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FIELD TRIP GUIDES

Edited by
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(with thanks to Bruce Hayward, Ashwaq Sabaa and Jessica Hayward for editorial assistance)

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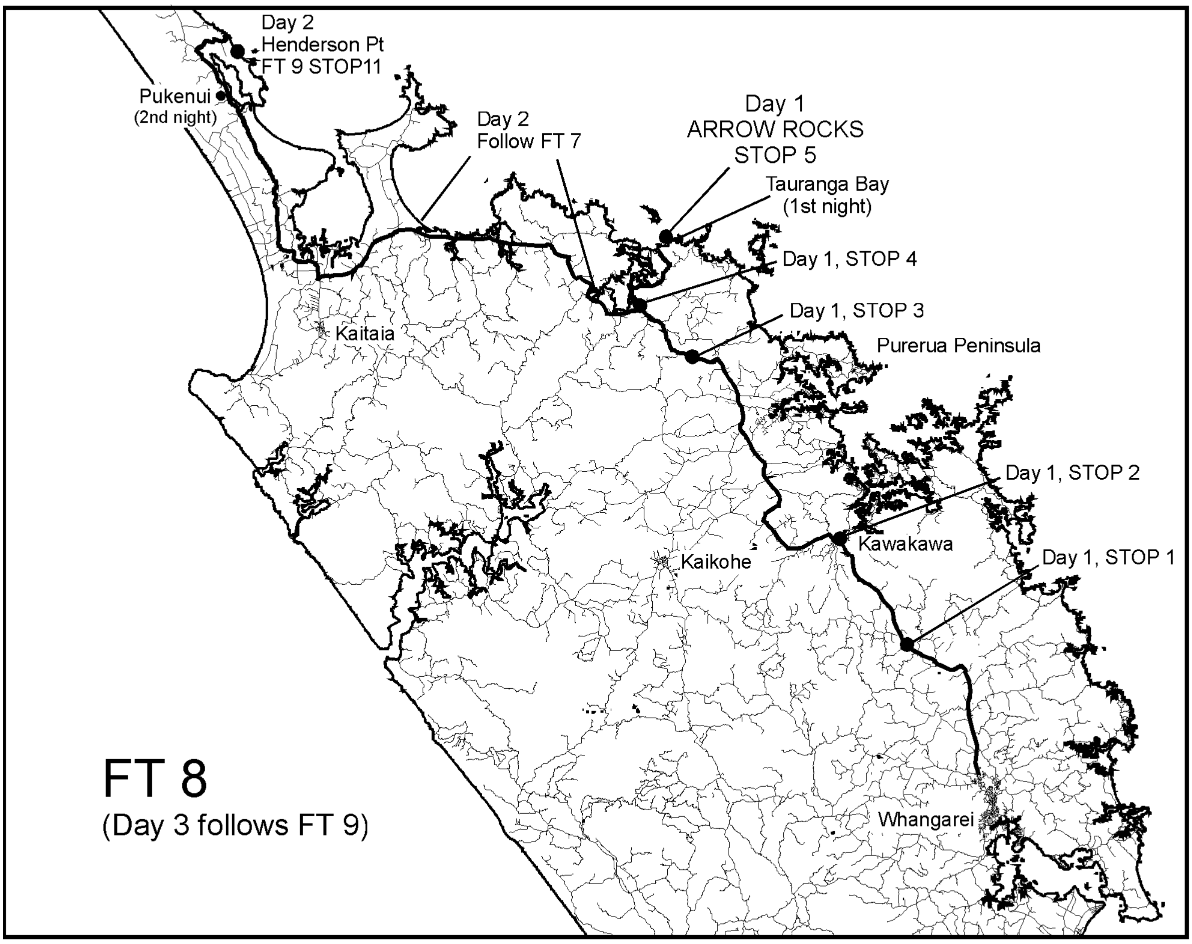

Fig. 8.1: Route map. Note that this trip will use some of the stops of FT 7and will merge with FT 9

Field Trip 8

Northland from the bottom up: P/Tr boundary to allochthon

Bernhard Spörli and Yoshiaki Aita

Post conference fieldtrips leave from The Quarterdeck (formerly Valentines) carpark, 56 Otaika Road at 8AM on Friday 6th December.

DAY 1

0 km Leave The Quarterdeck (formerly Valentines) car park, 56 Otaika Road, Whangarei 8am

Whangarei – Kawakawa

16 km **Wilsonville Quarry** (visited in FT 3-5), Mt Hikurangi Miocene volcanics in the background to the SW. The road (Highway 1) runs N -S approximately along the foot of **Waipapa greywacke hills to the east**, which dip under the swamp- covered flat land. Some of the hills to the W are also greywacke (overlain by Allochthon), part of a **system of three basement blocks** stepping down to the west. Isaac (1985) tested the hypothesis that if you drill through allochthon you eventually should find autochthonous coal measures. The coal measures were there, but no viable coal! The fault blocks mentioned above must have been already present during coal deposition as they appear to affect the distribution of mineable coal.

22 km Whakapara. Highway 1 now runs NW-SE. **Pass right-hand turnoff to beaches of the East Coast** (e.g. Helena Bay, Cape Brett, Russell). This road rises up to the “peneplain “ on the eastern greywacke block, which is cut by Pliocene rhyolite domes and covered by extensive Pleistocene intraplate lava flows, all associated with mineralised (Ag, Au, Hg) sinters in lake beds (Hampton 2002).

27 km Waiotu : Highway 1 cuts through the **greywackes of the middle of the three greywacke blocks**.

31 km Hukerenui Pub

32 km Relatively fresh road-cut of **folded multicoloured siltstones and mudstones** of the Northland allochthon on the left

38 km Towai, then

39 km pass turnoff right to **Ruapekapeka**, site of a historic battle between Maori and Pakeha (Dec.1845/Jan. 1846) involving the famous Hone Heke

The road winds through steep **hills underlain by Northland Allochthon rocks**, mainly siliceous mudstones of the late Cretaceous Whangai Formation (in part the Ngatuturi Claystone of older authors).

41 km **STOP 1**

In good weather there should be **spectacular views west**, down into a limestone-dominated area of Northland Allochthon, with the large jagged massifs of the **Tangihua ophiolites** (especially the Tangihua and Mangakahia massifs) looming above them to the west.

43 km pass left-hand turnoff to **Motatau and Opahi** (a road sign that contains two geologically significant names: Motatau complex and the now obsolete Opahi Group of Kear and Hay, 1961)

45 km **NW trending greywacke block to the right**, descending westward under Northland Allochthon, view north to upstanding flat-topped Kawakawa block, upthrown on the **NNE-SSW trending Kawakawa fault**, a major regional structure.

51 km **Kawiti Glow worm caves**, Waiomio, on the right, in the Te Kuiti Group on the westward descending greywacke block. (Kawiti was the chief who actually constructed the defenses at Ruapekapeka). In the 19th century, this area used to be an important coal mining centre. Here

the abnormal superposition of Cretaceous rocks on Tertiary sequences (the **Kawakawa thrust**) was recognised before the concept of the Northland Allochthon was accepted. The superposition has been confirmed by drilling (Isaac and Grieve, 1989).

53 km **Greywacke quarry** to the right with onlapping Tertiary on the right.

55 km **STOP 2: KAWAKAWA**

Hundertwasser Toilets: designed by Friedenreich Hundertwasser (who in 1986 also designed an alternative NZ-Koru flag) and completed shortly after his death on the QEII in 2000. Hundertwassser's art and architecture is spread from Austria to US, Japan, Australia, NZ and many other places in the world.

Out of Kawakawa, the road turns west with **Kawakawa fault scarp** to the right. The valley bottom is formed by **basalt lavas**, which have flowed eastward from the Kaikohe volcanic field (Fig. 7.3).

61 km Highway 1 climbs up the **western end of the fault scarp**. When road-cuts were fresh, they showed allochthon rocks draped over the greywackes.

65 km The upper surface of the greywacke block is veneered with allochthon, and to the right carries some of the volcanoes of the Kaikohe field. Note the **basalt stone fences**.

68 km **Major junction, turn right onto Highway 10** (Highway 1 goes NW to Lake Omapere and toward the head of the Hokianga Harbour. Ngawha Geothermal field (the object of FT6) lies to the south of Lake Omapere).

75 km **Puketona junction**, continue straight through on Highway 10 (road to the right goes to Paihia and Waitangi)

We now cross a large plateau underlain by the **Kerikeri basalts**, giving rise to the fertile soils of this horticultural centre.

82 km Right hand turnoff to Kerikeri township --- **continue straight ahead**.

88 km Right hand turnoff to **Purerua Peninsula**: site of abnormal silica-rich clastic Waipapa sequence (Meshesha and Black , 1989) --- **continue straight ahead**.

98 km view to the right of Purerua Peninsula with its rather high and rugged relief.

100 km The road now follows **peneplain surface on a greywacke block**, still covered by some basalt (clay pits!)

101 km Matauri Bay turnoff

102 km **STOP 3**

Orotere pinnacle (in sharp curve of road) signals first exposure of **Miocene Wairakau Volcanics of the Whangaroa region** (see detailed comment in FT 7 guide, Fig. 7.7). Here the volcanics are essentially on autochthonous greywacke basement and its Tertiary cover, however Northland Allochthon lies in the depression to the west.

108 km **Kaeo township**

112 km **Whangaroa turnoff --go straight ahead** (Highway 10 turns left across bridge.)
The massive block in the distance to the left (to the west) is **Taratara**, another remnant of the Miocene (laharic) volcanics

The road skirts para-autochthonous greensands of the Ruatangata Fm (Fig. 7.5).

STOP 4: (optional) (=FT 7, Stop 9).

Intertidal cliff exposures on sharp corner of middle Eocene (Ab) glauconitic **Ruatangata Sandstone** (para-autochthonous sheet)

St Paul's Rock above Whangaroa is another outlier of Wairakau Volcanics (good walking track for a good view!)

116 km Turn left to Whangaroa Township

119 km Whangaroa: Park vehicles at wharf just east of Game Fish Club.

STOP 4: 12:30pm: Boat trip to Arrow Rocks with the Kuri

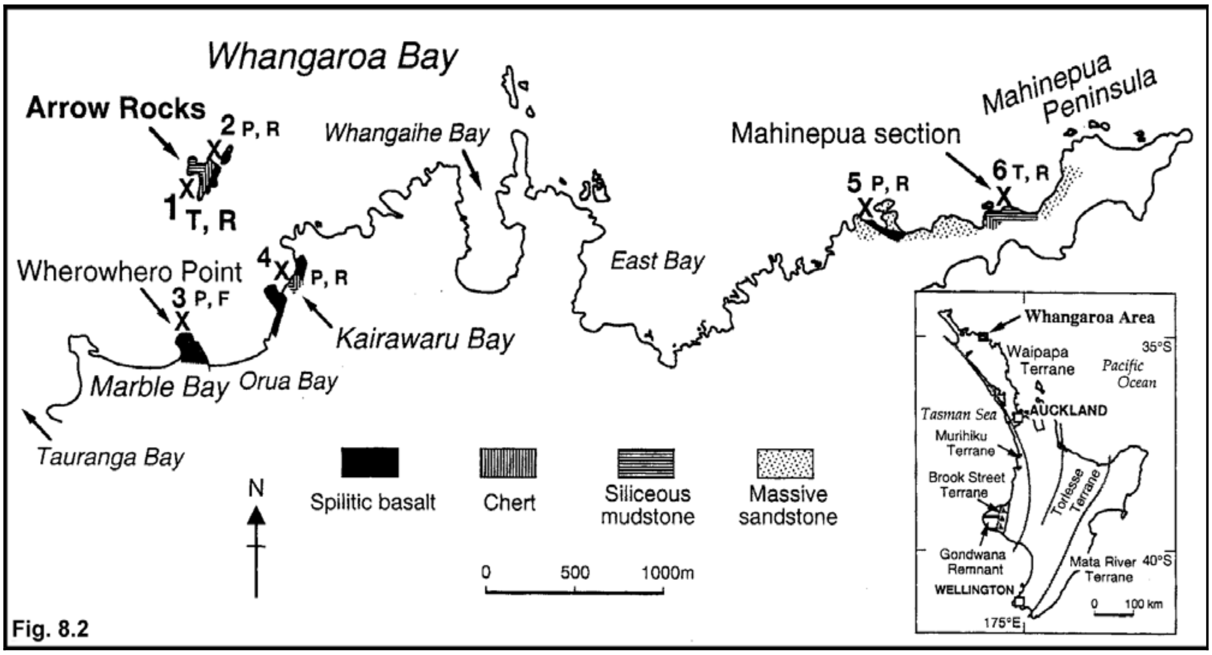

Fig. 8.2: Localities of Arrow Rocks and other fossil occurrences in the Whangaroa area (Takemura et al. 2002 and modified from Takemura et al., 1998). X: fossil localities, P: Permian, T: Triassic, F: fusulinids, R: radiolarians. Numbers indicate the lithology in which the fossils occur: 1: maroon siliceous mudstones at Arrow Rocks (this study), 2: limestone lens and bedded chert at Arrow Rocks (Takemura et al., 1998; Takemura et al. 1999), 3: fusulinid limestone at Wherowhero Point (Leven & Grant-Mackie 1997), 4: radiolarian chert (Caridroit & Ferrière 1988; Adachi 1988), 5: limestone and chert at the west end of Mahinepua Peninsula (Takemura et al. 1998), 6: phosphatic nodules within green siliceous mudstone at Mahinepua Peninsula (Aita & Bragin 1999). Inset: Index map of the North Island, New Zealand, showing the distribution of terranes (after Aita & Spörli 1992) and the location of the Whangaroa area (from Takemura et al. 1998).

Introduction

Arrow Rocks (Oruatemanu) provides a unique opportunity to study a chert- dominated ocean floor sequence spanning the catastrophic **Permian/Triassic boundary event**. While we are not yet able to put our finger on the actual millimetre interval marking the P/T boundary, by using stratigraphy and micropaleontology, we have been able to approach it sufficiently from below and above so that an interesting view of this crucial interval in geological history can be obtained.

The sequence is part of the Waipapa basement terrane (Spörli, 1978) which was accreted onto Gondwana in the late Mesozoic. **Subduction zone tectonics** caused ocean floor sequences (basalts, limestones cherts and green mudstones) of the Phoenix plate and overlying terrigenous clastics (greywackes) derived from Gondwana to be **structurally imbricated**, so that they now form multiply stacked slices several hundred metres to a km or so thick (Spörli and Gregory, 1981, Spörli et al.1989) . The stack was metamorphosed and further deformed in the accretionary prism on its way back to the surface and during the complex Cenozoic tectonics suffered by Northland.

Recently Black (1994) has suggested a new subdivision of the Waipapa terrane into units which are consistent with tectono-stratigraphic terranes of the South Island. According to this scheme the rocks we will be studying are part of the Bay of Islands-Northern Waipapa unit which can be correlated with the Rakaia sub-terrane (Torlesse) of the South Island.

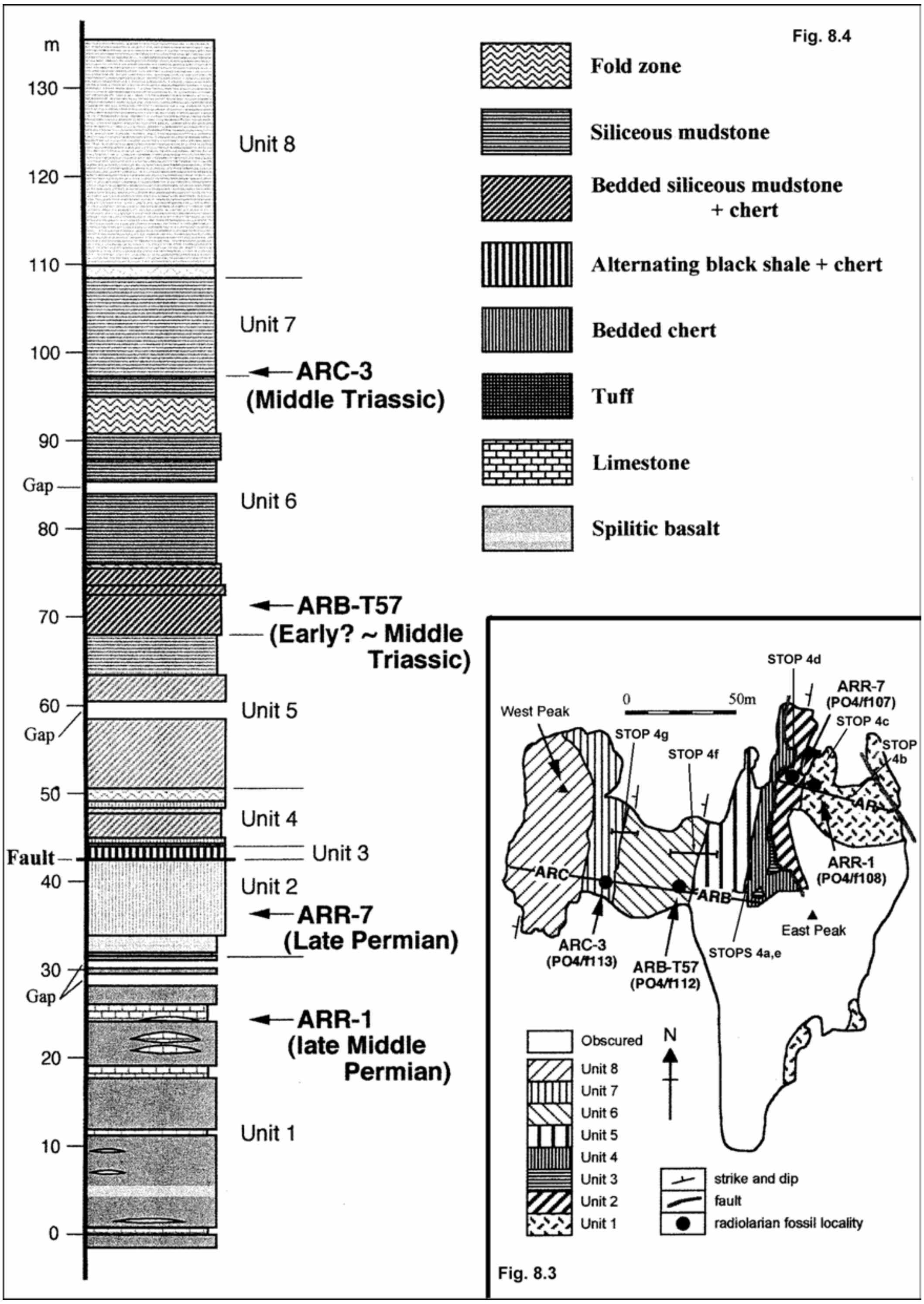

Fig. 8.3: Simplified geological map of Arrow Rocks, indicating fossil localities relevant to this paper (modified from Takemura et al. 2002) . ARR, ARB and ARC denote lines of measured section for the column presented in Fig. 8.3 and accurate location of horizons sampled for radiolarians. Area shown as "obscured" is either covered by sand and gravel (on the shore) or by dense vegetation (on the slopes of "East Peak"). Note the prevailing westerly dip. For lithological description of the units see Fig.8.4.

Fig. 8.4: Simplified geologic column of Arrow Rocks (Takemura et al 2002 and modified from Takemura et al., 1998), showing units mapped (see Fig. 8.2) and position of faunas described.

Lithology

The stratigraphic sequence youngs from E to W across the island (Fig.8.3) and **has been subdivided into 8 units** (Takemura et al.2002). Basalts with associated with scattered sedimentary layers and lenses (limestone, marble, calcareous clastics and shale, chert) outcrop in the east (unit 1). The rest of the island is underlain by thin - bedded siliceous sediments including a prominent sequence of red cherts (unit 4) and a unit with maroon and green cherts (unit 6).The highest sequence (unit 8) consists of brown weathering siliceous clastics intercalated with green mudstones, which may indicate an increasing terrigenous input. **True greywackes must lay further out west** under the sea and can be studied on-land at Tauranga Bay.

The P/T boundary beds (units 2 and 3) strike through the highest point (`East Peak`) and form the most prominent north and south points of the Island. Thin black mudstone and chert horizons are typical,but some units have unfortunately been recrystallised by a yet unknown process.

Structure

Considering the structural disruption normal for the Waipapa terrane (e.g. Spörli 1978) with its mélanges, broken formation and superposed folding, it is astonishing to have available a **practically homoclinal sequence** extending over such a large stratigraphic interval with the beds dipping uniformly to WNW. The cause for this lack of disruption is yet unknown, but the effects of the general deformation of the Waipapa can nevertheless be detected (Spörli et al 1999) and include several phases of **folding which cause local repetitions** of the sequence. A prominent set of **bedding-parallel extensional faults** causes excision of beds.

Paleontology

The four Permian fossil assemblages previously reported from the Whangaroa area (Fig. 8.2) are: 1. fusulinids from limestone lenses at Wherowhero Point (Hornibrook 1951; Leven & Grant-Mackie 1997); 2. radiolarians from bedded cherts at Kairawaru Bay (Adachi 1988; Caridroit & Ferrière 1988); 3. radiolarians from a limestone lens and chert near Mahinepua Peninsula (Takemura et al. 1998), and 4. radiolarians from a limestone lens and bedded chert at Arrow Rocks (Takemura et al. 1998; Takemura et al. 1999). Takemura et al. (1998) concluded that in the ocean floor sequence exposed in the Whangaroa area, basalts with occasional limestone lenses are Middle Permian whereas overlying bedded cherts were deposited in the Late Permian.

The radiolarian assemblages reported from Arrow Rocks until 2002 (Takemura et al. 2002) indicate Early or Middle Triassic and Middle Triassic (Anisian) ages for maroon siliceous mudstones in the upper part of the section. Between strata of known Permian and Triassic age there is a thin potential Permian/Triassic boundary interval consisting of alternating black shale and grey chert. Radiolarian paleogeography indicates that the Arrow Rocks sequence experienced long distance plate tectonic displacement from a position of relatively low latitude in the Middle Permian and to a high latitude in mid- Triassic time.

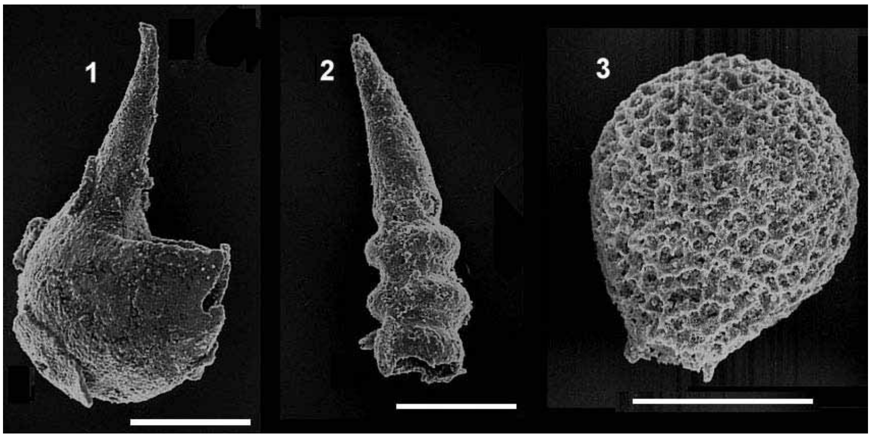

Fig. 8.5: Permian/Triassic radiolarians from Arrow Rocks: 1: *Follicucullus sphaericus* (Mid to late Permian, low latitude? from unit 1, ARR-1) 2: *Follicucullus whangaroaensis* (Mid to late Permian, low latitude? from unit 1, ARR-1) 3: *Glomeropyle* sp. (Early to middle Triassic , high latitude, from unit 6 ARB-T57)

Geology at the main stops

The boat will take us to the mouth of Whangaroa Harbour, cut into the Miocene volco-rudites of the Wairakau Volcanic Centre (see FT7) which unconformably overlie the basement rocks we are about to study. Note the conical island (Red Island) in the harbour, site of the **torching of the "Boyd" in 1809** and a short distance to the east, **Kingfisher Lodge, of Zane Grey fame**. As we head for the open sea, Stephensons Island straight ahead (another site of current studies of ocean floor sequences by your guides). Next promontory to the north: Early Tertiary Tangihua Volcanics near Taupo Bay, overthrust from the east in the late Oligocene/Early Miocene.

STOP 4a

Cave: Boundary between units 3 (chert and black mudstone) and 4 (red cherts) marked by a prominent green tuff bed, which can be traced considerable distance N and S. Note interference of steeply plunging dextral folds, with subhorizontal, E-verging folds. Spectacular exposure of kink folds.
PLEASE PROCEED STRAIGHT TO THE NEXT STOP. Explanations will be given on the way back.

STOP 4b

Permian limestone in lavas: Note coarse bioclastic layer. Both top and bottom of the limestone are altered (baking or metamorphic effect?). Left end of exposure has a fold verging to the north.

STOP 4c

Red mudstone: Is calcareous and mostly very massive, but shows some bedding at the seaward end (N). Is in close contact with underlying mafic igneous rocks, together with which it forms a faulted dextral fold. In the gut to the east it is in contact with another, tabular igneous body, which in turn is overlain by a section of green cherts., which are adjacent to the P/T ridge Note the well developed calcite en echelon tension gashes.

STOP 4d

View of P/T ridge: Here we can again pick up the green tuff at the unit 3/4 boundary, but we note considerable bedding parallel disruption and (amongst others) a prominent west verging fold. Note the yellow to pale grey colour of some of the cherts on the ridge, indicating various degrees of recrystallisation. **Looking towards 'East Peak'**: The red cherts of unit 4, which we can trace to our right, continue up to the peak but are affected by at least two phases of folds. There is also excision of part of the section by a steep, north -south trending extensional fault. (*Here you may get involved in a discussion of the stratigraphic problems amongst the people working here. We are still uncertain how the individual sections go on top of each other. Excision and lateral transport of units is the issue*.)

STOP 4e

Grey chert shear zone (BRIEF STOP!): Forms the top of Unit 4 and shows dextral folding, followed by dextral extensional faulting, with an almost purely strike slip vector of movement. Is the grey colour primary or due to the deformation?

STOP 4f

Maroon sequence (Units 5 and 6): This part of the section is still relatively monoclinal, but there are scattered asymmetric folds. These, although thickening the sequence somewhat, do not affect the general westward younging. Stratigraphy can be traced by thin (1-3cm) layers of green chert and brown manganese carbonate.

STOP 4g

Unit 6/7 fold zone: although it appears hideously complex, overall has the structure of an asymmetric, east - verging fold, that contains earlier structures (steeply plunging folds and bedding parallel dextral shears) Some of the complexity is apparent only, as the shore platform cuts the structure at a low angle to its axis. There are also a number of late cross cutting faults.

DISCUSSION
The apparently simple homoclinal structure is disturbed by folding and thrusting. We have little difficulty with these structures. Because of repetition they cause and the availability of many lithological markers, they can be easily accounted for in most cases, but probably still have caused us to overestimate some thicknesses. However, there have also been at least two phases of extensional faulting involving bedding - parallel shear. Since these tend to separate markers, it is more difficult to fully work out their effect on the stratigraphic sequence. They are in part the reason why we have not been able to track down the actual bed which records the P/T event.

Pick-up by Kuri 5:30pm

Sail back to Whangaroa, pick up vehicles (~ 6:30pm)

Drive back to **junction with road to Kaeo** (121 km). Turn left to Tauranga Bay. We are still driving on autochthonous sediments which overlie greywacke basement to the right, but this is overlain by various allochthon lithologies on our left. The high hill ahead are Miocene volcanics.

129 km **T-junction**. Turn left towards Tauranga Bay. About at 131km, ridge of Miocene volcanicaniclastics crosses the road

132 km **Tauranga Bay Motel**

8pm BBQ dinner at Motorcamp

DAY 2

8 am leave Tauranga Bay.

WE WILL BE FOLLOWING FIELD TRIP FT7 TO THEIR STOP 16 (Price's Waipawa Black Shale Quarry). Use FT7 guide book for this section! Also see FT 9 Stop 2.

64 km 11 am leave Price's Waipawa black shale quarry. The road skirts a large turtle-shaped dome of parautochthonous lower Tertiary sediments to the south.

80 km **Awanui:** make final descent into the sand-dune county of the northernmost peninsula of New Zealand. Turn right onto Cape Reinga road, pass Rangaunu Harbour in the distance to the right, with Rangiputa promontory at its entrance and the conical hill of Puheke to the right with Karikari Peninsula in the background.

115 km **Pukenui**, Mount Camel to the right.

122 km Turn right to **Henderson Point**

12 - 1pm Lunch

Mount Camel terrane rocks **Henderson Point: we will be following FT9 Stop 11**

Stay the night at Pukenui Lodge

DAY 3

Follow field trip FT9 : Pukenui -Auckland

Appendix

Supplementary excursion: Marble Bay to Kairawaru Bay (east of Tauranga Bay)

This excursion is an **optional evening trip for FT7 participants** and is **a fallback for field trip FT 8** in case Arrow Rocks is not accessible.

Access

Non-tide dependent: Go back south along Tauranga Bay road, cross bridge and immediately turn left. Follow track across Te Anina Point promontory (Fig. 8.6)

Tide dependent: Go north to beach, turn right go towards Te Anina Point, wade creek go around shore platform

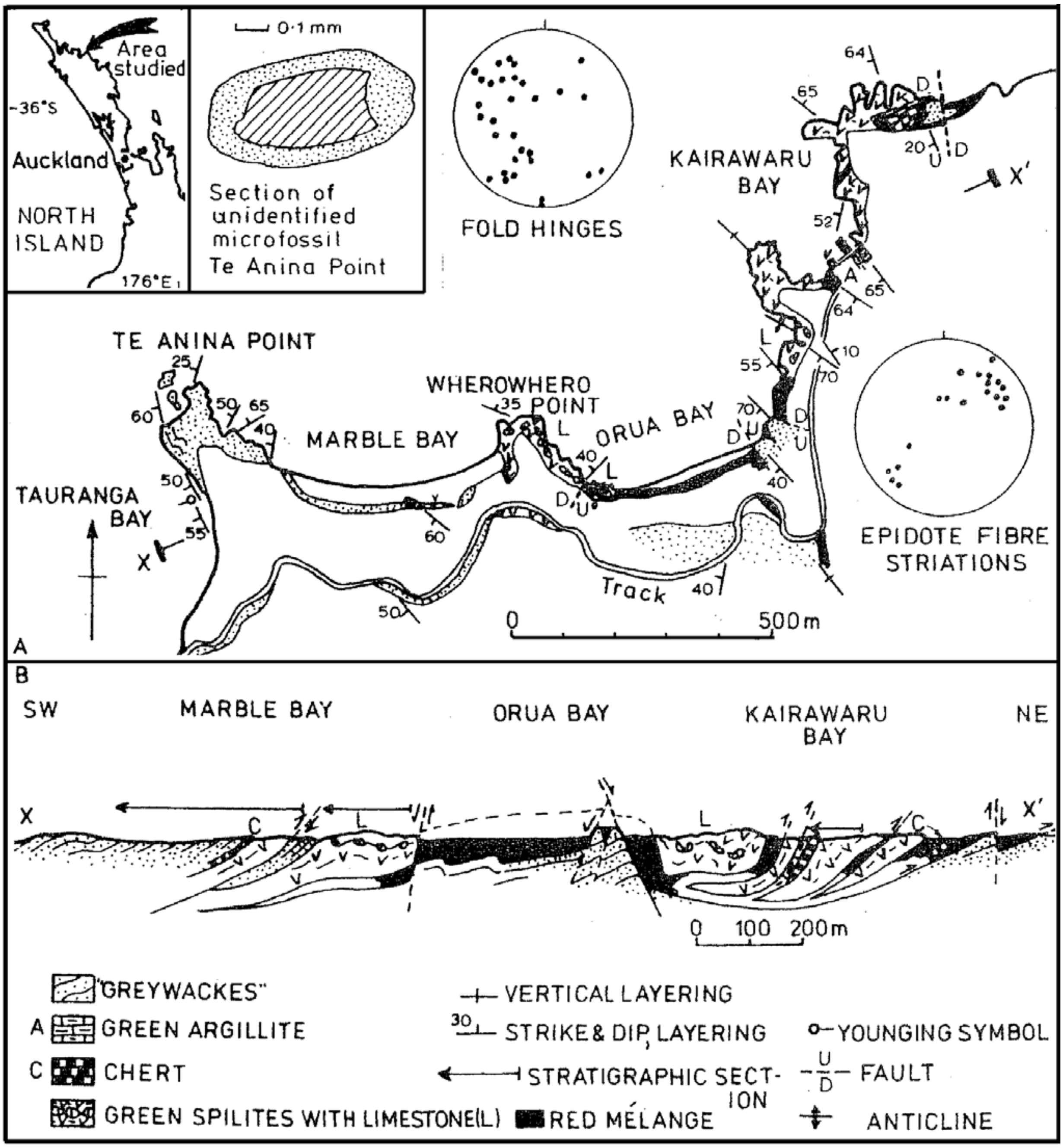

Fig.8.6 Geological map of the Marble Bay area. Fold hinges and striations are shown on lower hemisphere equal area nets. Younging symbol: line points to top of beds. B. Schematic section, projected onto line XX' in A. Deeper parts of section are entirely speculative.

after Spörli and Gregory (1981)

Marble Bay:
West end exposes **terrigenous clastics** (greywackes) dipping and younging westward. Age unknown. Note unidentified fossil found (Fig 8.6 top left).

In the back of the beach there is (if the exposure is still preserved) **a contact of greywacke with a layer of volcanics overlain by chert**. This marks the bottom of the westernmost (highest) of the accretionary slices in this area (see cross-section in Fig. 8.6).

Wherowhero Point
Volcanics and limestones (**marble**) are well exposed in this headland. Note transitions from limestone to white marble. Intercalations of carbonate in the volcanics. Occasional red and green tuffaceous mudstones. Is marble contact metamorphosed by lava?

Note prominent **epidote veins**, some with well-developed striations.
Some of the large marble/limestone pods on the eastern side of the point have **tails of conglomerate/breccia**, indicating that they may have slid into place.

The stack of (deflated?) boulders on the east side of the peninsula have yielded most of the **fusulinid faunas** (**and other fossils**) indicating warm shallow water and a Permian age. (Note that at that time, the Gondwanaland portion of New Zealand was at the South Pole!)

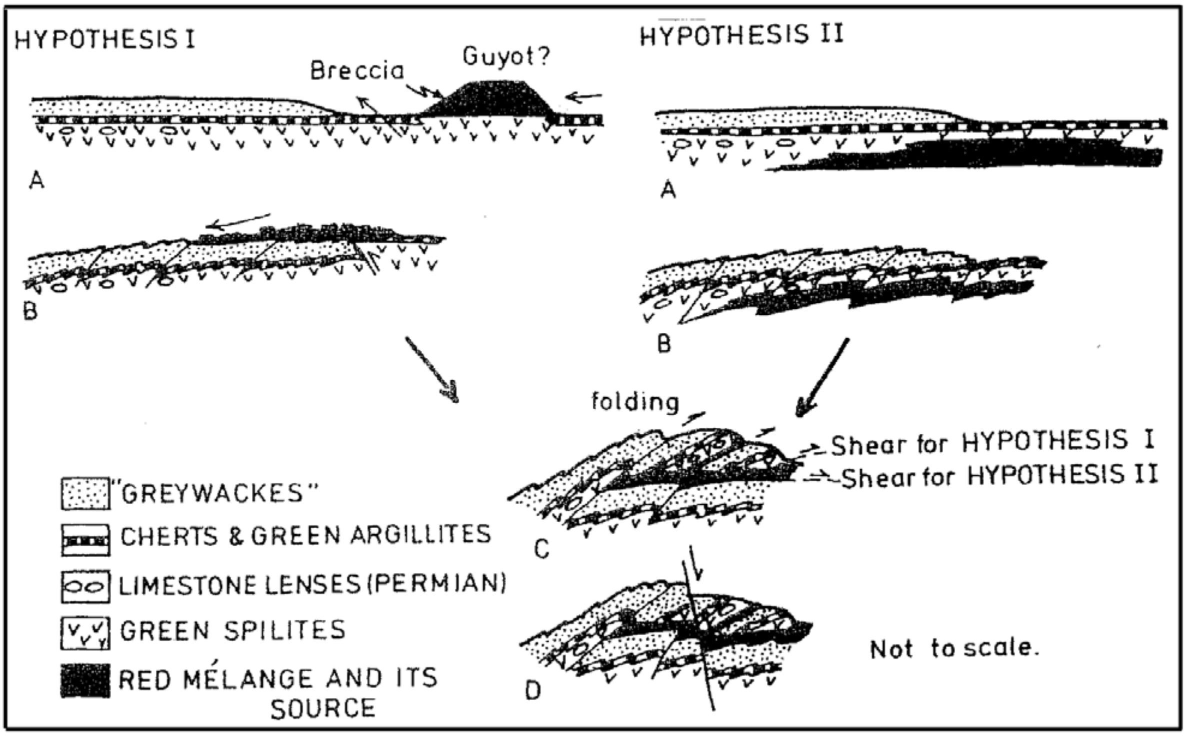

Fig.8.7-Hypothetical development of structure near Marble Bay during under-thrusting and imbrication of uppermost oceanic crust in a subduction zone along the Gondwana margin. I: Both top and bottom contacts of red mélange are shear zones. II: Shear along base of red mélange, top contact stratigraphic. For stages A and B in both hypotheses, the join between converging plates (trench?) can be visualized to the left of the diagram; in subsequent stages the material has been transferred to the Gondwana side. Note that direction of folding and imbrication in stage B may be at right angles to that in stage C.
after Spörli and Gregory (1981)

Orua Bay
The main slope at the back of the beach is occupied by **red mélange**: slivers (lozenges) of various rock types (chert, limestone, marble green argillite, volcanics etc.) included in red mudstone matrix. Is this a true tectonic mélange or is it due to gravitational collapse? (Or are they a combination of both?)

Note that the geochemical work of Jennings (1991) has shown that the ocean floor volcanics of the area are of **intraplate origin**, therefore some of the volcanoes could have been substantial edifices, which are now known to be **prone to large scale submarine slumping** (favouring hypothesis I in Fig. 8.7). Such slumping could explain the association of **shallow water faunas** (limestones) with **coeval deep-water faunas** (radiolarian cherts, see below).

Red mélange type rocks are also known from Arrow Rocks, Stephenson's Island (unpublished data KBS) and have been reported by Moore (1981) from Okahu Island in the Bay of Islands.
Somewhat east of the middle of the bay there is an upstanding mass of **greywacke**, brought up from below as a **horst by late faulting** (see Fig. 8.6, map and cross-section)

The headland at the eastern end exposes well developed **pillow lavas**. This is interpreted as a 'klippe'-like part of an upper slice floating on red mélange (see Fig. 8.6 cross section).

Kairawaru Bay
In the middle of the bay is the **Permian chert location** of Caridroit and Ferrière (1988).

In this area there are some well developed **calc-mylonites** with shear sense indicators.

Eastern end of bay is occupied by another, **deeper slice of volcanics** (see Fig. 8.6 cross section).

Headland north of Kairawaru Bay

The outcrop is complicated by cross faulting, but the **easternmost chert** (exposed in an east-facing cliff) is remarkable that it is **cut by an oblique basalt sill**. This indicates that volcanic activity was coeval with chert deposition on this ocean floor, which can again be most easily envisaged in an environment of ocean island volcanism.

Interpretation
This exposure clearly demonstrates the **imbricate structure of the Waipapa Terrane**. The **Permian ocean floor**, decorated with intra-plate (ocean island) volcanoes moved from **equatorial regions** of Panthalassa south to the **New Zealand Gondwana margin** (**at or near the South Pole**) getting covered with terrigenous clastics (greywackes) as it approached the super-continent. In the subduction system at the edge of Gondwanaland the top of the oceanic crust and the overlying greywackes were successively sliced off to be stacked in an **accretionary prism**. In the Marble Bay to Kairawaru section we can see **at least 6 such slices.** This is the process by which new crust is added to a continent!

Folding in the accretionary stack is not uni-directional. As the stereonet of fold hinges in Fig. 8.6 (map) shows, there is interference between NW -SE, and SW-trending folds (note that the epidote fibre striations are compatible only with the former). This may either indicate refolding after accretion or complexities caused by oblique subduction.