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FIELD TRIP GUIDES

Edited by
Vicki Smith & Hugh Grenfell

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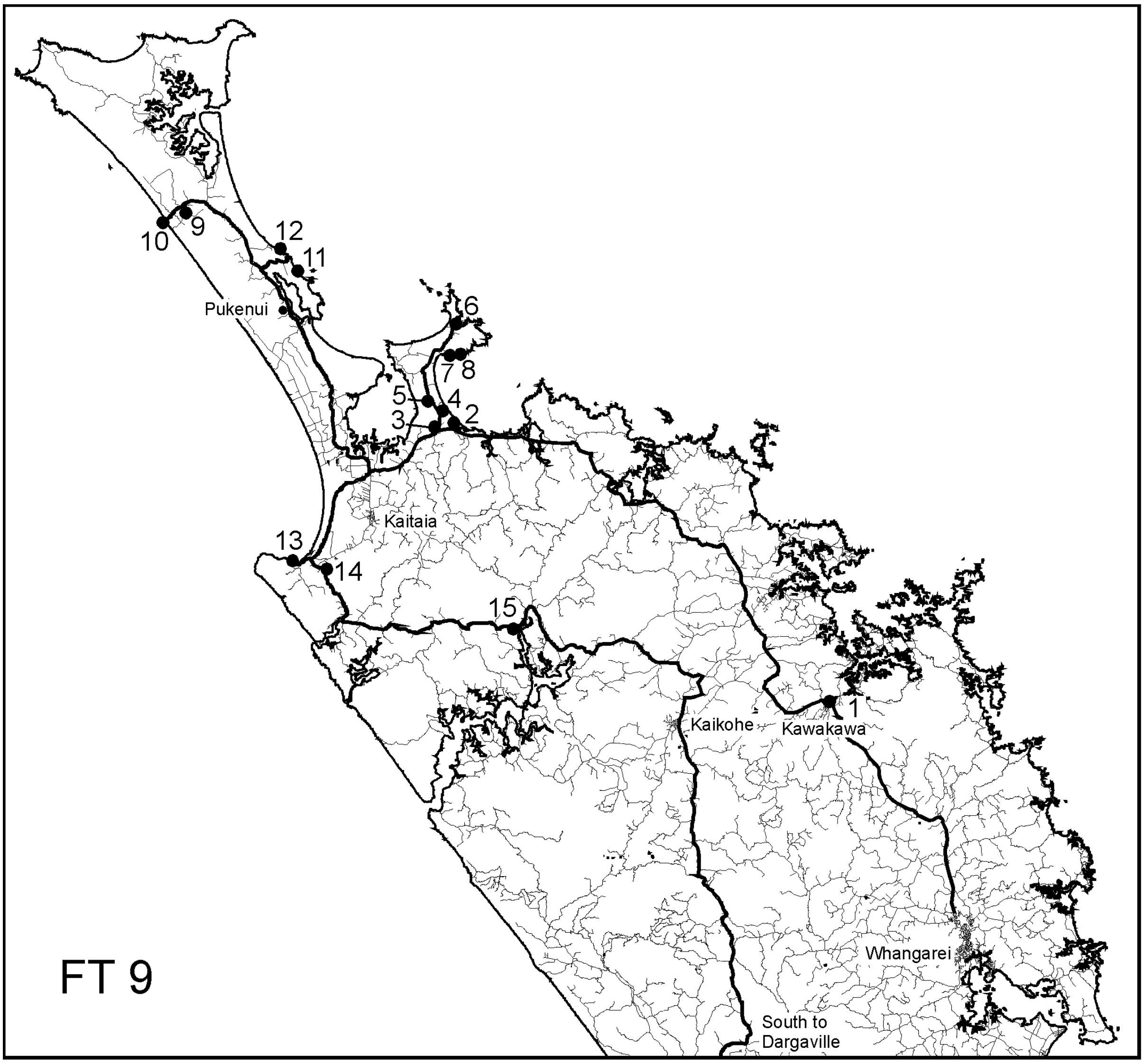


Route guide for field trip 9.

Field Trip 9

Geological Gems of the Far North

Philippa Black and Murray Gregory

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

The following notes should be read to provide background information to the stops for that part of this field excursion that is in Northland's Far North.

Notes on the Quaternary of Karikari and Aupouri Peninsulas

During Quaternary times, extensive siliciclastic aeolian dune-field and coastal sand accumulation lead to the development of two large tombolos. Through Aupouri and Karikari Peninsulas, these have permanently linked an archipelago of small and once-upstanding, erosionally resistant islands of Mt Camel Terrane and Cretaceous pillow lava/sedimentary complexes and Miocene arc intrusives, to the New Zealand mainland. The largest of these are the North Cape massif, Mount Camel and the Cape Karikari blocks, but there are also several smaller ones, e.g. the Bluff on Ninety Beach, Paxton and Henderson Points on Great Exhibition Bay. Three possible sources for this sand have been suggested. Of these the most important and favoured is northwards long-shore dispersal from the Egmont volcanics and the Taupo Volcanic Zone when an ancestral Waikato River flowed into the Tasman Sea (Ricketts, 1975; 1979). This source has been supplemented by admixing with material derived from Mesozoic basement lithologies (Stokes and Nelson, 1991). The possibility that silica-rich (95 - 99%) sands of Kotoka Spit, and southwards along eastern shores to Cape Karikari, could have been derived locally from heavily leached and podzolised soils was explored by Schofield (1970) but has been discounted (Stewart et al., 1986). Minor chromite in these deposits suggest some supply from local ultramafics. Rhyolitic volcanism on Coromandel, Great Barrier Island and elsewhere are potential sources that warrant further attention (Osborne and Nichol, 2002).

Hicks (1975) recognised several basic dune types. Those of interest at this time are the younger and older fore-dunes, which more or less parallel modern beach development, and stabilised parabolic dunes. The latter are older, strongly aligned, and have advanced northeastwards from the west (Hicks, 1975, Collins, 1995). These Holocene deposits unconformably sit on a surface of subdued relief that defines the central core or spine to Aupouri and Karikari Peninsulas. Where exposures are adequate, consolidated or lithified aeolian and water-laid sandstones can be recognised in this Pleistocene sequence. Paleosols are well developed in these deposits, as are lenses and sheets of peaty sands passing into true peats and lignites. Case-hardened, ferricrete (limonitic and humic) cemented hard-pans and crusts often concordant with erosional surfaces are common. These can be related to water-table movements followed by later exhumation that accompanied deflationary episodes. Terrace flights cut into and across these "coffee rocks" (see Fig 9.1) have been related to Quaternary eustatic sea-level movements (Goldie, 1975; Ricketts, 1975, Hicks, 1975, 1983). However, uplift rates of 20-35mm/yr given by the above authors are difficult to reconcile with known sea-level still-stands at 80,000 and 105,000 yrs BP. By now, these terraces should have risen to heights substantially above their present elevations (Osborne and Nichol, 2002).

Trace fossils produced through the rooting activities of plants as well as invertebrate burrowing and boring are conspicuous in Karikari parabolic dunes and pre-parabolic "terrace" exposures at Henderson Bay. It is often difficult to distinguish between phyto- and zooturbation in mottled and composite ichnofabrics. A rich avifauna is also associated with these deposits (Millener, 1981). Bones of many extinct or threatened species (moa, kiwi, kakapo and takahe) are present, together with those of the tuatara and kiore. Semi-consolidated, charcoal-stained sands, fire hearths and compacted shell middens are common in dunes close to the coast.

The dunes of Aupouri and Karikari Peninsulas were once heavily forested, with kauri dominating, and for which numerous radiocarbon dates between 40,000 and 20,000 yrs BP have been obtained. The demise of this forest cover may be related to podzolisation, heavy leaching and impervious iron-pan development, with ground conditions becoming increasingly boggy. Kauri prefers well-drained soils. Thus in the longer term, the very success of Kauri, may ultimately have doomed it to self- destruction (Osborne and Nichol, 2002). Later human intervention accelerated deforestation. This initiated a period of dune destabilisation and development of a broad coastal deflation zone along the west coast of Aupouri Peninsula. Modern pine plantations have largely immobilized many advancing dune sheets.

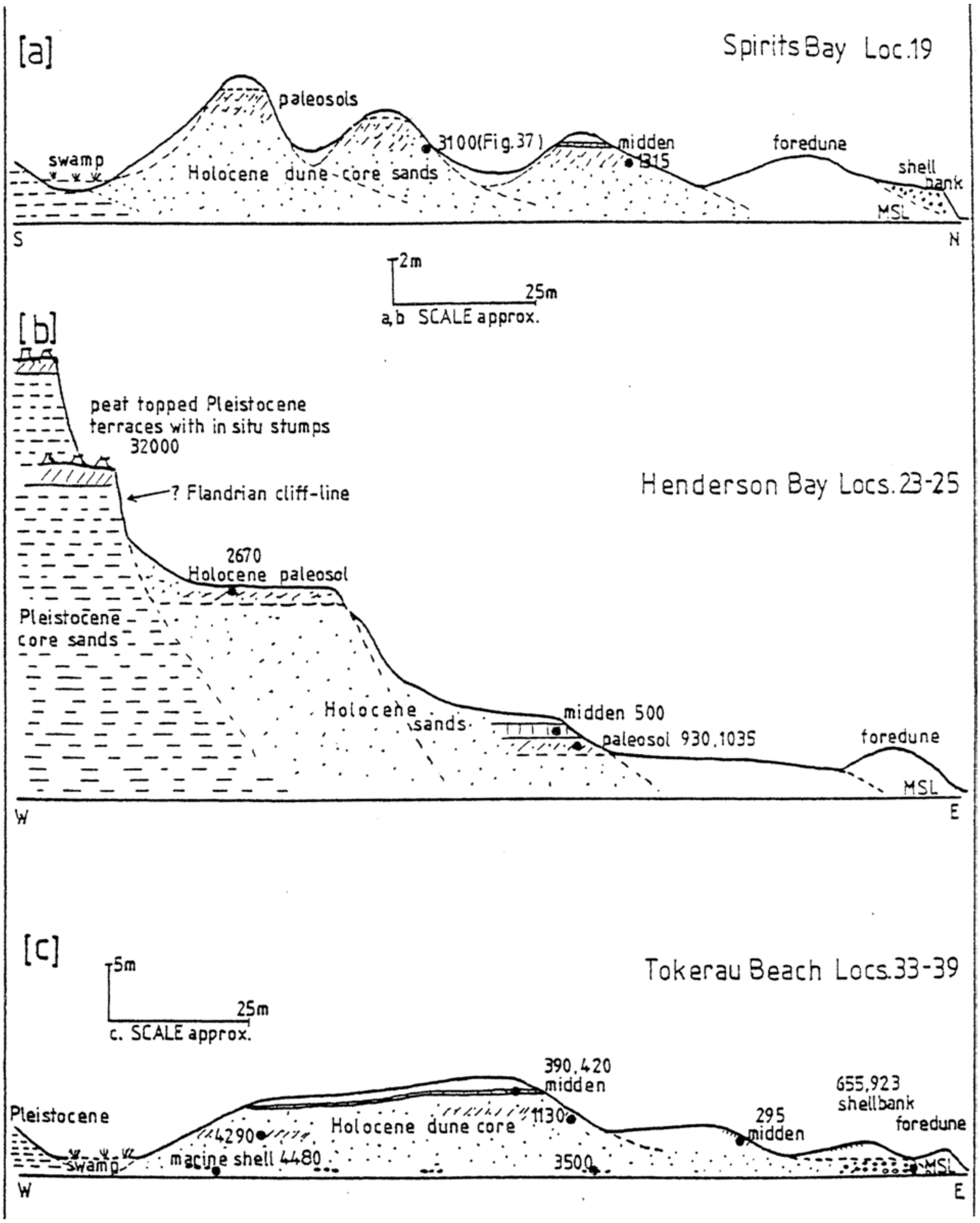


Fig. 9.1: Schematic cross-sections of dunes at Spirits Bay, Henderson Bay and Tokerau Beach (from Millener, 1981).

Sea rafted Loisels Pumice is common along these northern shores (Wellman, 1962) – either as layers within fore dunes or as lags between them, and up to 200m inland from the present beach (Millener, 1981). Claimed ages of these deposits range between *c* 1200 yrs BP and *c* 590 yrs BP and have been the subject of continuing debate (Osborne *et al.,* 1991; Shane and Gregory, 1999). Beached pumice clasts are of similar character wherever found. Visual differences do not necessarily signify geochemical ones. Because of compositional diversity (SiO_2 63-78 wt%) any so-called "Loisels Pumice units" are not necessarily isochronous, either locally or regionally. Osborne et al (1991) and Shane and Gregory (1999) have stressed the need for caution when using Loisels Pumice for correlation purposes.

Notes on the Miocene Karikari Plutonic Complex and associated dike swarm

The Karikari plutonics, part of the Miocene Northland volcanic arc association, are unique in that they are intruded into Cretaceous – Early Tertiary Mt Camel terrane sediments and volcanics rather than Waipapa terrane, as is the case elsewhere in Northland.

Ruddock (1990) recognised that the Karikari Plutonic Complex was composed of two distinct plutonic phases and a dike swarm. All phases of the complex were intruded over a short time period, estimated from KAr dates of whole rock and biotite and hornblende separates to be 18.3 to 22.9 Ma.

The older pluton, which is dominantly diorite to quartz monzonite in composition, is exposed over an area of at least 12 x 5 km in the northern and western part of Karikari Peninsula. Contacts of the older pluton with the county rocks are exposed only in the Matai Bay area (central part of the peninsula) in a complex mixed roof pendant zone. The older pluton is texturally variable, ranging from medium grained equigranular to strongly porphyritic, shows evidence of cumulate crystallisation and has a multiphase structural and dike intrusion history.

The younger pluton, has approximate dimensions 4.5 x 1.5 km, and forms the southeastern part of the intrusive complex. The younger pluton is homogeneous, quartz monzonite to adamellite in composition. The main textural variations are close to contacts with the Mt Camel terrane country rocks, which are metamorphosed up to pyroxene hornfels facies. The last stage of this intrusive event is a hydrothermal system, with minor associated copper mineralisation, which is focused on a breccia pipe at Knuckle Point.

A dike swarm cutting the plutonic complex and the country rocks ranges from basic to felsic in composition, with dike compositions changing with time, becoming more felsic and more voluminous and also changing in intrusive direction from an earlier west – east (basaltic pyroxene andesite to andesite) to NW-SE trend (hornblende bearing andesites and dacites).

Notes on the Mt Camel Terrane

Mt Camel terrane is exposed in a series of former islands now joined to mainland New Zealand by tombolos and the Three Kings Islands (50 km NW of Cape Reinga). Mt Camel terrane rocks have no known counterparts, in terms of age or lithologies, elsewhere in New Zealand but similar rocks are known in New Caledonia. Recent oceanographic work carried out by Australian and French scientists on the Three Kings Rise and the submerged areas north of New Zealand (Mauffret *et al.*, 2001; Meffre *et al.*, 2002) record a thick sequence of sediments in the Three Kings Basin and conclude the Three Kings Ridge itself to be a Cretaceous island arc. Bernardel *et al.* (2002) have correlated the Three Kings Ridge system with the Loyalty Ridge. The Mt Camel terrane of Northland's Far North thus can be regarded as representing the only onland exposure of a submerged sedimentary basin and volcanic arc which are major tectonic features of the crust to the north of New Zealand.

The Mt Camel terrane outcrops considerably north of the northernmost exposures of the Paleozoic – Mesozoic sedimentary terranes, which form the Gondwanaland margin crust of the North Island of New Zealand. The lack of basal contact exposed in the Houhora Complex renders the terrane suspect (Isaac *et al*., 1998; Toy 2001). Some authors consider the Houhora Complex to represent an autochthonous Cretaceous ocean floor sequence (Isaac *et al*. 1994, Mortimer *et al*. 1998). A recent structural study (Toy, 2001) of the terrane suggests that deformation in the sequence is consistent with accretionary tectonics and as such is allochthonous.

Regardless of the unresolved and potentially suspect nature of the Houhora Complex, its location and age make it an important sequence in the Mid – Late Cretaceous evolution of the eastern Gondwanaland margin.

The stratigraphic succession in the Mt Camel terrane is:

Tokerau Fm: Early Cretaceous continental shelf mudstone sandstone sequence. Clastic debris in the sandstones is dominated by quartz, feldspar and biotite.

Whatuwhiwhi Fm: Late Cretaceous conglomerates, sandstone – mudstone sequence, containing abundant debris derived from the Tokerau Formation and "keratophyres" of the Houhoura Complex

Houhora Complex mafic and felsic volcanics (Rangiawhia volcanic Fm): intruded / extruded into the Tokerau and Whatuwhiwhi Fm sediments. The felsic volcanics appear to have been erupted into both the Tokerau and Whatuwhiwhi Fms and are always extensively hydrothermally altered (i.e. keratophyres). Zircons from dacitic tuffs have been dated at 104 to

131 Ma (Isaac *et al*, 1994). The mafic lavas are variably altered (spilites) and have only been observed in Tokerau Fmn, where they form sills and pillow lava complexes. Mafic intrusives at Rangiputa, believed to also be part of the Houhora Complex, have yielded a K-Ar date of 75 Ma (Law, 1984). Resolving the stratigraphic and petrogenetic relationships between the basaltic and felsic magmas is a subject of current research at the University of Auckland.

Waiari Fm: Paleocene – Eocene carbonaceous shales and black cherts; the shales contain abundant detrital muscovite.

Structural and stratigraphic studies have revealed that, except in the Whatuwhiwhi section, the Mt Camel terrane consists of a quasi- conformable sedimentary sequence ranging in age from Cretaceous to Early Tertiary. The Mt Camel terrane sediments and volcanics have all experienced the same early – mid Cenozoic deformational sequence which progresses from accretion in a westward subduction regime, to the west- and southward obduction of the Northland Allochthon, associated with sinistral strike-slip motion (Toy *et al,* 2002). Significantly, this deformational sequence predates the intrusion of the arc-related Miocene Karikari Putonics and associated andesitic dike swarm into Mt Camel terrane.

The sedimentary succession in the Mt Camel terrane has two unusual features that have widespread tectonic implications:

1. The change in sedimentary depositional environment from shallow continental shelf to a deepwater environment in the Eocene indicates some major tectonic event in the region.

2. The clastic debris, especially the micas, in the Mt Camel sediments indicates derivation from a mature continental environment and thus raises the question of a source. At present northernmost New Zealand is far from any granite or high-grade metamorphic terrane that might have provided the debris for the sediments, although schists have been dredged from the Cavalli seamount approximately 120 km northeast of Mt Camel (Mortimer *et al.,* 2002).

Notes on the pillow lava complexes of the Far North

Although early workers clearly distinguished between the Tangihua Volcanics and the pillow lava complexes of the Far North which have been mapped as either Whangakea Volcanics, Mt Camel or Houhora Volcanics (eg Hay, 1975), recent workers have tended to distinguish only pillows in the Mt Camel terrane exposed along Great Exhibition Bay and Doubtless Bay areas and have assigned the rest to the Tangihua volcanics. However, new dating and geochemical studies of the Tangihua Volcanics (Whattam *et al*, 2002) have shown a wide variation in ages of the basalts and their emplacement and that the basalts in the Mt Camel terrane are geochemically distinct from the Tangihuas. New geochemical studies of individual Far North basaltic pillow complexes and the Tangihua Volcanics (Nicholson and Black, in press) have shown several geochemically distinct from the allochthonous Tangihua Complex rocks outcropping to the south in mainland Northland and can be grouped into two associations:

1. The Houhora Complex basaltic volcanics which all have geochemistries with a clear subduction related signature and trace element and continental REE data suggesting continental arc affinities. The continental signature of the magmas supports the presence of a fragment of continental shelf material in the region during the Cretaceous as suggested by the clastic content of the sediments.

2. The basaltic pillow complexes in the Mt Camel terrane (Rangiawhia Volcanics), and in the Te Kao and Cape Reinga areas have geochemistries indicating that they are strongly arc related but and in all cases the pillow lavas are associated with extensive sedimentary sequences of Cretaceous to early Tertiary age although the structural and stratigraphic relationships between the volcanics and the sediments are poorly known.

The Tangihua Complex contains two clearly geochemically different tectonomagmatic phases: (i) an older pillow lava sequence of subalkaline tholeiites and calkalkaline lavas with geochemical signatures suggesting a suprasubduction zone setting and (ii) younger predominantly calc-alkaline basalt intrusions which have geochemistries typical of arc / back arc systems. Currently there is little evidence allowing estimation of the age difference between the two phases. Both phases predate the tectonic emplacement of the Tangihua Complex and the Northland Allochthon. Nevertheless, it is important to note the similarity between the Houhora Complex lavas and the younger intrusions within the Tangihua Complex. Element ratios such as Zr/Y and Th/Yb versus Ta/Yb show they both have arc signatures and also a continental component to the chemistry.

DAY 1

STOP 1 Kawakawa

Brief comfort, tourist and photograph stop - Hundertswasser's iconic contribution to New Zealand architecture. Watch out for the train when crossing the road. Well worth a visit to both sides.

STOP 2 "Ohia oil shale" -- Waipawa Black Shale

Near the junction of SH 10 and Karikari Peninsula's Inland Road there are three quarries that have worked "… a massive, highly carbonaceous mudstone which weathers dark grey to black, but is dark brown when freshly broken (i.e. unoxidised)". (Isaac *et al.*, 1994; p.60). (We will be examining the eastern most of these quarries).

Shearing should be evident in the quarry wall and a weak, pervasive fissility is suggestive of depositional stratification. Its general homogeneity is attributed to bioturbation. Small spherical pyrite concretions and the enigmatic tubular fossil, *Terebellina*, may be locally abundant. While many authorities today consider the latter is a foraminifera (*Bathysiphon*) there are also similarities with the trace fossil *Schaubcylindrichnus.* The rock reeks of hydrocarbons – it has an oily feel and smells of kerosene. We have been informed that the quarry has been abandoned for safety reasons – spoil dumps have has a tendency to spontaneously ignite. (SMOKERS BEWARE). This lithology and similar mudstones elsewhere around Northland are considered identical to the Waipawa Black Shale of eastern North Island (Isaac,et al., 1994).

Look for evidence of bedding, shearing, fissility and bioturbation;
scrape a sample and sniff deeply;
Terebellina – foraminifera or trace fossil, black outer lining and tube fill.

(For stops 3, 4 and 5 see "Notes on the Quaternary of Karikari and Aupouri Peninsulas).

STOP 3 Lake Ohia (after Hicks, 1977)

This lake sits in a hollow *c.* 3.5m a.s.l. It lies between parabolic dunes to the west and north, and the innermost older fore dunes to the east. The exposed lake floor is an indurated hardpan. It is ringed by a low ridge, which on the eastern shore shows evidence for successive falls in lake water levels over the recent past. Although once drained for the purpose of kauri gum digging, it is now marginally seasonal and becomes more-or-less flooded to swampy in winter. Countless tree stumps, some >1.5m in diameter and roots, project to a uniform height (*c.* 10cm) from the lake-bed. Large tree trunks (>1.5m diameter, 15 – 20m in length) were once common, lying flat in the lake-bed and planed off at a similar height. Much wood (swamp kauri) appears to have been "mined" although the site is a scientific reserve. Radiocarbon dates from wood samples are invariably >30,000yrs BP. For reasons that are yet to be understood, the lake-bed has remained immune from peat accumulation.

STOP 4 Gum Diggers Reserve

A quick tourist stop to view a cluster of pits dug in the search for kauri gum. (Do not fall in – some seem to have been used for other purposes).

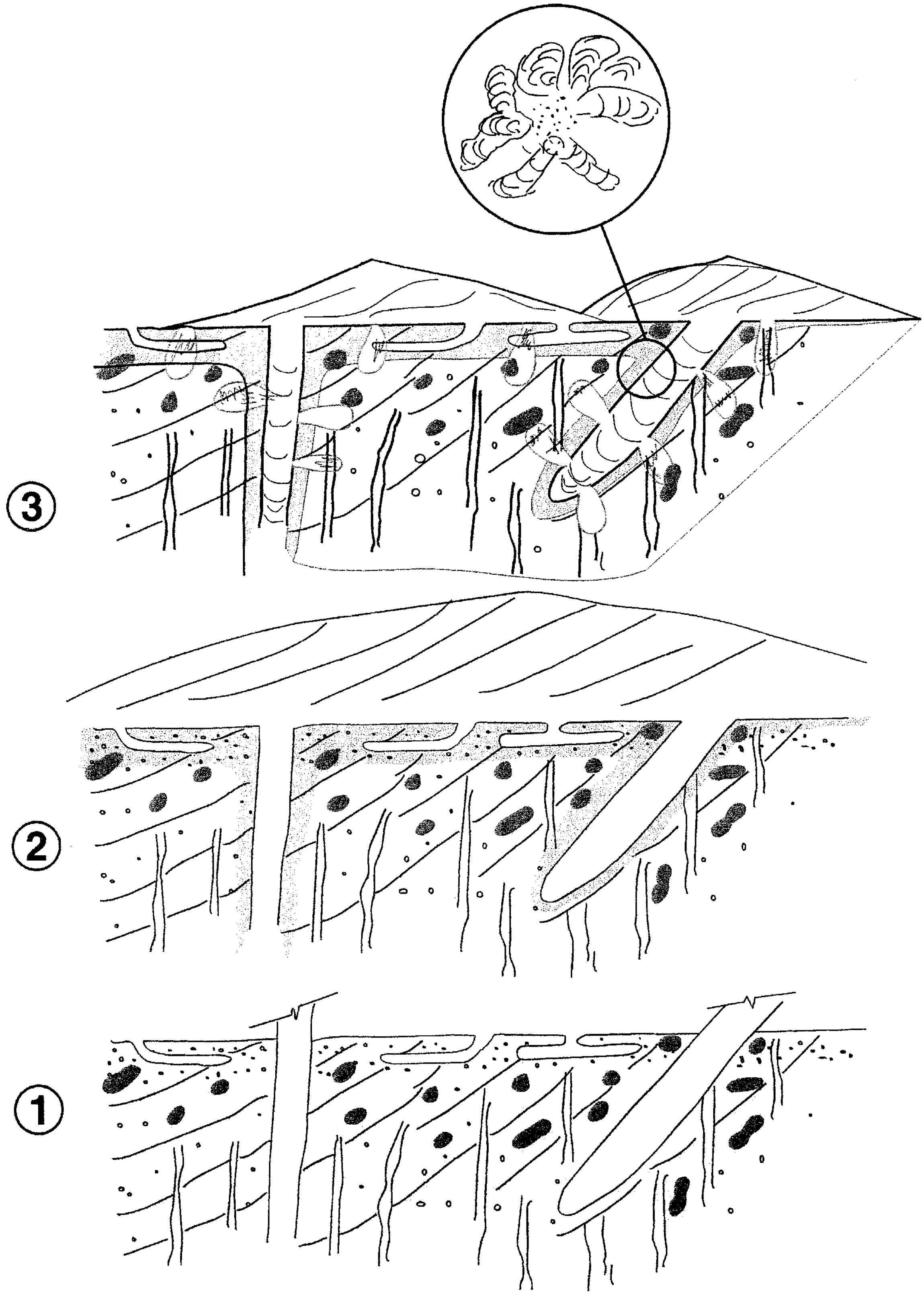


Fig. 9.2: Development of disjunct ichnofabric. **1)** dune with weakly developed vertical (rooting fabric); erosion removes paleosol; invertebrate burrows parallel to surface; tree trunk and root moulds left open: **2)** development of iron-pan or strong humic staining across surface and as haloes around root moulds; firmground formation: **3)** clavate burrows normal to exposed surface of humic firmgrounds; back-filled with drifting very fine white sand, some meniscate burrow construction (inset); note variable cross-cutting and orientation relationships.

STOP 5 Inland Road

(a number of roadside stops will be made over a distance of several kms)
This road follows along the boundary between the innermost fore dunes (to the east) and parabolic dunes (to the west). Its route cuts through the rounded crests of the latter and expose sections up to 5m thick.
Look for the following:-

i) cross bedding, with one exception it is generally difficult to identify:
ii) these sands are deeply weathered and clay-rich:
iii) peats and carbonaceous sands are developed in inter-dune swales – modern analogues can be seen nearby:
iv) in vertical profiles a vague-to-strong, pervasively mottled ichnofabric is often present; is this a plant rooting structure related to fixing of an advancing dune or invertebrate burrowing activity:
v) erosional and "bedding" surfaces with patterns suggestive of degraded "*Thalassinoides*" and /or irregular *Planolites* – could these have a plant progenitor:*vi*) conspicuous large cavities, open or back-filled with fine white sand; vertical and steeply inclined to slightly oblique to dune surfaces; resemble solution pits in calcareous aeolianites; margins sharply defined by dark brown, iron and humic stained sandy haloes, which upwards may merge into paleosols; interpreted as root casts (kauri), and in some instances trunks of trees engulfed by advancing sand:
vii) haloes may be extensively bioturbated; rare meniscate fill suggestive of *Taenidium*; possible firmgrounds burrowed or bored by invertebrates seeking a moist habitat; tiering and ichnofabrics often disjunct (Fig 9.2); could some rooting effects be mistaken for marine ichnotaxa:
viii) root traces sheathed in carbonate – rhizoliths; should these be considered trace fossils.

(For stops 6, 7 and 8 see Notes on the Miocene Plutonic Complex and Associated dike swarm)

STOP 6 Matai Bay Campground: Karikari Plutonic Complex (Fig. 9.3)

This stop allows us to view the complexities of the Miocene Karikari plutonics. The roof zone of the older pluton is well exposed and contacts can be seen with Mt Camel Terrane sediments and volcanics. The textural and compositional complexity of the older pluton is readily seen in Joliffe Point where the plutonics range from microdiorite to strongly porphyritic phases and are intruded by a variety of dikes. In this particular outcrop there is also a considerable structural complexity as indicated by Figure 9.3c.

STOP 7 Northern end of Tokerau Beach (Fig. 9.4A)

The outcrops at the end of Tokerau Beach show pillow lavas in apparently intrusive contact with Tokerau Formation both cut by one of the hornblende andesite dikes related to the Miocene Karikari Plutonic Complex. The dark grey, thinly bedded Tokerau Formation sandstones and mudstones are folded by south verging E-W trending folds and cut by numerous veins and faults. Just around the headland the sediments contain one prominent east-dipping 6m+ thick layer of pillow lavas, which lies conformably on the sandstone/mudstone unit below. The pillow lavas are offset by several faults and are overprinted by a remarkable set of closely spaced sub-vertical curved joints. The origin of the joints is uncertain but they could be either due to cooling or to tectonic causes (fracture cleavage).

There are also sills of massive mafic rock, some of which form complex anastomosing networks. These are displaced by several sets of faults. In contrast to this, dikes of massive andesite related to the Miocene Karikari plutonics are practically not deformed.

The pillow lavas are probably in sedimentary contact with the underlying alternating sequence, but their relationship to the sill-forming massive igneous rocks is uncertain. A common origin is probably the simplest interpretation. The south-verging folds in the sediments have the same orientation and vergence as the main structure at Whatuwhiwhi. The curved fracturing in the pillow lavas may be due to the response of this mechanically resistant unit to folding.

The relationship of the Tokerau formation rocks to the other units in the area is still somewhat problematic. A "raft of Tokerau formation" in the Rangiawhia rocks at Patia Point (Fig. 9.4B) may indicate that Tokerau Formation is older than Rangiawhia.

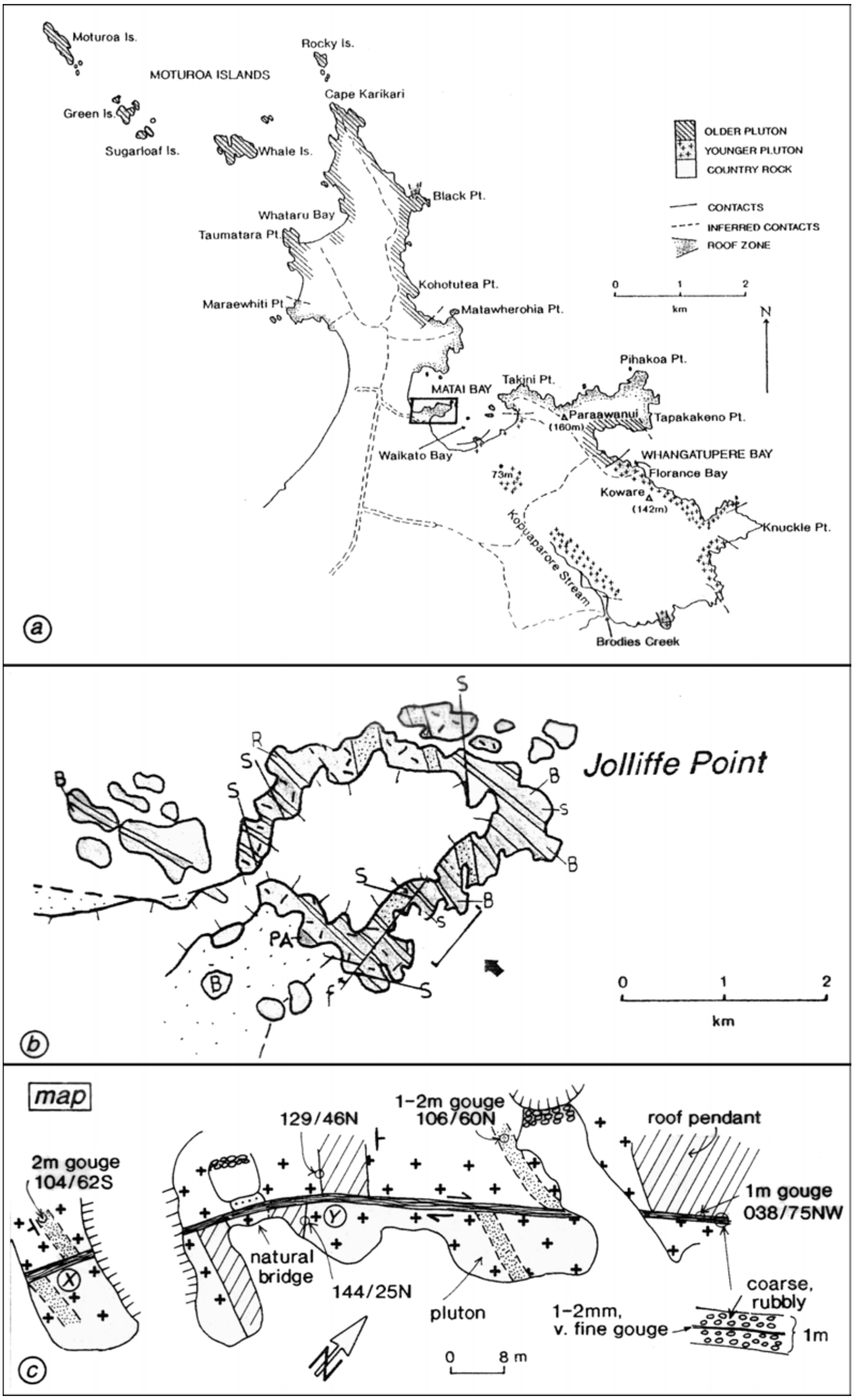


Fig. 9.3: (a) Cape Karikari pluton showing the distribution of the older and younger plutons (from Ruddock, 1990). The Jolliff Point area (center of Matai Bay) is indicated. **(b)** Geology of Jolliffe Point showing 2 phases of the older pluton: microdiorite (dashed) and strongly porphyritic phases (dotted) and dikes in contact with rafts of country rock. Various lithologies in the country rock are indicated as follows: B – pillow basalt; R – rhyolite; S – sediment. The presence of a pyroxene andesite dike (PA) and the detailed section are also indicated (after Ruddock 1990). **(c)** detailed map showing gouge fault displacing earlier ESE-trending faults and contacts of pluton with roof pendants. Separations on markers X and Y indicate a considerable component of dextral slip (from Ruddock and Spörli, 1989).

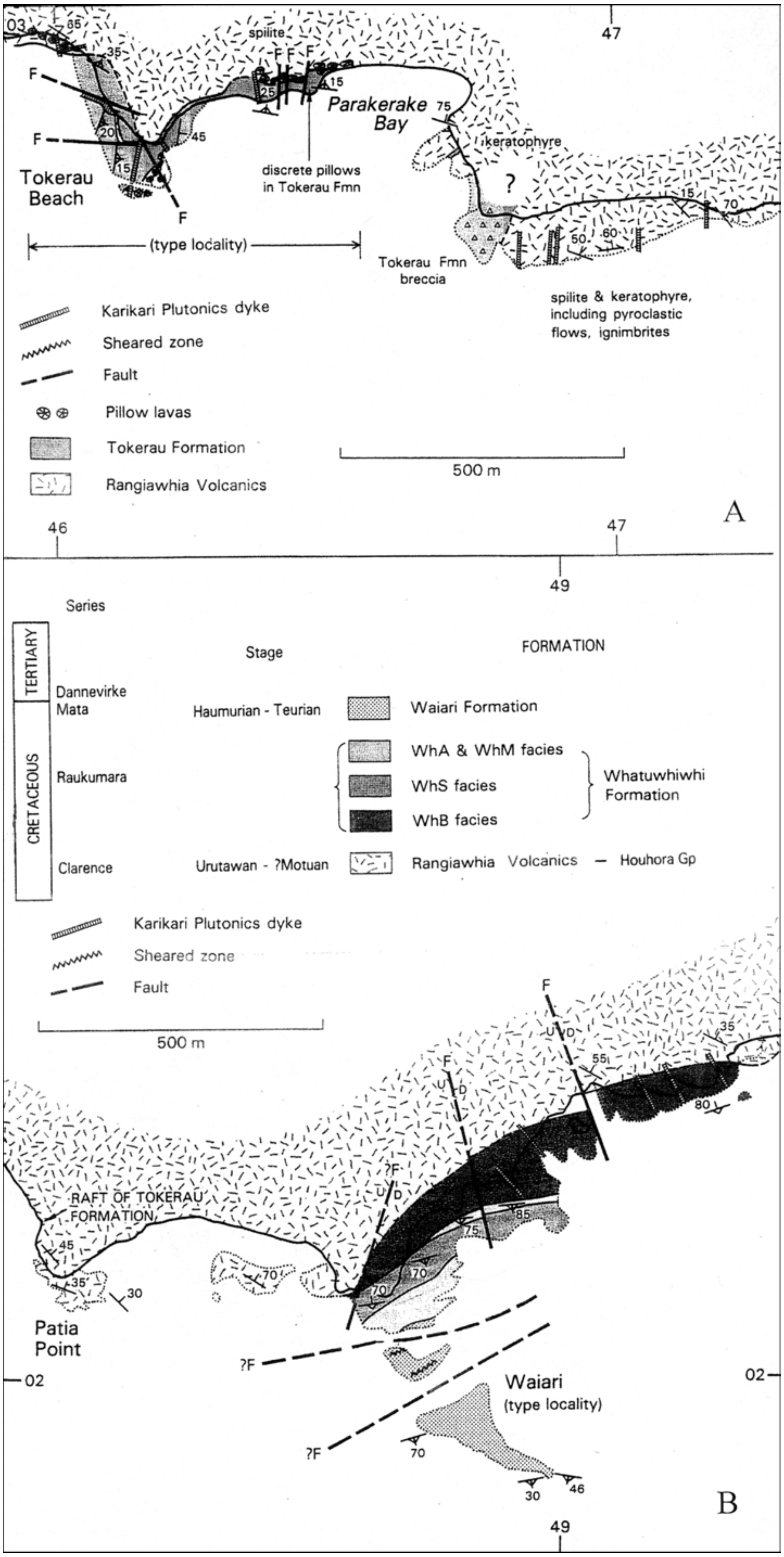


Fig. 9.4 A and B: Map showing Mt Camel sections in the shore platform from the northern end of Tokerau Beach to Parerake Bay **(A)** and from Whatuwhiwhi to Waiari **(B)**. Both from Isaac et al. (1988).

STOP 8 Whatuwhiwhi - Waiari section (Fig. 9.4B)

This area provides excellent exposures of the keratophyric Houhora Complex (Rangiawhia Volcanics), unconformably overlain by an upward fining and thinning sequence of Whatuwhiwhi Formation clastic sediments and Waiari formation black mudstones and cherts (Isaac *et al.* 1988). Rangiawhia volcanics are metasomatically altered and consist of green flow banded, porphyritic and massive brown weathering "keratophyres" which probably represent different original extrusive types and possibly also chemical compositions. Some of the "keratophyres" display vague pillow forms, others are massive and porphyritic. In some localities the "keratophyres" display breccia structure. Isaac *et al.* (1988) recognised pyroclastic flows and ignimbrites. In some places the two units form regular alternating bands, at other localities there are lozenge shaped bodies with folding, indicating deformation on steeply plunging axes. These structures are truncated by the unconformity at the base of the Whatuwhiwhi Formation.

The unconformity surface under the Whatuwhiwhi Formation has relief up to several metres. It is overlain by spectacular rudites (WhB facies of Isaac *et al*. 1988 in Fig 9.4B) with large "floating" blocks of igneous and other rocks. Both in this facies and the overlying sandstone/mudstone alternation of the WhS to WhM facies contain internal folds, shears, and sand mobilisations. Isaac et al 1988 considered that there is another unconformity at the base of the Waiari formation so that it lies unconformably on block –faulted older rocks.

The whole sequence strikes E-W to NE – SW and youngs to the south. Some of the older units are overturned. These attitudes indicate that the Whatuwhiwhi section lies on the steep southern limb of a major south–verging anticline. Because Waiari Formation is involved, the fold is a Tertiary feature. This age constraint and the geometry of the fold make it likely that it was formed during Northland Allochthon emplacement. The structure is cut by dikes associated with the Miocene Karikari plutonic complex.

DAY 2

STOP 9 Te Kao

Te Kao Volcanics and Awapoko Fm. The area north and west of Te Kao contains very poorly exposed weathered outcrops of Te Kao volcanics (note the very deep red colours of the soils exposed in the high terraces west of Te Kao) and to the west of the Te Kao volcanics, near Lake Wahakari are Cretaceous sediments which Hay (1983) correlates with Awapoko Formation. An outcrop of a sheared cream, blue and purple shale sequence is exposed in a road cut on Oromanga Road near the intersection with Te Ahu road. In a nearby abandoned quarry the Te Kao “volcanics” are seen to be coarse grained mafic / ultramafic plutonics showing distinct mineralogical layering and areas of werhlite and dunite. How extensive these layered plutonic bodies are within the Te Kao volcanics is uncertain but a second abandoned quarry to the north of Te Kao is also composed of microgabbro.

STOP 10 The Bluff (Te Wakatehaua Island) Ninety Mile Beach

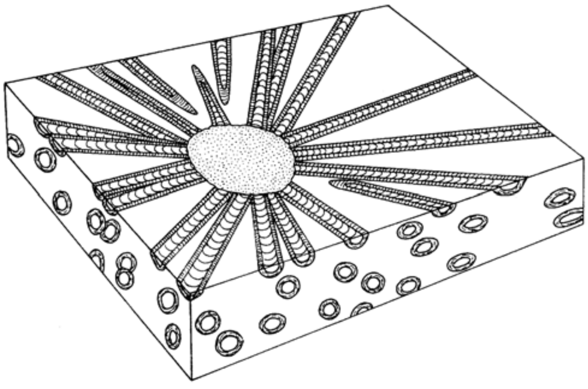
The Bluff is the only disruption to the otherwise long smooth sweep of Ninety Mile Beach. Rocks of The Bluff are pillow lavas and dolerites with some interpillow sediments. The outcrop is composed of at least 3 sheared slices and some of the pillow lavas appear to be overturned, which suggests the sequence may be folded. The volcanics exposed at the Bluff have been variously correlated with Mt Camel and with the Tangihua Volcanics, but detailed geochemical studies suggest that they are closest in affinity with the Cape Maria van Dieman and Reinga.

STOP 11 Henderson Bay

(involves a 15 – 20 minute walk southwards along soft beach sand from the road’s end)

The gently arcuate beach of this bay extends for 5km from Grenville Point in the South to Henderson Point in the north. Along much of this shore modern fore dunes abut and partly hide cliffs cut in consolidated Pleistocene shallow marine and aeolian sands that form the core to the Aupouri tombolo (Goldie, 1975; Millener, 1981). Terraces, at heights of 2 – 4m, 6 – 8m, 19 – 29m, *c.* 40m and *c.* 60m in these deposits are commonly overlain by peat horizons (Goldie,1975). Tree stumps *in situ*, other woody material and weathering kauri gum are a conspicuous feature of the 19 – 29m terrace. A kauri sample has given a radiocarbon date of 32,000 ± 2000 yrs BP (Goldie, 1975). Other trees identified on this surface include totara, rimu, manuka and kanuka. Rounded pebbles are encountered in terrace paleosols and are often concentrated across erosional surfaces. Down-slope movement, reworks pebbles into younger sands drifting over this and lower level surfaces. The varied volcanic and sedimentary lithologies represented amongst these pebbles, suggest their source lies in the Mount Camel Terrane. Millener (1981) saw similarities to beach lag deposits and argued for a marine or fluvial origin. Serious thought must now be given to the possibility that these pebble concentrates, and similar deposits at Tom Bowling Bay and perhaps Waikuku Beach are tsunami deposits (Gregory, unpub., Nichol, *et al.,* work in progress).

The monospecific ichnogenus *Phoebichnus trochoides* (Fig. 9.5) is a large and unusual compound, deep-tier trace fossil described from the Jurassic of Greenland (Bromley and Asgaard, 1972) and is of restricted occurrence in a few other Mesozoic sequences. It is typically found in slowly accumulating, organic-rich, fine sandy muds of dysaerobic inner-shelf environments, and with North Sea cores its identification has become significant in the hydrocarbon exploration game. Remarkably similar structures, now called the “*Phoebichnus* look-alike” (Fig. 9.5) are present at Henderson Bay (Gregory and Campbell, in press). They occur in a dark grey/brown sandy paleosol that can be traced laterally over a short distance into a peat >50cm thick (Fig. 9.6). The compound “*P.* look-alike” structures have been identified as rooting systems. The most likely progenitor is the nikau palm. It prefers damp ground. The well-drained margin of an inter-dune swale, the core of which is now defined by a lensoid peat, would have provided a nikau-friendly environment. Discernable differences between *P. trochoides* and the ”*P.* look-alike” are minor. The former is indicative of a marine environment and the latter of a terrestrial setting. Modern traces of similar architecture are known from deep-sea photographs. Could structures of these kinds be confused in paleoenvironmental reconstructions?



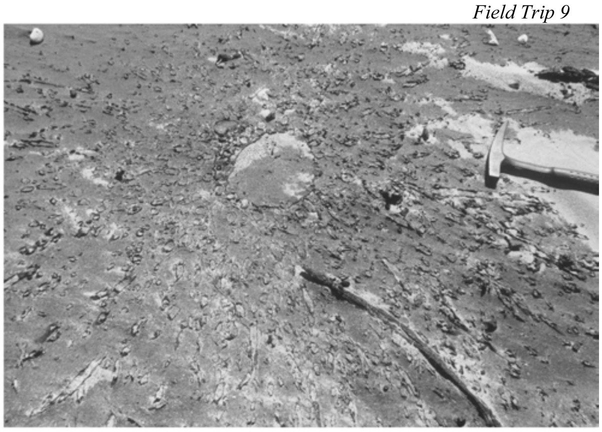


Fig. 9.5: Schematic illustration of *Phoebichnus trochoides* (from Bromley and Asgaard, 1972) (left) and the "*Phoebichnus* look-alike" (right) (hammer for scale).

For observation and discussion:-

i) striking landscape, terraces and their extent, form, origin
ii) paleosols, crusts and hard-pans:
iii) the "*Phoebichnus* look-alike", is it ever over-printed:
iv) rhizomes of pingao in modern drifting sands, relevance to story:
v) vertical fabric in paleosols; resemblance to *Skolithos*
vi) clavate burrows in firmgrounds; potential omission surfaces;
vii) modern traces (birds, insects) in ephemeral pools; mud-flakes:
viii) tsunami deposits.

(Note:- this locality is an ever-changing feast. Some of the previously observed and/or expected features may be hidden under shifting sand or lost to view from wind and sand abrasion!).

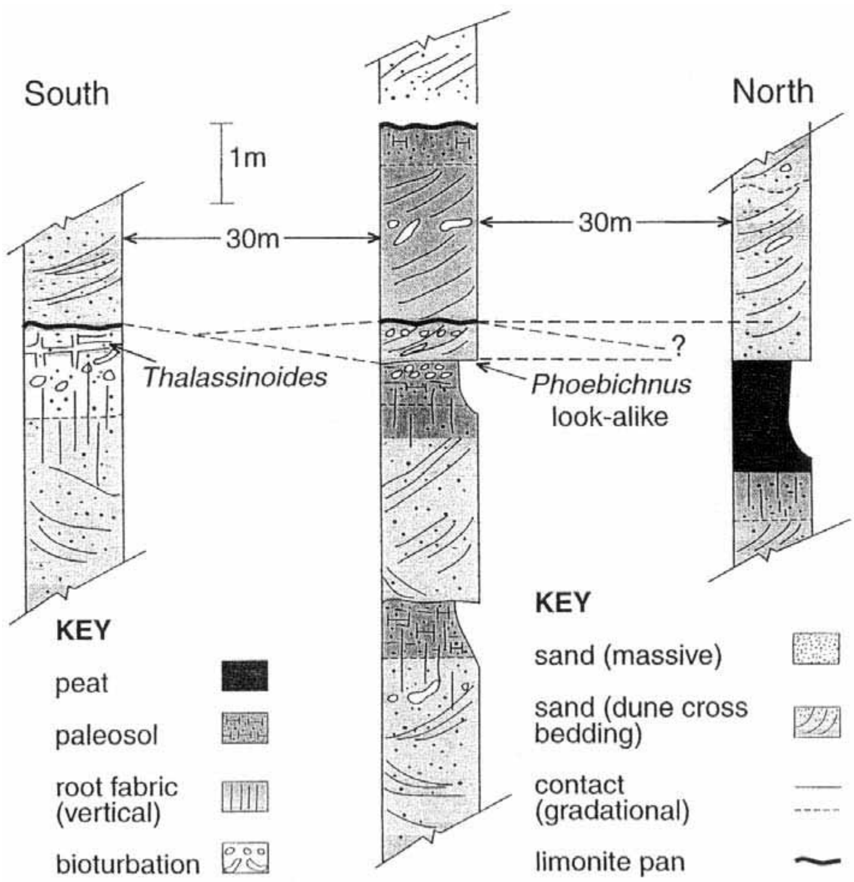


Fig. 9.6: Stratigraphic columns from the "*Phoebichnus* look-alike" locality. Note the lensoid peat and over a short distance southwards its passage into a paleosol and humic-rich, fine sand.

STOP 12 Henderson Point

Locations are labelled on Fig. 9.7. This is also a lithological map of the Henderson Point section.

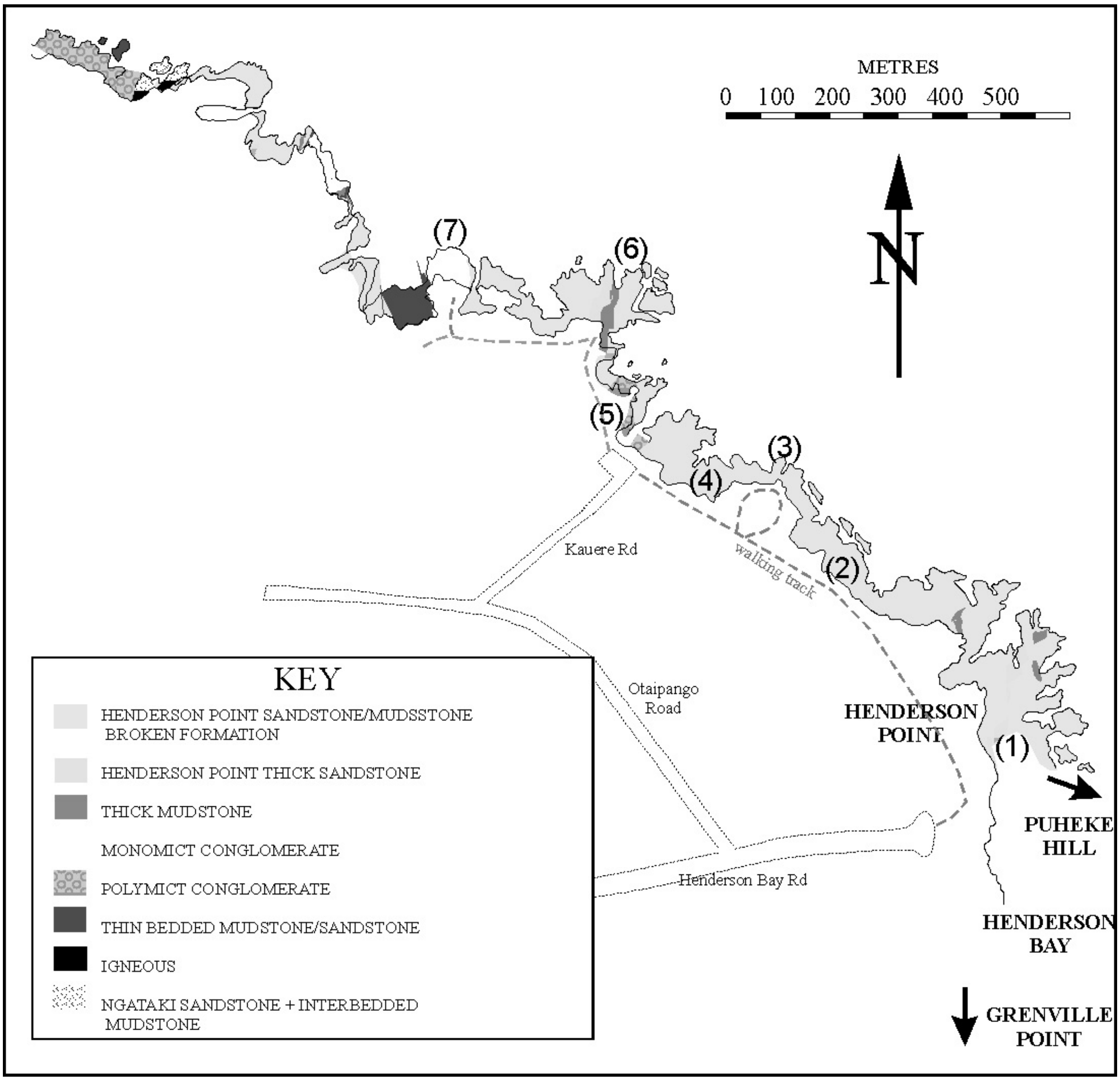


Fig. 9.7: Lithological map of Henderson Bay section. Numbers in brackets refer to locations mentioned in the text of the guide.

Location (1) – Henderson Point

Locations are labelled on an enlarged map of this area (Fig. 9.8).

The shore platform and cliffs are composed of Tokerau Formation sediments. The sediments are Cretaceous age from *Inoceramus kapuus/ipuanus* fossils found at Grenville Point (at the southern end of Henderson Bay).

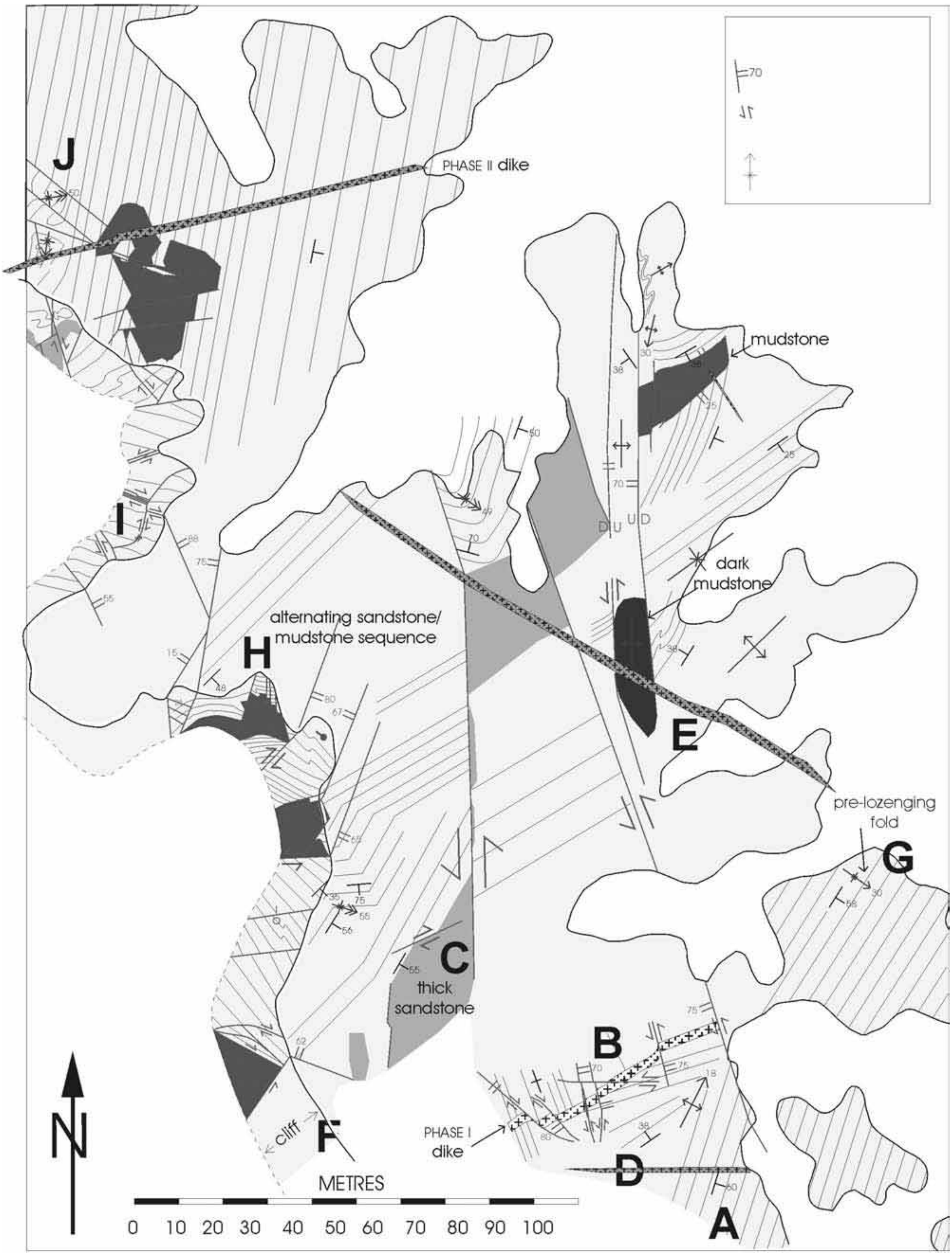


Fig. 9.8: Location 1 Shore platform and cliffs at Henderson Point. Lithological units are labelled on the map. Letters identify locations mentioned in the text. Parallel ruled lines are form lines of bedding formation fabric – attitudes shown by strike and dip symbols.

(A) Shear packages in the sediments are fault-bounded with an overall sinistral deformation. These packages occur throughout the entire sequence of Tokerau Formation, Rangiawhia Volcanics and Whatuwiwhi Formation correlatives in this shoreline.
(B) A "spilite" dike protrudes from the shore platform just below high tide level. The dike is disected by late faults. A slip vector determined from en echelon tension joints indicates sinistral and reverse movement on the N-S trending faults.
(C) A thick sandstone bed that has been offset on N-S striking faults like the "spilite" dike.
(D) Dolerite dike - 0.5m thick, banded, strikes E-W. This example has weathered to a light turquoise colour.
(E) Rust-brown, NW-SE striking dike of the same phase
(F) Small dike 'fingers' in broken formation sediments.
(G) Large scale folding changes the trend of the broken formation fabric. The fold sequence is:
(1) small-scale isoclinal folds
(2) open NE-SW trending subhorizontal folds
(3) steeply plunging sinistral folds
(H) Thin bedded sediments show broken formation (see Fig. 9.9 for broken formation geometry).
(I) On the northern side of the small cove, a braided fault pattern indicates the following sequence of events:
(1) steep N-S fault (relatively wide shear zone)
(2) low angle faulting (top-to-the-west)
(3) steep faulting (reactivation of (1))
(4) low angle faulting (top-to-the-east).
(J) Box shaped folds refolding earlier structures in the shore platform. In the cliff above are SW-verging small-scale asymmetric folds below a thrust zone.

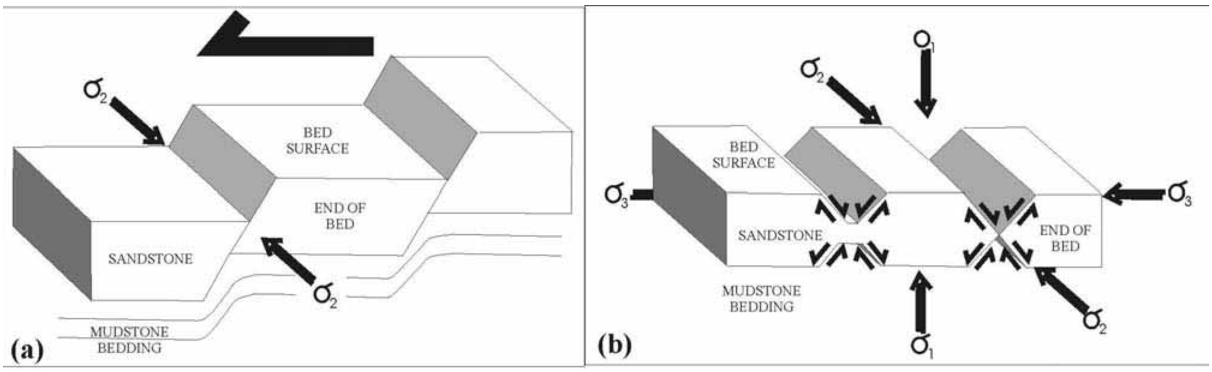


Fig. 9.9: (a) LOZENGE: One direction of faulting under pure strain conditions. **(b)** BOUDIN: Two directions of faulting under coaxial strain.

Continuing to the northwest. (return to Fig. 9.7)

Location (2) - Boulder-strewn beach

The Tokerau Formation behind this bay is relatively undeformed/monoclinal compared to all other outcrops in this coastal section and provides a good location to look at sedimentary structures and search for younging directions. If any are found, they generally indicate that sequence is overturned (NW-younging).

Location (3) - Point at north of boulder-strewn beach

This location provides the definitive age-relationship for the two dike phases and later faulting episodes (Fig. 9.10).
The sequence is:
(1) Broken formation
(2) Sinistral shear package faulting
(3) "Spilite" dike intrusion (NE-SW trend)
(4) Sinistral fault (NE-trending, near vertical). Clearly offsets the "spilite" dike. Has re- activated a bounding fault of a sinistral shear package.
(5) Dolerite dike intruded across the sinistral fault and the spilite dike. Two intrusion directions of the dolerite dike are probably controlled by pre-existing fractures.

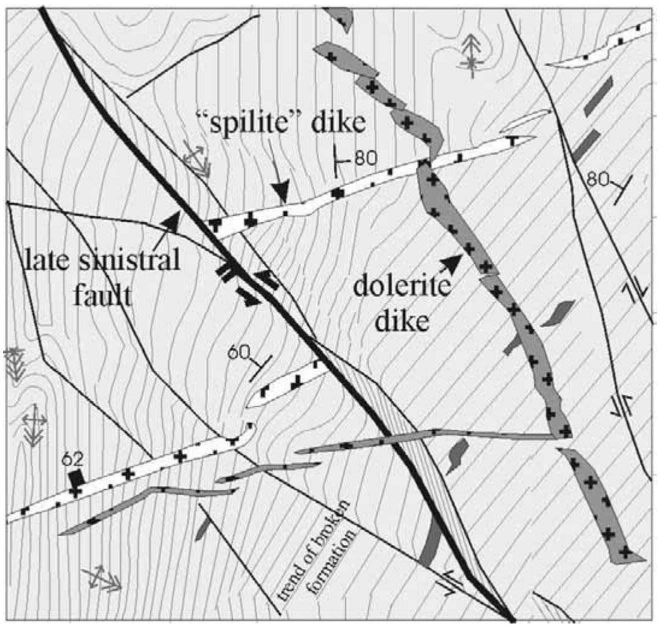


Fig. 9.10: Map of dikes and relationship to faulting at Location 3.

Location (4) - Cliffs at back of sandy bay

Spectacular exposure of broken formation folded by chevron folds. Two main phases of folds interact to produce refolding patterns including mushroom structures. Look at the faults forming the broken formation and consider the intersection of the broken formation axes with the overall beds.

Location (5) - Continue to the northeastern end of the sandy bay

The first outcrop of polymict conglomerate within this sequence occurs here. There is a sedimentary contact with the Tokerau Formation beds - one of only a handful preserved anywhere in this 3 km long rock shoreline. The entire conglomerate outcrop appears to have been uplifted as a block between bounding faults.

Additional features of interest in this area include:

(1) re-folding in Tokerau Formation sediments on the shore platform
(2) shear packages within the mixed Tokerau/conglomerate sequence
(3) transposition of bedding on low-angle faults in the conglomerate sequence

Location (6) - Dolerite Plug

The plug forms a prominent headland. Dolerite dikes issue out from the plug, and generally strike E-W and NE-SW. The sedimentary sequence has very thick sandstone and mudstone units.

Location (7) - Monomict Conglomerate Outcop

This massive conglomerate unit has rounded porphyritic igneous clasts in a coarse sand matrix. It is inferred that the conglomerate was deposited from debris flows off the side of a volcanic edifice (?Rangiawhia Volcanics).

On the northwestern side of this outcrop there is a (rare!) sedimentary contact with mudstone and very thinly bedded sandstone/mudstone. The conglomerate has scoured channels in the mudstone surface, indicating that the conglomerate is stratigraphically above the mudstone.

DAY 3

STOP 13 Ahipara – Shipwreck Bay Section through a Tangihua Complex

A quick departure in the morning permitting, the tide will be low enough for us to visit the coastal road section west of Ahipara and to have a brief look at the Shipwreck Bay section of the Ahipara massif. In the shore platform we can see a good range of lithologies in the Tangihua Complex: highly indurated thin-bedded mudstones, cherts and tuffs are interbedded with and in fault contact with pillow lavas and massive flows. *Inoceramus* fragments have been found in some of the sediments.

In Shipwreck Bay a gabbroic intrusive complex is exposed. Some parts of the gabbro are very felsic; there is minor pegmatite veining in the gabbro and anorthosite veins occur in adjacent rocks. To the north, east-west trending faults juxtapose the gabbro against massive basalt; in the western part of the bay the boundary is uncertain; while there are shears along the contact, small scale shearing and recrystallisation of the adjacent siliceous sediments suggest an intrusive boundary. Dikes, some of which are alkaline (camptonitic), cut the pillow lavas and gabbro. West of Shipwreck Bay along the coast there is a progression from equidimensional pillow forms to flattened small tube-like pillows with thick glass selvedges and then into pillow breccia and hyaloclastites.

STOP 14 Herekino Gorge

In road cuts and an old quarry we will see pillow lavas, and contacts between lavas and shaley mudstone. The Herekino Gorge itself follows the trace of a complex lineament (? fault) which contains strongly deformed Cretaceous - Tertiary rocks upfaulted into the Tangihua Volcanics on a set of steep, NW trending conjugate normal faults (Larsen and Spörli, 1989).

We will drive south through typical Northland Allochthon slump topography through Broadwood to join State Highway 1 at Mangamuka Bridge.

STOP 15 Mangataipa Scenic Reserve (Figs 9.11, 7.12)

The sedimentary component of the Northland Allochthon is composed of a highly sheared mixture of siliceous claystone and blue-grey mudstone containing lenses or rafts of late Cretaceous Mangakahia Group sandstones and Early Eocene – Early Oligocene Opahi Group sandstones and limestones (Hay, 1960). In road cuts along the Mangamuka River we can observe the interior structure of one of the km-scale rafts of Early Oligocene limestone enclosed within the Allochthon. Bedding is easily recognizable, as are sedimentary structures which are particularly well preserved in the glauconitic horizons.

The excellent preservation of sedimentary structures and internal folding and faulting within the limestones allowed Clark *et al.* (1989) to determine the following deformational sequence:

1. Localised soft sediment bedding-parallel sliding.
2. Formation of tight, recumbent, E-W trending, south-verging and south facing chevron folds.
3. Formation of open south-verging chenvron and kink folds, associated with southward thrusting.
4. Refolding by open N-S trending folds with gently curved axis trends.

Towards the end of the deformation sequence the generally contractional regime has been replaced by extensional deformation, which presumably marks the change from southward thrusting of the Northland Allochthon. of the bed. B = Lower hemisphere equal area nets showing conjugate fault couples (from Clarke et al. 1989).

While the road outcrops have suffered somewhat from the ravages of time, these sedimentary and deformational structures are still quite clearly seen in the roadcuts (Fig. 7.12).

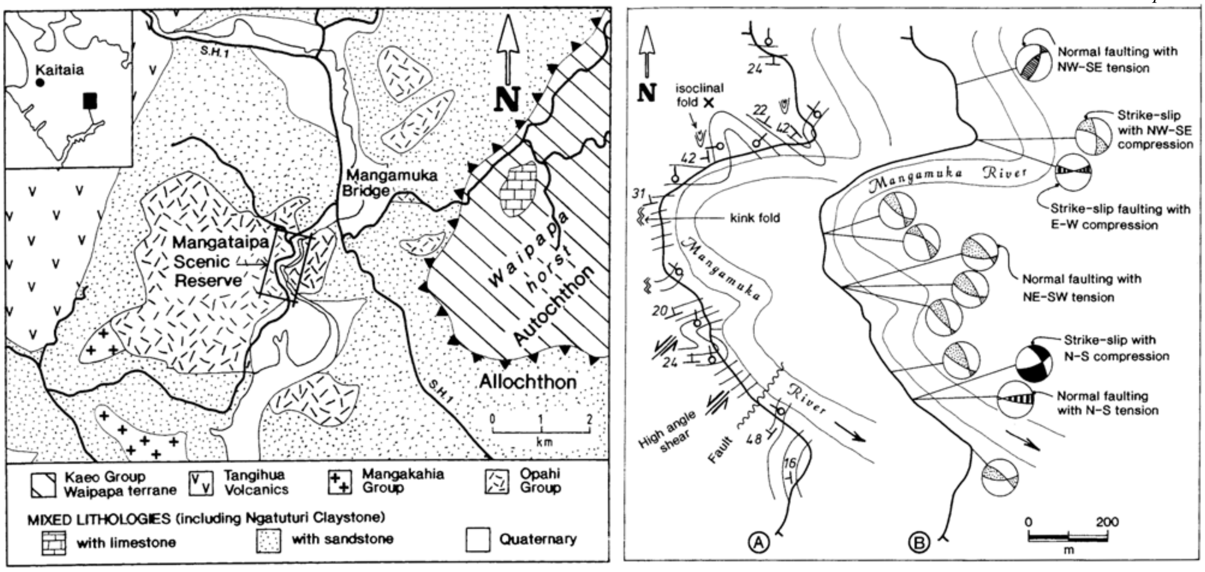


Figure 9. 11 Left: Location map, Mangamuka Bridge area and Mangataipa Reserve. Line with teeth marks lower thrust contact of the Northland Allochthon. Right: Structure in limestones exposed in road cut through Mangataipa Reserve. A = form lines of bedding; dot and line symbol marks younging with line pointing to top.

Remainder of Route

Drive to Kaikohe to pick up with Field Trip 7 for the remaining trip back to Auckland. Route will go through Kaikohe (FT7, Stops 8, 7, 6, 3; Fig. 7.3) down the road to Pakotai to Kirkopuni Junction and then through Dargaville and Tokatoka (Fig. 7.16) and back to Auckland.