an analogue structure to that which we will examine at northern Ocean Beach (see below).

Resume trip
Follow **Whangarei Heads Road** 4km east through greywackes, past Parua Bay Hall and School, to where Whangarei Heads Road makes a **right angle turn** at the beginning of Pataua South road.

Proceed **straight on** along **Pataua South Road**.

The road now enters the Northland Allochthon depression at the head of Parua Bay. This is a rectangular, **fault and fold-controlled outcrop** (a "klippe") of Northland Allochthon (Fig. 4.2). Yellowish, poor soils in the paddocks and cuts on the side of the hills indicate presence of the Ngatuturi claystone of the Cretaceous/Tertiary **Whangai Formation**. Multi-coloured mudstones in some of the roadside drains are of lower Tertiary age.
In good weather: spectacular views south of the rugged topography in the Miocene volcanics of Mt. Manaia on the Bream Head Peninsula (Fig. 4.2).

After 2.3 km, **turn right** on to **Taiharuru Road**, follow it for only 1.3km.
Turn right again at **Kauri Mountain turnoff**, proceed southward 4.3km.

We are still in smooth Northland Allochthon topography. However, note the high, rounded forested hill to the SE: Miocene Kauri Mountain Pluton (Age 19 Ma, Fig. 4.2) studied by Weigel (1971) for contact metamorphism and base metal mineralisation in Northland Allochthon sediments. The contact between sediments to the north and pluton to the south is marked by an **upward step** in the topography seen to the left, as the road starts winding up to the little saddle marking the boundary to the Ocean Beach drainage.

Descend winding road through native forest to bottom of the valley. Ahead: sand dunes of Ocean Beach and views of Bream Head and south end of Ocean Beach (site of tonight's BBQ!). East slopes of Mount Manaia (Miocene volcanics) to the right are underlain by Northland Allochthon.

STOP 3: North end Ocean Beach (main stop)

Park vehicles (on left hand side inside gate). We will stay here until about 3pm (Low tide 2 pm).

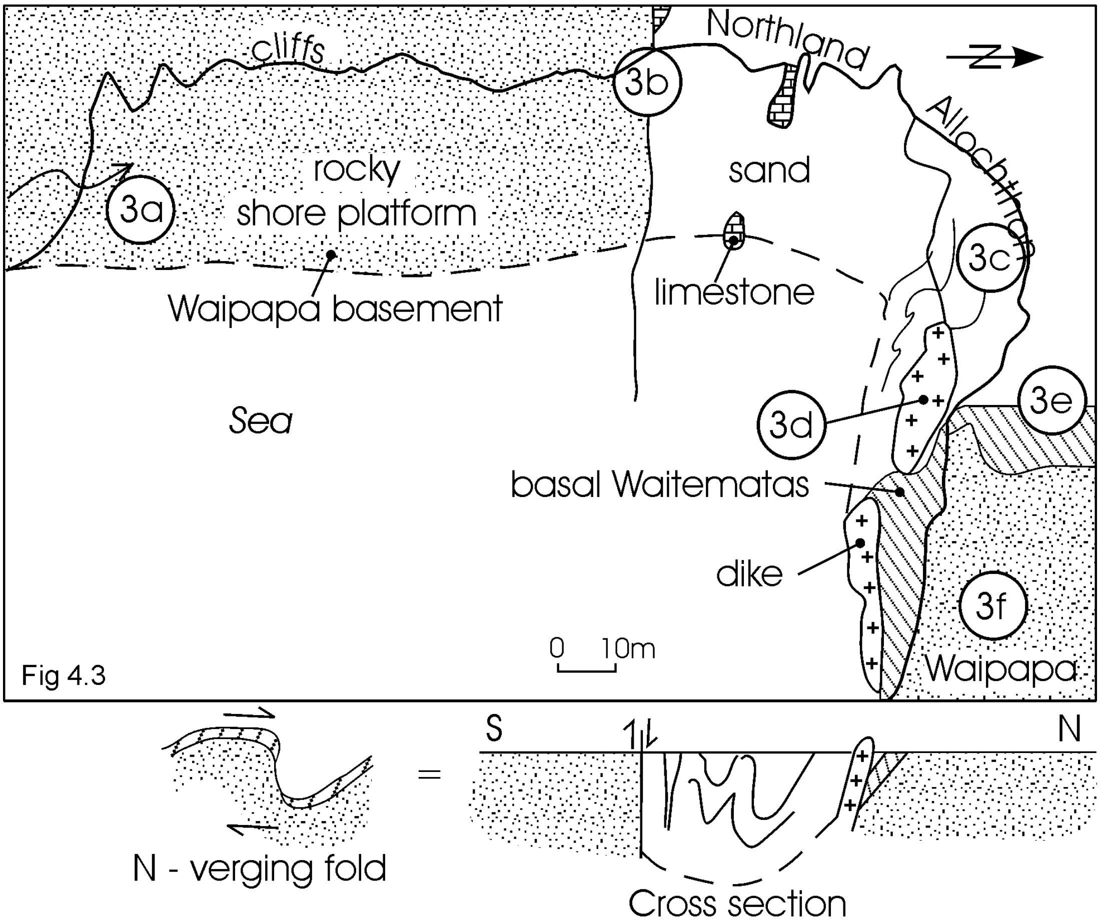


Fig. 4.3: Geological Sketch Map and schematic cross-section of "Dyke Bay" with locations of interest.

Short introduction
The seashore here exposes Northland Allochthon, which overlies an "autochthon" consisting of basal Waitemata calcareous clastics onlapping unconformably onto the Waipapa basement. The **allochthonous rocks are jammed tightly between two greywacke basement blocks**. The E-W striking structure has the geometry of an asymmetric**, northward verging syncline** with a sheared-out southern limb (Fig. 4.3). The structure also contains a **Miocene porphyritic dacite dike**.
(NOTE: None of the rocks overlying the greywacke basement so far have been dated by microfossils. Their allocation to the various Allochthon lithologies is based on lithological correlations).

After a short walk to the beach we will head north:

STOP 3a: (Fig.4.3) **Southern "greywackes"**

Initially we cross hundred metres ++ through **Waipapa terrane** rocks. Besides the normal "greywacke" argillite and sandstones, there are at least **three chert layers** and one exposure of **ocean floor volcanics**. The overall strike is NW-SE and dips are to the SW. Note the intense development of **broken formation** in the 'greywackes", the local vein swarms, striated fault surfaces and occasional crush and gouge zones. The presence of three or more seams of ocean floor rocks (volcanics and cherts) with such thin intervening "greywackes" is unusual. More commonly these markers of accretionary slicing are spaced several hundred meters to more than a km apart.

STOP 3b: (Fig.4.3) Faulted southern contact of Allochthon

The area north of here was given the informal name **"Dyke Bay"** by Weigel (1971).
Several tens of metres to the south of the contact, the greywackes contain numerous gouge faults. The **main contact** (if exposed) can be seen as a vertical shear zone, with contorted mudstone of the allochthon to north. Note the block (fault sliver) of autochthonous crystalline **shallow water Whangarei limestone** (Oligocene Te Kuiti Group) above in the fault gully. In contrast, the next ridge to the north protruding into the shore is composed of very sheared allochthonous **deep water Oligocene Mahurangi limestone.**

STOP 3c: (Fig.4.3) Northwestern part of "Dyke Bay", deformation in the allochthon.

Multi-coloured mudstones, siliceous rocks (lower Tertiary?) and alternating brown grey mudstones and sandstones (Cretaceous Mangakahia Group?) outcrop in cliffs and variably exposed shore platform. One dark mudstone unit may be the Waipawa black shale (see FT 7 Stop 16, and FT9 Stop 2). Note **broken formation** in these sedimentary rocks, **multiphase folding** (mushroom structures!) and cross-cutting **clastic dikes** (see Fig. 4.4).

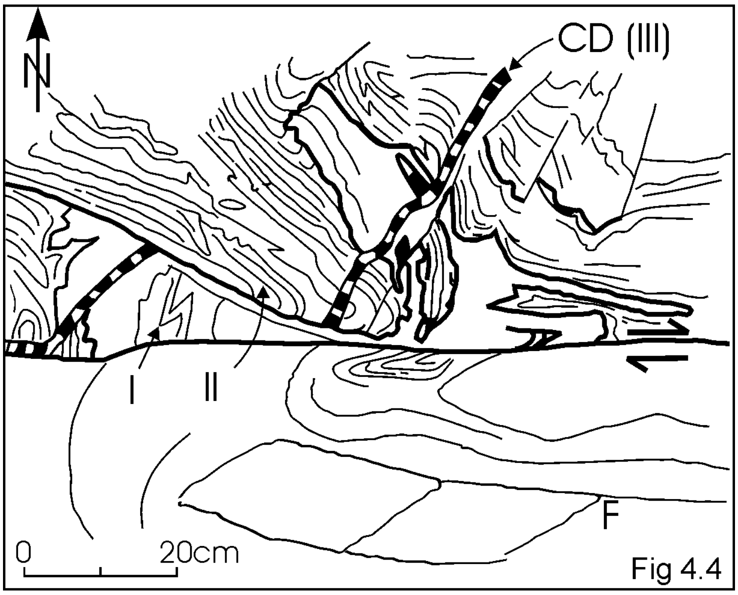


Fig. 4.4: Detail structure in the allochthon, location 3c (see Fig. 4.3), as seen on shore platform, from Spörli (1982). Sinistral folds (I) and mélange-type fabric are refolded by dextral shear (fold/fault II), and both are post-dated by Miocene(?) clastic dikes (CD(III)) which are part of a transform pattern, implying a sinistral component of shear. Sediments north of fault are thin-bedded alternating dark and light grey mud- and sandstones; south of fault they are light grey, thicker bedded siliceous limestones. F = lozenges (shear lenses) in mélange-type fabric.

STOP 3d: (Fig.4.3) Miocene porphyritic dacite dike.

These massive, orange-brown weathering igneous rocks form the prominent E-W trending ridge in the northern part of the bay. There have been no age determinations on this dike. It is probably associated with the intrusion of the Kauri Mountain Pluton. The dike dips steeply to the south and is divided into at **least two segments** with steep axes. Note laminar marginal structures at SW–end of the dike.
The dike cuts all the structures surrounding it and does not appear to be faulted (the segmentation is a syn-intrusion feature). However Weigel (1971) reports some fault offsets in the dikes further north. In "Dyke Bay" the clastic dikes mentioned above are most likely associated with intrusion of the dike and some of these are offset by late faults.

STOP 3e: (Fig.4.3) Northern contact of Allochthon.

Greywacke basement is overlain unconformably by **basal Waitemata calcareous sandstones** which go through an almost 90^{o} turn in strike pattern, probably indicating the nose of a steeply plunging dextral fold. The N- S trending part of the contact (the short limb of the dextral fold) is usually best exposed and shows disrupted Northland Allochthon rocks overlying autochthonous Waitematas along **shear zones** with sinistral sigmoidal shear sense indicators (it may be interesting to discuss these in relation to Northland Allochthon movement directions). Basal Waitematas display good calcite fibre striations (some with steps as shear sense indicators) implying a NE-SW (035^{o} –215^{o}) shortening (KBS, unpublished data).

STOP 3f: Northern greywacke basement.

We will not follow the coast along this exposure, but the greywackes here include another layer of cherts. It and the fabric of the greywackes trend at right angle (NE-SW) to those in the south.

Significance of these outcrops

Since the allochthon rocks **overlie the basal Waitematas on shear zones**, it is not clear whether this structural contact represents the initial phase or the remobilisation phase of allochthon emplacement (Isaac *et al.*1994 and Field trips FT 1 and FT 7).

Subsequent to emplacement, the **allochthon was folded into a syncline**, the asymmetry of which implies **northward thrusting** (Fig.4.3, cross –section). Similar asymmetry is also indicated at Parua Bay. Structures of this kind are also found in the Tertiary rocks on the south shore of the Whangarei Harbour (see Field trip FT1). The significance of this rather wide-spread deformation phase is not clear. Its age may have been intra- Miocene, as the andesite dike, while exploiting previously formed structures, did not participate in the formation of the syncline and its almost E-W strike implies north south-directed extension rather than shortening.

However the 20km long, 19Ma old Matapouri–Onerahi micro-diorite dike (Brothers 1989) trends NNE and therefore would be more compatible with N-S component of shortening. These scattered bits of deformation could imply that basement blocks in the Whangarei **were significantly mobile in the Cenozoic**, as already implied by Hayward (1989).

However, by the Holocene, volcanic alignments were dominantly ESE-WSW, indicating a change to extension in the N-S direction (e.g. Brothers 1965a, fig. A-3).

(Optional trip (steep climb) **will only be done in exceptional conditions**)
Cross over ridge at N-end of “Dyke Bay” to study base metal mineralisation (pyrite, chalcopyrite, arsenopyrite, sphalerite, magnetite marcasite, galena and native copper) at contact between Mahurangi limestone and Kauri Mountain Pluton. Alteration has occurred along the contact and faults cutting it. Limestone has been changed into “tactite”, a calcium-garnet (andradite, grossularite) –bearing carbonate rock with wollastonite, diopside epidote and chlorite (Weigel 1971).

Walk back to vehicles

Ocean Beach – Pataua South

Drive back 4.3km to Kauri Mountain turn-off, turn left onto Taiharuru Road. Follow this road for 1.3km, do **very sharp right turn** onto **Pataua South Road.**

Follow Pataua South road for 3.3km:
prominent **Conical Hill dacite** on the right (see Fig. 4.2). This is the last expression of the Whangarei Heads igneous rocks. From now on the landscape is entirely cut into Waipapa terrane. The road now winds down into the **Taiharuru River estuary**.

2.1km further:
The road goes through a classical **watergap,** cut through a NW-SE trending ridge of Waipapa chert. The cherts dip steeply to the west. The chert **ridge and valley topography** of this area is **very unusual** for the North Island. All the inland basement rocks commonly weather uniformly to one undistinguishable clay mass. (The only other exceptions are the chert ridges of Waiheke Island in Auckland). What has made this chert more resistant? Is it just the nature of the chert or is it due to some type of metamorphism due to the Miocene igneous rocks? The answer is still outstanding.

Proceed 0.4km to Pataua and Hutchinson Road:
Pataua River estuary ahead. The high, steep hill on the other side is the expression of another chert ridge, skirting the seashore (another, lower, chert ridge goes through the landward side of Treasure Island Holiday Park).

Turn left and follow Hutchinson Road 0.5km.

STOP 4: Roadside quarry of chert

We can now examine a cross section of the chert ridge, which we crossed on the road earlier. Note the steep dips, some evidence of folding. Only the outer part of the ridge is underlain by true red chert, the **main part is recrystallised** to a light grey to yellow colour. It is probably this effect that makes the chert weathering- and erosion-resistant.

Drive to BBQ
Back to **Pataua South Road** and follow it for 8.1km, then:
Turn left onto **Whangarei Heads Road** and follow this to **Urquharts** Bay (~ 12 km)
Turn left onto **Ocean Beach Road**, and follow this to the **end** (Ocean Beach Surf Club).

Points of interest along this route can be checked in the **guide for FT3**:
McLeod Bay autochthon?/allochthon relationship: **FT3, Stop 4**
Taurikura Bay "Natural jetty" dike: **FT3, Stop 5**

All come together again at **Ocean Beach Surf Club** for BBQ, 5.30 PM till dark
(wet weather BBQ venue: Manaia Baptist Camp, end of McDonald Rd, west end Taurikura Bay).