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Field Trip Guides

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Field Trip 6

The Miocene-Pliocene interior seaway of the central North Island: sedimentary patterns and tectonic styles in the Kuripapango Strait

Greg H. Browne

Institute of Geological & Nuclear Sciences, Gracefield Research Centre,
PO Box 30 368, Lower Hutt
(g.browne#gns.cri.nz)

INTRODUCTION

During the course of this three day field trip, we'll follow the little travelled Inland Patea Road between Taihape and Napier. This is not only a historic region in the nineteenth century settlement of the central North Island, but also an area of surprisingly varied late Miocene to latest Pliocene-earliest Pleistocene sedimentation. These sediments were deposited adjacent and atop the tectonically evolving Kaimanawa, Ruahine, and Kaweka basement blocks, and we'll examine the interplay between tectonics and the sedimentation of Neogene cover beds. The sediments reflect changing tectonic tempos marked by an initial transgressive and overall subsiding basinal configuration in the late Miocene to early Pliocene, followed in the late Pliocene, by a regressive and increasingly active uplift history which has continued to the present day.

Most studies of the sedimentary and tectonic history of the central North Island have concentrated on the major depocentres of the Hawke's Bay and Wanganui Basins. In contrast this field trip will provide a different perspective from the North Island ranges themselves. Sediments atop the Ruahine and Kaweka ranges provide important insights into the sedimentary cover, prior to and synchronous with Neogene uplift, as well as the tectonic evolution of the axial ranges themselves. Today these Neogene rocks are preserved as several small fault-bounded blocks or outliers across the eroded central North Island ranges (Kingma 1957; Crippen 1977; Browne 1978, 1981, in press; Beu et al. 1981).

During the Neogene, the central North Island formed the northern part of the Wanganui Basin, and extended to the East Coast Basin through the region of the present-day northern Ruahine and southern Kaimanawa-Kaweka Ranges. Previous workers have referred to this as the Kuripapango Strait (Grant-Taylor & Hornibrook 1964). Though the marine connection between the west and the east was first described by Cotton (1916, p. 247), the notion of an interior seaway has not figured prominently in subsequent regional studies (cf. Beu et al. 1980). Developed in the late Miocene, the Kuripapango Strait was most fully developed in early Opoitian time, and was comparable to the present day Cook Strait. The strait had a width of around 15 km, with a likely embayment in the vicinity of Ngamatea Station (Fig. 1). Maximum water depths were probably no greater than mid-shelf at any given time, and it is possible that several islands existed within the strait, labelled Sparrowhawk and Otupae Islands in Figure 1. Low-lying greywacke landmasses existed north and south of the strait, areas that would later develop into the Kaimanawa, Kaweka, and Ruahine Ranges. These areas may have been island archipelagos in a more regional sense. A similar Manawatu Strait centred on the Manawatu Gorge, was also present at this time, and in general, is better known (Lillie 1953; Zutelija 1974). By the late Pliocene, the Kuripapango Strait had shallowed, and in latest Pliocene-earliest Pleistocene time, was near to becoming emergent.

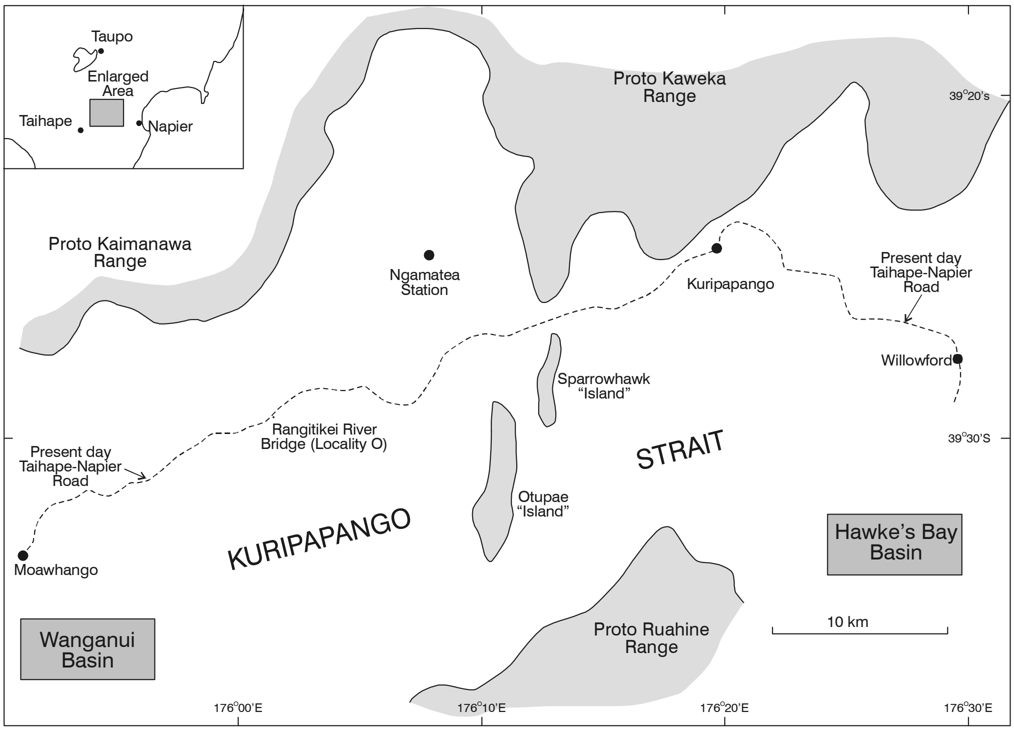


Figure 1. Paleogeographic map of the Kuripapango Strait during the early Pliocene (approximately 4 Ma).

During the course of the 3-day field trip, we'll examine the sediments deposited in the Kuripapango Strait, from fluvial to the deepest marine rocks developed during the maximum development of the strait. The three day field trip is centred along the Taihape-Napier Road with accommodation at a Department of Conservation facility at Kuripapango some 50 km west of Napier. The region was an important route for early Maori who, during summer months, lived in this area in search of the prolific bird life. In the late nineteenth and earliest twentieth centuries, Kuripapango was an important staging post on the inland Patea Road, one days coach ride from Napier. It boasted a hotel (three were built in all) and enjoyed somewhat of a "resort status", attracting Hawke's Bay settlers wishing to escape the summer heat of the 'bay'. Much of the area around Kuripapango and The Blowhard was farmed from the late nineteenth century, until the 1930's depression. The ravages of wind erosion forced soil conservation practices in the 1950's and 1960's, such as the planting of pine trees by the New Zealand Forest Service. Farming around Kuripapango and Mt. Kohinga continued until the 1960's and 1970's, and the flats are still used periodically for grazing.

Today there is next to nothing at Kuripapango – once you leave the farmland of Hawke's Bay, there are no shops, next to no cell phone coverage, no mains electricity, just a dusty metal road for 100 km to the Rangitikei River and three sheep and cattle stations along the way - Timahanga, Ngamatea, and Otupae Stations. On day three we'll visit Ngamatea Station. Ngamatea Station covers an area of 28 300 hectares and is the largest (by area) in the North Island.

The guide is divided into two parts. The first is a stratigraphic overview of Neogene sediments in the region, the second, descriptions of the field stops.

Part I

GEOLOGICAL OVERVIEW

In the Kuripapango-Ngamatea region a maximum 2 km thick succession of late Miocene – latest Pliocene/earliest Pleistocene marine deposition is recorded (Fig. 2). Initial Neogene uplift and transgressive sedimentation occurred during Tongaporutuan-Opoitian time, initially as alluvial fan and braid plain deposits, becoming fully marine up sequence. No rocks of Waipipian (late Pliocene) age are known from the study area, this period being marked by a slight angular unconformity of a few degrees. A regressive succession overlying this unconformity comprises late Pliocene and earliest Pleistocene (Mangapanian-Nukumaruan) marine carbonates, sandstones, and conglomerates, deposited during a period of renewed tectonic uplift.

The pattern of sedimentation at Kuripapango suggests two tectonic uplift pulses during the late Neogene, one centred around the Tongaporutuan-Kapitean (~10.5-5 Ma), the other from Mangapanian–Recent time (~3 Ma-present day), separated by a period of relative tectonic quiescence and subsidence during the Pliocene. This intervening period may have resulted in the erosion of basement rocks to form a widespread erosion (peneplain) surface. Sedimentation in the region also indicates that different fault blocks had distinctly different sedimentation histories through the late Neogene.

TRANSGRESSIVE LATE MIOCENE-EARLY PLIOCENE SEDIMENTATION

The oldest sediments overlying the basement Torlesse Terrane comprise a <150 m thick, crudely upward-fining succession including conglomerate and minor interbedded sandstone called the Blowhard Formation (Browne 1981; in press), that became increasingly sandy and muddy stratigraphically upward. These rocks form much of the Kuripapango-Blowhard area, and area around Timahanga and Ngamatea stations further west.

Blowhard Formation (Tt-Tk) (after Browne in press)

The Blowhard Formation comprises conglomerate, sandstone, calcareous sandstone/limestone and minor siltstone. Two members are recognised.

Spiral Conglomerate Member (Tt-Tk) (after Browne in press)
The Spiral Conglomerate comprises poorly sorted conglomerate with well rounded to angular, Torlesse Terrane-derived clasts, with thinner interbedded pale grey, non-calcareous, moderately well sorted, fine to medium-grained sandstone and rare siltstone (Fig. 3). The member rests unconformably on Torlesse Terrane.

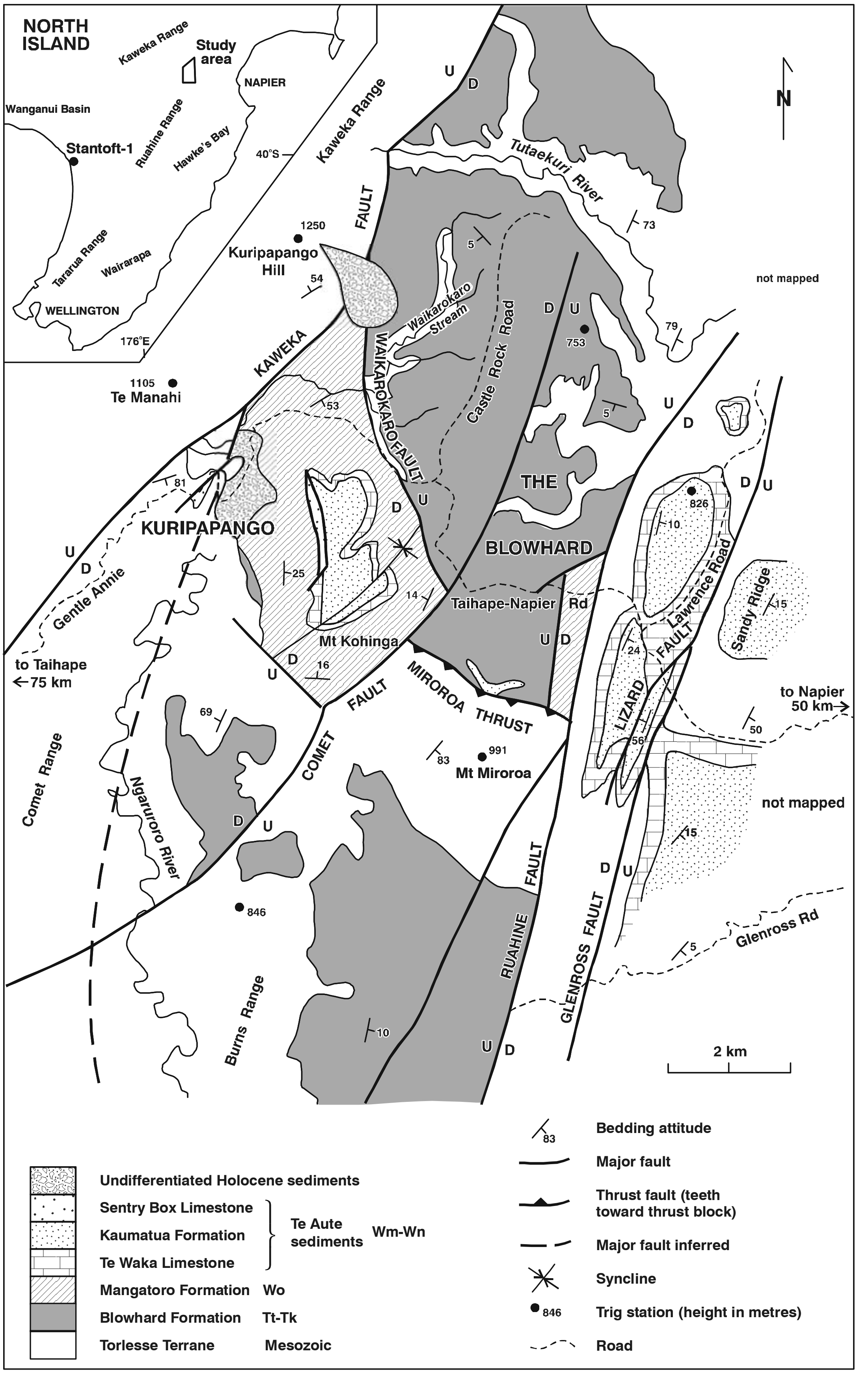


Figure 2. Geological map of the Kuripapango region (after Browne in press).

Figure 3. Photo of Spiral Conglomerate adjacent to Taihape-Napier highway (U20/997957) showing the abundance of conglomerate with lenticular interbedded sandstone.

The conglomerate is typically clast-supported in the basal portion of the member, but display better sorting, increased clast roundness, and an increase in fine to coarse-grained sandstone matrix support up-sequence. Thinner-bedded (20-150 cm thick), scour-based (relief <1 m) sandstone beds occur approximately 15 m above the base of the member, and increase in abundance and thickness upward. Up-sequence, these sandstones eventually dominate over conglomerate lithofacies. The top of the member is taken arbitrarily to be where sandstone beds dominate over conglomerates.

The member is thickest and best developed along the Taihape-Napier Road (Locality A) and in the Waikarokaro Stream catchment where it is >100 m thick (Fig. 2). The member is consistently thicker adjacent to faults which are assumed to have had contemporaneous movement during deposition, and localised uplifted greywacke, the source of the conglomerate clasts. Palynological sampling indicates a Tongaporutuan (late Miocene) or younger age (Dallas Mildenhall pers. comm.). As the member is overlain by Kapitean age sediments of the Waikarokaro Member (see below), a Tongaporutuan-Kapitean age is adopted.

The preferred paleogeographic setting in the earliest parts of the member is as a series of alluvial fans dominated by debris flow deposition, which developed adjacent to fault blocks in the Torlesse Terrane (Fig. 4). The stratigraphically higher and laterally more distal portions of the depositional succession represent a progressively greater degree of fluvial sedimentation in coarse-grained braided river depositional settings.

<u>Waikarokaro Member (Tk)</u> (after Browne in press)
The Waikarokaro Member is exposed throughout the Blowhard Plateau, Timahanga, and Ngamatea regions and rests unconformably on Torlesse Terrane basement (eg. Locality B) or the Spiral Conglomerate. The member comprises three lithofacies, which in order of abundance (in the Kuripapango region) are: sandstone, conglomerate, and calcareous sandstone/limestone (Fig. 5). At Ngamatea, conglomerates are rare.

The dominant lithofacies is medium brown, massive and trough cross-bedded, very well sorted, fine-grained, micaceous sandstone. Beds are typically decimetre bedded, though may be as much as 2 m thick, usually planar based, but may show broad scours up to 50 cm deep. Mudstone rip-up clasts occur at the base of some beds.

A second lithofacies comprises centimetre to decimetre-bedded, poorly to moderately well sorted lensoidal sandy conglomerate. Basal contacts of conglomerate beds are erosive (amplitude <50 cm) and tops are planar or gradational. A sandstone matrix support is characteristic and consists of well-sorted fine-grained sandstone with a minor proportion of mudstone. Pebble clasts are dominated by greywacke sandstone, and may show normal grading or crude imbrication fabrics.

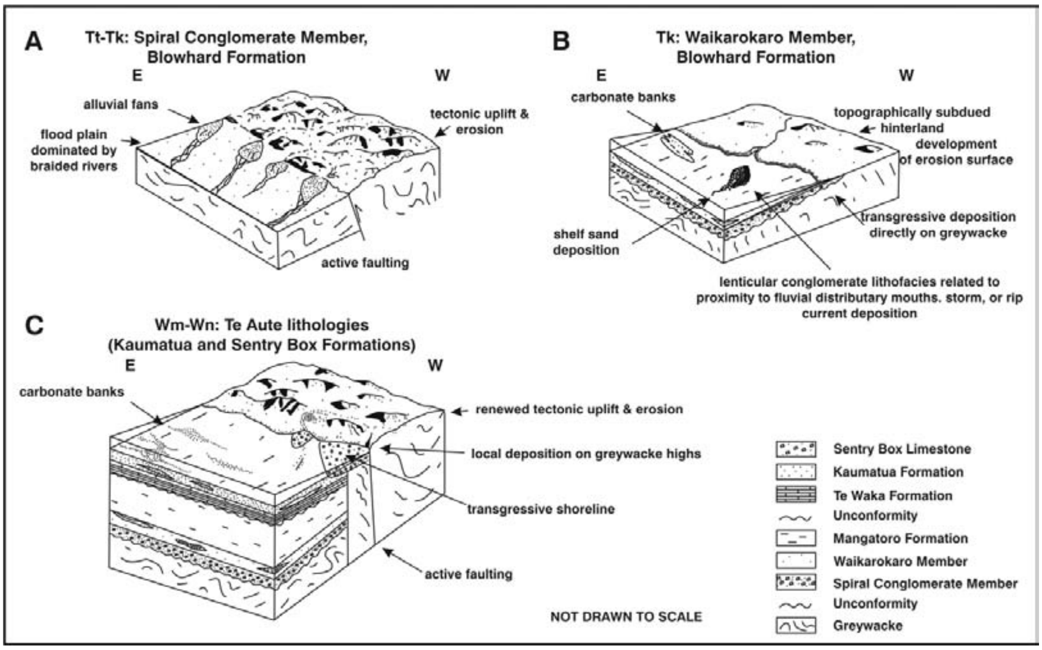
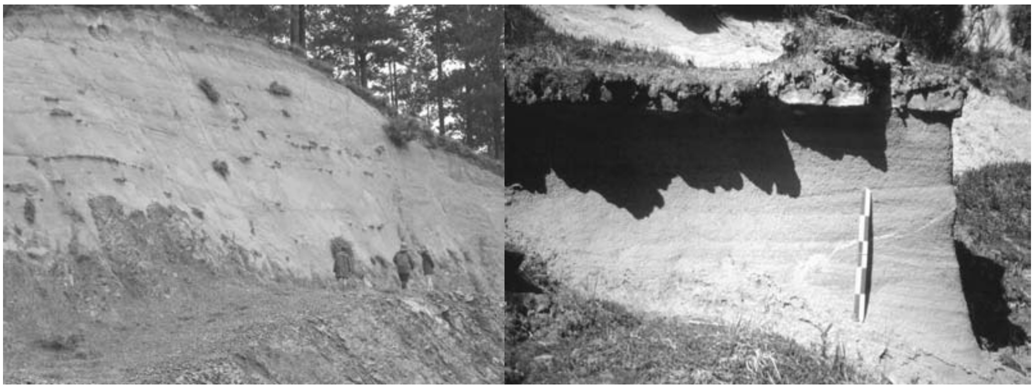


Figure 4. Cartoon summary of the sedimentation and tectonic evolution of the Kuripapango-Blowhard region during late Neogene time (after Browne in press).

A third lithofacies are coarse pebble to granule-sized, gravelly calcareous sandstones and grainstone. The coarser clasts consist of rounded to well-rounded greywacke and minor intraformational mudstones. Trough and planar cross bedding is common. Macrofossils are dominated by molluscs of which *Sectipecten wollastoni* and *Crassostrea ingens* are the most abundant, but include less common bryozoa, serpulids, echinoderms, and barnacle fragments.

A **B**



C

Figure 5. Various lithofacies of the Waikarokaro Member. A. Onlapping Waikarokaro Member sandstones on Torlesse Terrane at Locality B. B. Trough cross-bedded sandstone and thin calcareous sandstone, Castle Rock Rd (U20/015994). 50 cm scale with 10 cm divisions. C. Channelised conglomerate cutting sandstone, Miroroa Rd (U20/004936).

The member is between 0 and 70 m thick. The occurrence of *Sectipecten wollastoni* indicates a Kapitean (late Miocene) age (Beu et al. 1980; Beu & Maxwell 1990).

The typical occurrence of the fauna as fragmentary material together with the trough cross-bedded and well-sorted to very well sorted texture, suggests high-energy shelf environments during sedimentation.

Mangatoro Formation (Wo) (after Lillie 1953)

Mangatoro Formation includes grey, moderately sorted, bioturbated, micaceous very fine and fine-grained muddy sandstone and sandy mudstone (Fig. 6). Foraminifera are abundant and well preserved, and occur with ostracods, molluscs (mostly gastropods), echinoid spines, bone fragments, and fish teeth. Thin (<1 cm thick) rhyolitic tuffs are also present.

The formation is confined to the Kuripapango area. A basal sedimentary contact to the formation is not exposed, and the formation is in fault contact with older formations. The exact thickness is not known, but on the basis of mapping, the formation may be as much as 1500 m thick. A gravity profile through the formation immediately east of the Kaweka Fault modelled a depth to basement of approximately 1 km (Browne 1981). A middle to late Opoitian (early Pliocene) age is indicated for the formation based on foraminifera (Martin Crundwell pers. comm.).

Figure 6. Mangatoro Formation with abundant vertical and sub-vertical Paramoudra concretions, Waikarokaro Stream (U20/984974).

REGRESSIVE LATEST PLIOCENE-EARLIEST PLEISTOCENE SEDIMENTATION

No record of Waipipian (early late Pliocene age) sedimentation is known from the area. This is in contrast to extensive siliciclastic and carbonate sedimentation at this time in Wanganui, Hawke's Bay, and Wairarapa. The Mangapanian-Nukumaruan regressive phase is dominated by carbonate lithofacies, included within the Te Aute sediments.

Four formations are recognised from the Kuripapango area.

Te Waka Formation (after Beu 1995)

Greyish to pinky brown grainstone with abundant mollusc, barnacle, bryozoan and foraminiferal bioclasts are included in the Te Waka Formation (Figs. 7 – 8). Te Waka Formation rests conformably or with slight angular unconformity (up to 5^0) on Mangatoro Formation sandstone or unconformably on Torlesse Terrane in the east. Cross-bedding indicates paleocurrent directions toward the east and southeast.

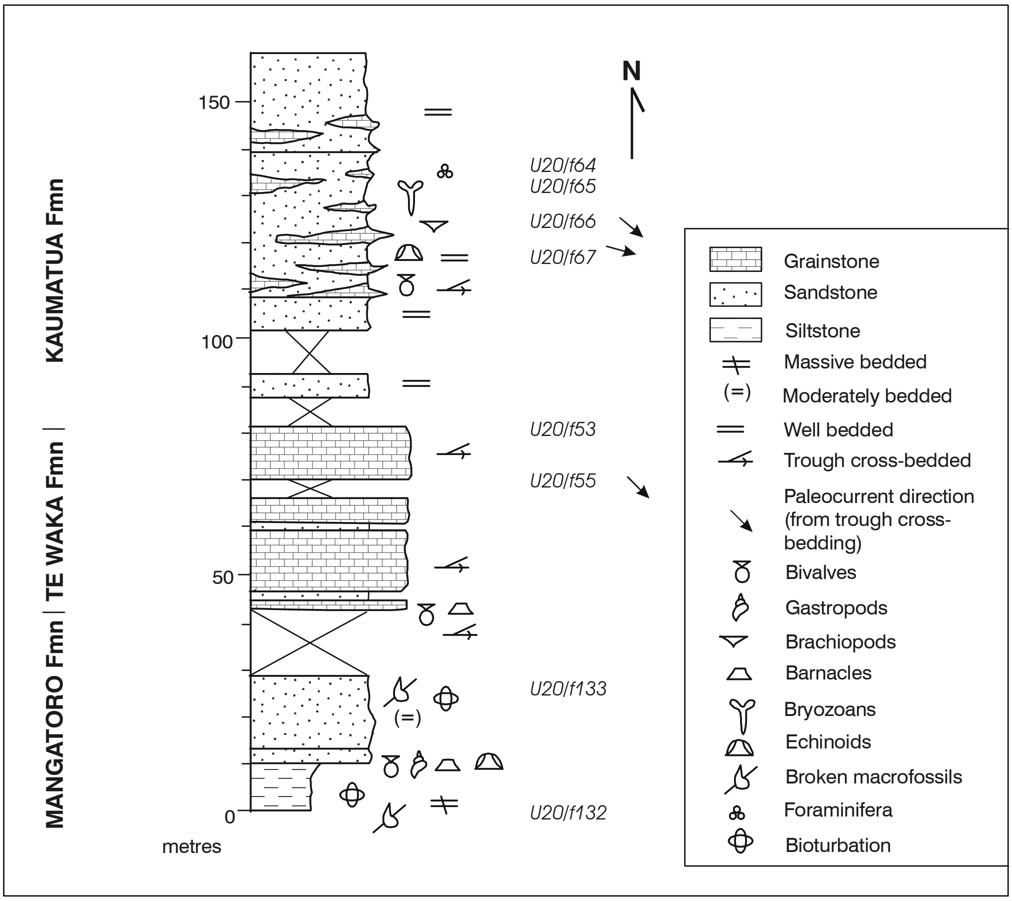


Figure 7. Stratigraphic column from the western side of Mt. Kohinga (U20/978936 to 980936), through the Mangatoro, Te Waka, and Kaumatua Formations. Location of faunal samples are prefixed with “U20/f” (after Browne in press).

The presence of *Phialopecten triphooki triphooki* indicates a Mangapanian (late Pliocene) age (Beu 1995). Caron et al. (in press) refer to these limestones as cool-water “continent-attached” deposits, as distinct from “continent-detached” limestones that developed further east in central parts of the forearc basin.The broken condition of the bioclastic material and abundance of trough cross-bedding indicates deposition by strong traction currents. In keeping with Beu’s (1995) interpretation of Te Aute sediments, it is concluded that the rocks at Kuripapango were deposited as carbonate dunes or mounds, in inner to mid-shelf depths. Strong swell-dominated and storm-related shelf currents were likely during the deposition of the unit.

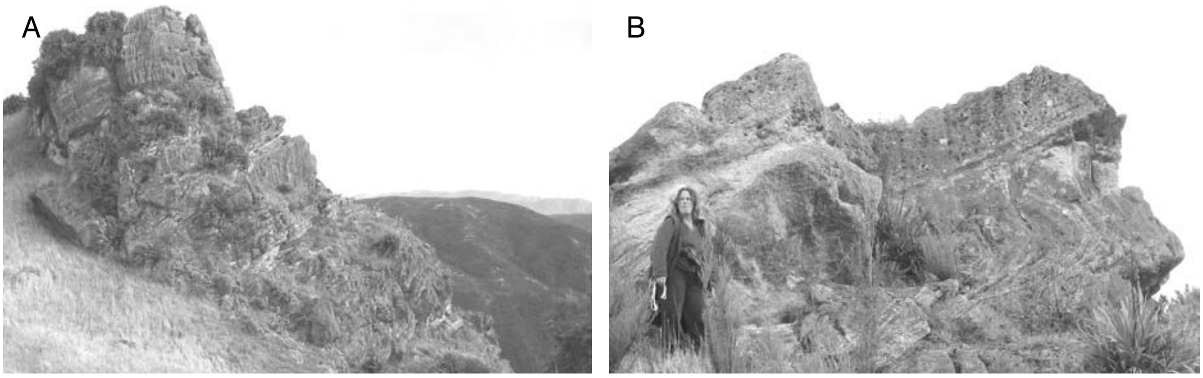


Figure 8. A. Te Waka Formation limestone lithofacies on the western side of Mt. Kohinga (cliffs are approximately 20 m high). B. Overturned foreset bedding east side of Mt. Kohinga (U20/986934).

Kaumatua Formation (after Erdman & Kelsey 1992)

In the study area the formation consists of interbedded lithic grainstone (biosparite/biosparrudite), sandstone, and mudstone lithofacies that rest conformably on Te Waka Formation or unconformably on the Torlesse Terrane at Sandy Ridge (Fig. 9). At Sandy Ridge, poorly sorted, angular to rounded greywacke boulders up to 25 cm diameter occur within a crudely bedded rudstone, which pass rapidly up into better stratified cross-bedded floatstone and grainstone. Paleocurrent directions are generally north to southeast.

The carbonates display a lenticular geometry, forming discrete pods or lenses up to 5-10 m thick, and extending for up to 150 m along strike. Well developed centimetre and decimetre-scale flaggy stratification, and trough and planar cross-bedding (sets up to 50 cm thick) are common. Bioclasts are dominated by barnacles, with less abundant molluscs, echinoderms, brachiopods, bryozoa, and foraminifera. Centimetre-thick foraminifera-rich mudstones also occur within the grainstone lithofacies.

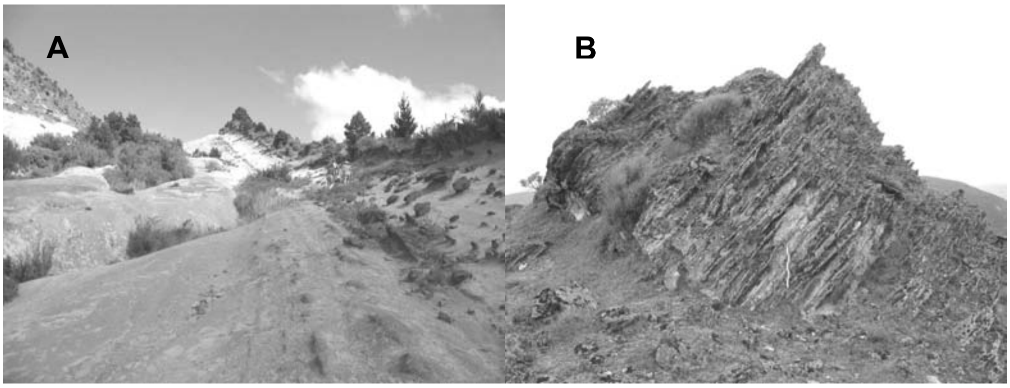


Figure 9. **A**. Sandstones (foreground) interbedded with lenticular grainstones (ridgeline right) of the Kaumatua Formation, The Lizard (U20/035913). The grainstones are interpreted as offshore bioclastic ridges or bars that pass laterally into the surrounding sandstone lithofacies. Here the formation dips approximately 60^0 west (toward right), back toward the Ruahine Fault. Outcrop view is approximately 150 m wide. **B**. Grainstone lithofacies of the Kaumatua Formation with typical flaggy appearance along the summit ridge of Mt. Kohinga (U20/981937). Scale at lower centre, is 50 cm long with 5 cm gradations.

Sandstone interbeds surrounding the lenticular limestones are greyish orange to brown, non-calcareous, bioturbated, horizontally and less commonly cross-bedded, well sorted, medium grained sandstone. They are intercalated with centimetre- to decimetre-thick brownish mudstone often occuring as mudstone rip-up-clasts (Fig. 9A). Trace fossils are locally abundant, and include *Scolicia*, *Ophiomorpha, Teichichnus,* and *Phycodes.*

The presence of *Phialopecten triphooki* indicates a Mangapanian age (Beu 1995). The formation is characterised by shallow-water taxa such as *Crassostrea ingens, Tawera subsulcata, Chlamys gemmulata, Anomia trigonopsis*, and *Gari lineolata.* The lenticular limestone beds within the sandstone lithofacies are interpreted as shelfal (fair-weather wave to above storm wave-base) carbonate ridges or bars.

Sentry Box Formation (modified after Erdman & Kelsey 1992)

Description

At Mt. Miroroa and in the vicinity of Kuripapango, the formation comprises a 30 m thick, dark yellowish, very poorly sorted, fine-grained sand, interbedded fossiliferous siltstone, and gravelly grainstone. The formation rests on the Blowhard Formation at Mt. Miroroa (contact not observed), or with angular unconformity on Torlesse Terrane along the Gentle Annie, west of Kuripapango (Fig. 10). Elsewhere, outcrops are fault bounded.

An early Nukumaruan (latest Pliocene-earliest Pleistocene) age is indicated by the diverse fauna, which includes *Zygochlamys delicatula* (Beu et al. 1981; Browne 1986). Deposition in a shallow marine (<50 m depth) setting is inferred. The wide variety of sediments ranging from gravel to siltstone suggests varied and localised sedimentation histories, with deposition in places over an extremely irregular basement topography.

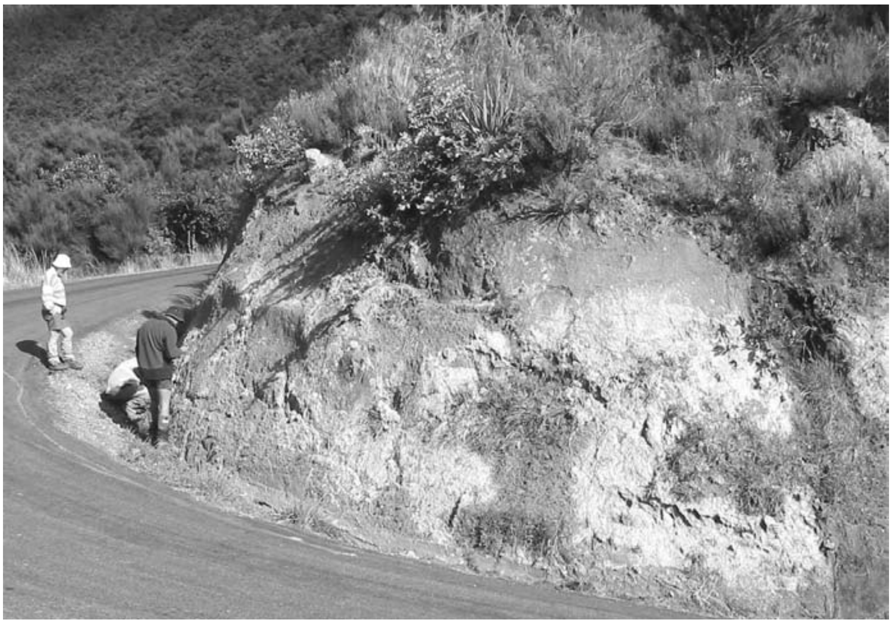


Figure 10. Outcrop of Sentry Box Formation (at this locality a sandy mudstone), Gentle Annie Rd, Kuripapango (U20/961953).

DISCUSSION

Tectonic Controls

The present-day tectonic configuration of the Kuripapango region is dominated by the Ruahine and Kaweka Faults. These are both considered dextral strike slip structures. Both faults appear to be major systems with recent movement, though the Kaweka Fault can not be mapped with confidence much further south than Timahanga Station. A number of other structures (such as the Comet and Waikarokaro Faults) were active in the past, but not today. The Comet Fault for example, along with the Ruahine Fault, were both active during the inception of the Miroroa Thrust (Browne 1986). Late Miocene faulting associated with the deposition of the Spiral Conglomerate marked an early phase of tectonic uplift of the axial ranges. This was followed by a period of relative tectonic quiescence and widespread subsidence in the latest Miocene-early Pliocene (the acme of the Kuripapango Strait). Renewed uplift in the late Pliocene to Recent formed the axial ranges as we know them today.

Fault-bounded depocentres across the Kuripapango-Ngamatea region display different stratigraphic aged successions, indicating that fault blocks had distinct uplift histories. Some depocentres were receiving sediment, whereas other adjacent depocentres were not.

Petroleum Geology Considerations

In the past, several companies have pursued the petroleum potential of the western Hawke's Bay region, principally the limestone lithologies of Plio-Pleistocene age. The most recent exploration interest was from Indo-Pacific (now Austral-Pacific), who in 1996, drilled the Kereru-1 well to the south of the present study area to target some of these limestone reservoirs.

The petroleum potential of the Kuripapango region is not considered high. The c. 2 km Neogene stratigraphic thickness evident at Kuripapango is not sufficiently thick to generate hydrocarbons, unless there had been a considerable additional thickness of Neogene sediments, subsequently uplifted and stripped by erosion. In addition, the area lacks suitable source rock lithologies, despite favourable porosity and permeability in the Neogene sediments (Table 1). The considerable groundwater flux of the region, the result of high rainfall in the ranges, is an impediment to the trapping of hydrocarbons if any were produced in this part of western Hawke's Bay.

Table 1. Porosity and permeability measurements from representative samples, Kuripapango. Porosity values were determined by Archimedes principle (dry:wet weight ratio); permeability values based on a portable N-gas minipermeameter. Measurements from the latter may not be particularly reliable.

Formation	**Member**	**Age**	**Lithology**	**Porosity (%)**	**Permeability (mD)**	**Sample # Porosity**	**Sample # Permeability**
Blowhard	Spiral Cgl	Tt-Tk	Mudstone	24.5	30.5	2	1
Blowhard	Spiral Cgl	Tt-Tk	Sandstone	23	31.5	1	1
Blowhard	Waikarokaro	Tk	Mudstone	21	-	2	-
Blowhard	Waikarokaro	Tk	Sandstone	27.3	-	3	-
Mangatoro	-	Wo	Siltstone	30.6	20.6	5	1
Mangatoro	-	Wo	Sandstone	28.5	-	2	-
Te Waka	-	Wm	Mudstone	22	-	1	-
Te Waka	-	Wm	Sandstone	26	66.8	1	1
Te Waka	-	Wm	Limestone	-	214	-	2
Kaumatua	-	Wm	Limestone	-	424	-	1
Sentry Box	-	Wn	Sandstone	33	-	1	-
Sentry Box	-	Wn	Limestone	-	557	-	3

Part II

After leaving Napier, we travel through the central and western portions of the Hawkes Bay monocline/forearc basin. Sediments include interbedded siliciclastic mudstones, sandstones, and conglomerates, as well as bluff-forming carbonates of late Pliocene to early Pleistocene age. They represent a range of depositional environments from fluvial (conglomerates) to shallow marine (sandstones and limestones), to mid and outer shelf mudstones (for details see Pettinga 1982; Beu 1995; Bland et al. 2004; Caron et al. in press).

LOCALITY DESCRIPTIONS

Localities to be visited in the Kuripapango-Ngamatea region are labelled Localities A-P in Figures 11 & 12. They are listed in the order in which they are intended to be visited.

Day One

Locality A – Spiral Conglomerate, Taihape-Napier Rd (U20/996958 to U20/999956)

Suggested Duration – 1 hour

Observations – The oldest Neogene rocks are coarse-grained clastics of the Spiral Conglomerate (Tt-Tk), which rest unconformably on Torlesse Terrane (Fig. 3). The succession exposed from the bridge eastward adjacent to the road, represents a fining-upward section dominated by poorly sorted coarse clasts at the base, changing up-sequence to finer grained greywacke conglomerates and increasing proportions of interbedded finer grained sandstone. The lithofacies are interpreted as a series of alluvial fans that shed coarse-grained sediments in a series of debris flows from adjacent fault-bounded Torlesse Terrane blocks. These pass up-section to braided fluvial deposits in the upper portion of the member (Fig. 4).

Significance - The Spiral Conglomerate indicates an important phase of late Miocene uplift in the Kuripapango region. Currently, this phase has not been appreciated in published models of the tectonic development of the central North Island axial ranges. These models recognise widespread uplift of the axial ranges from latest Pliocene (Mangapanian)-Recent time but not earlier (Grant-Taylor in Smale et al. 1978; Beu et al. 1981; Melhuish 1990; Beanland et al. 1991; Erdman & Kelsey 1992). There is however, evidence from fission track thermochronology for >4 km uplift of basement underlying the Ruahine Range starting about 15 m.y. ago, and providing considerable sediment flux to adjacent basins from 7-8 m.y. ago (Kamp et al. 2002). The tectonic event recognised at Kuripapango may be part of this uplift; certainly the stratigraphic ages reported here are compatible with such an inference. However, the distinction should be made that in the Kuripapango region, this latest Miocene uplift was temporally distinct from the latest Pliocene-Recent event, separated by a period of subsidence and deposition in the early Pliocene (Mangatoro Formation).

There is supporting evidence that the latest Miocene tectonic event may have been widespread. Similar facies, though poorly dated, occur atop the Ruahine Range (Browne 1978) and Otupae Station. Lillie (1953), Wells (1987), and Nicol et al. (2002) all report a major phase of latest Miocene uplift in southern Hawke's Bay and Wairarapa marked by coarse-grained conglomeratic lithofacies.

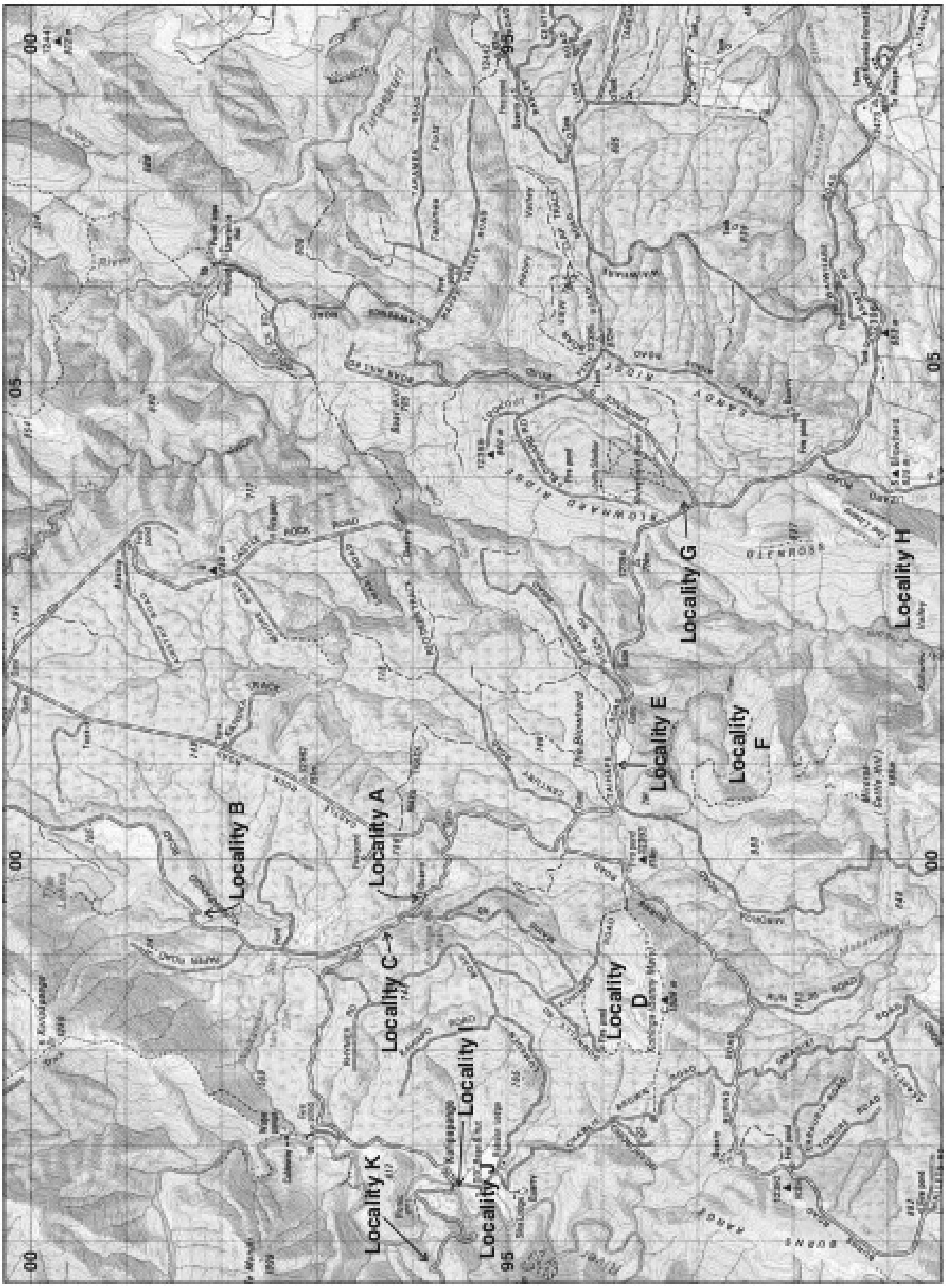


Figure 11. Field stop locations in the Kuripapango region. Map is based on NZMS 260 sheet U20, Kaweka. Grid squares are 1 km; bold numbers at margin are easting and northing coordinates.

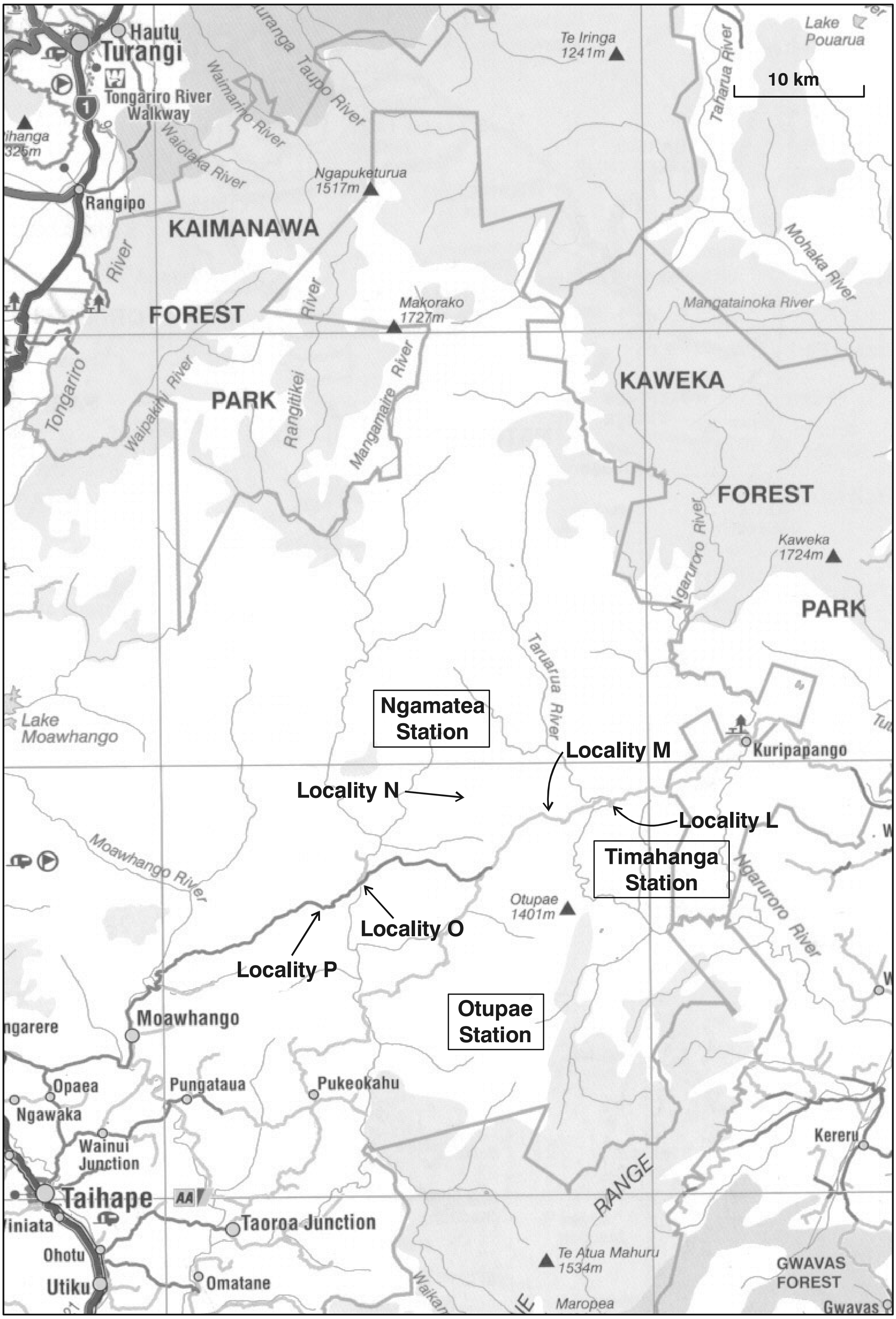


Figure 12. Field stop locations in the Ngamatea region.

Locality B – Waikarokaro Member, Kuripapango Road (U20/995982)

Suggested Duration – 45 minutes

Observations –Sandstones of the Waikarokaro Member form the bulk of the country between the Kaweka Fault in the west, and the Ruahine Fault in the east. Much of the geology is dominated by sandstone, and at this locality, we can observe the unconformable nature of Waikarokaro Member sandstones resting on an irregular greywacke surface. At locality A, the Waikarokaro Member is conformable with the underlying Spiral Conglomerate. At locality B, the Waikarokaro Member was deposited over an irregular basement topography (in part a faulted topography).

Significance – Deposition of the Waikarokaro Member represents open shelf deposition. Here we can see that the transgression occurred (locally) over a shallow rocky submarine topography, though elsewhere on the Blowhard Plateau, deposition occurred over a sandy shelf.

Locality C – Mangatoro Formation, Taihape-Napier Road (U20/993962)

Suggested Duration – 30 minutes

Watch for traffic!

Observations –Foraminifera from Mangatoro Formation in the Kuripapango area indicate a mid-shelf depositional setting (Martin Crundwell pers. comm.). The formation is in the order of 1 km thick based on both regional mapping and a gravity profile between this locality and Kuripapango. Exposures of the formation in Waikarokaro Stream (adjacent), display Paramoudra concretions though we are unlikely to have time to observe these (Fig. 6).

Significance - Mangatoro Formation siltstones occur in the Kuripapango area east of the Kaweka Fault and west of the Ruahine Fault. Mangatoro Formation records a period of significant subsidence, and marks the maximum development of the Kuripapango Strait at the peak of the transgression.

Locality D – Mt. Kohinga, Kuripapango (U20/980939 to U20/986933)

Suggested Duration – Half day

Observations - The lower slopes of Mt. Kohinga comprise Opoitian Mangatoro Formation siltstones. The upper flanks of the mountain are capped by well exposed Mangapanian Te Aute carbonates and associated siliciclastics folded about a northeast trending syncline (cf. Beu 1995, fig. 64). At this locality, we will walk 2-3 km around the perimeter ridge of Mt. Kohinga, the ridge forming the limbs of the Kohinga Syncline. We will walk initially upward through successively younger Te Aute lithologies; bluff-forming Te Waka Formation limestone, and interbedded carbonates and clastics of the Kaumatua Formation, the latter forming the summit ridge. Several faults cut the summit ridge of Mt. Kohinga.

The first significant outcrops are the bluff forming Te Waka Limestone dipping east toward the core of the Kohinga Syncline (Figs. 7 & 8). On the ridge top and hinge of the syncline are lenticular carbonates bodies with intercalated sandstones and siltstones of the Kaumatua Formation (Figs. 7 & 9). The carbonates are interpreted as high-energy shelf sediments representing migrating carbonate banks. On the eastern side of the ridge, the beds dip both west and east due to numerous ridge tops faults.

In good weather we will be able to observe the general aspects of the peneplain developed on the distant Ruahine Range dipping toward us, across an area called No Man's. This surface is largely greywacke, with remnants of ?Kaumatua Formation carbonates. We can discuss the possible age of the peneplain. It must pre-date deposition of the Te Aute sediments which rest unconformably on the erosion surface. We don't have much of an idea about the possible maximum age. The peneplain could correlate to the period of uplift and erosion marked by the Spiral Conglomerate or the Waipipian unconformity.

Significance - A subsequent change in lithofacies is marked by Te Aute deposition. The Waipipian appears to have been a period of uplift and erosion, with development of an angular unconformity and possible peneplain development, and initiation of regressive sedimentation. Te Aute sediments record an increase in Torlesse Terrane-derived clastic material through time, indicating renewed uplift of basement rocks nearby. Similar lithofacies changes occur in many parts of the eastern North Island (Katz 1973; Beu et al. 1980; Pettinga 1982), and have been related to dextral strike-slip movement on the major faults (Melhuish 1990; Beu 1995).

Day Two

Locality E – Mt. Miroroa Overview (U20/011938)

Suggested Duration – 20 minutes

The Miroroa Thrust was first described by Kingma (1957) and Cotton (1957), and remains to this day a seldom visited, yet spectacular geological feature of Hawke's Bay. Here the Torlesse Terrane has been thrust northward (toward us), over Nukumaruan (basal Pleistocene) shallow marine Sentry Box Formation (Fig 13). The lower buttresses on the east and west side of the mountain are made up of these Nukumruan sediments, resting on late Miocene Blowhard Formation. The postulated rate of uplift based on the age and facies of the Sentry Box Formation was 0.6 mm/year (Beu et al. 1977).

Figure 13. Overview of Mt. Miroroa from the Taihape-Napier Rd.

Locality F – Mt. Miroroa (U20/005927 to U20/012921)

Suggested Duration – Half day

Observations – Undoubtedly the most structurally complex part of the region occurs at the northern flanks of Mt. Miroroa, where Nukumaruan sediments of the Sentry Box Formation have been over-steepened immediately below Torlesse Terrane greywacke which have been thrust northward over the Nukumaruan sediments (Figs. 14-15). Relationships have been described by Browne (1981 & 1986) and Beu et al. (1977 & 1981). We will walk through Blowhard Formation sandstones at the base of the mountain, then onto the northern buttress, with several fault-bounded greywacke horsts bounded by W-E trending faults from Plio-Pleistocene limestone. Two calcareous units are present – the stratigraphically youngest is the Sentry Box Formation of Nukumaruan age; the lower and bluff forming limestone could also be Sentry Box, though Browne (1986) called it the Miroroa Limestone.

Figure 14. Miroroa Thrust from the approach along the northern buttress (at U20/005924). Neogene limestones in the foreground and middle distance are separated by a fault-bounded block of Torlesse Terrane greywacke. The Miroroa Thurst is located below the summit peak of the mountain.

A B

Figure 15. A. View of the Miroroa Thrust from the north (U20/007922). Darker coloured rocks in the upper part of the photo are Torlesse Terrane greywacke, overlying lighter coloured Nukumaruan marine sediments below. View is ~50 m wide. B. Detail of the Miroroa Thrust at U20/008920. Thrust plane in the middle view dips to the south (toward the right); Torlesse Terrane to the right, Nukumaruan marine sediments to the left. Units to the right at an acute angle to the thrust plane within the Torlesse Terrane represent argillite bedding planes. Hammer (centre) for scale.

The geology gets a whole lot more interesting on the eastern buttress of the mountain as we approach the summit area. Here, Pleistocene sediments dip up to 75° below the Miroroa Thrust. The thrust plane itself dips at 50°S in the surface exposure (Figs. 15-16). We will get into considerable detail as the structural style is very complicated.

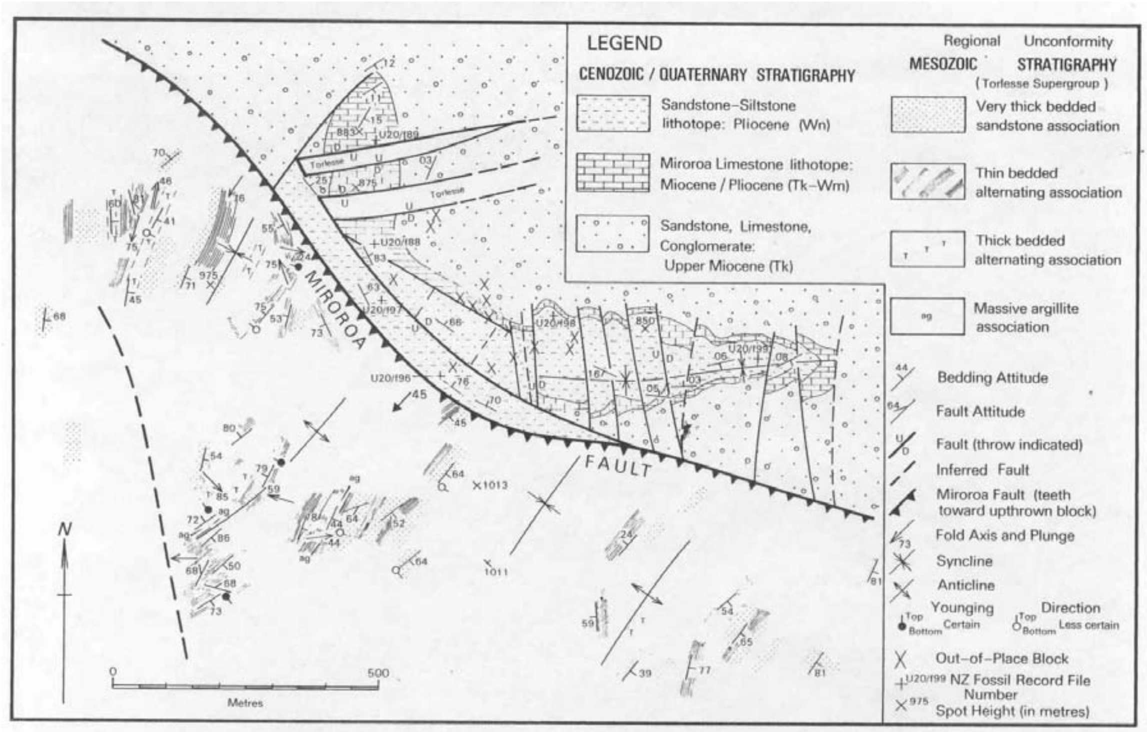


Figure 16. Geological map of northern flank of Mt. Miroroa (from Browne 1986).

Significance – The section illustrates how complex Hawke's Bay structure can be, here involving Nukumaruan sediments overthrust by basement, and uplifted to 1000 m asl in the last 2 million years! These and other aspects are described in Beu et al. (1980), Beu et al. (1981), and Browne (1986).

Locality G – Te Waka Limestone, Taihape-Napier Rd (U20/036932)

Suggested Duration – 15 minutes

Watch for traffic!

We examined the Te Waka Limestone yesterday on the summit region of Mt. Kohinga. Here, just east of the Ruahine Fault, similar carbonates form the summit ridge of the Glenross Range (to south) and Blowhard Ridge (to north). Lapiez weathering is common in the limestone (Fig. 17). The Blowhard Bush in this area is part of a Royal Forest & Bird Protection Society reserve and represents the last remaining vestige of broadleaf-podocarp forest in the region.

Figure 17. Sketch of the Te Waka Limestone, Blowhard Ridge (from Kingma 1957).

Locality H – The Lizard, Glenross Range (U20/039920 to U20/033910)

Suggested Duration – 1-2 hours

Observations - The walk up to the ridge crest takes about 30-40 minutes, made difficult by the numerous washouts and thick vegetation. On the way we can observe steeply west-dipping outcrops of Kaumatua Formation, which are better exposed towards the top of the ridge (Fig. 9A). Here there are several examples on bedding plane surfaces of *Phialopecten triphooki triphooki,* the index fossil for the Mangapanian, From the ridge crest, there are views of the Ruahine Fault in the Omahaki Stream adjacent, Mt. Miroroa, the Kaweka Range, and Glenross Range marking the western limb of the Hawke's Bay Monocline.

Significance - Well exposed Kaumatua Formation with abundant fossils showing the lenticular geometry of the carbonate bodies and their relationship to the surrounding sandstones. Were the carbonates deposited as mounds ie., with positive relief, or do they infill depressions (troughs)? The western side of the Lizard is bounded by the Lizard Fault, while the eastern side is bounded by the Glenross Fault.

Day Three

Locality I - Ngaruroro River, Kuripapango (U20/965955)

Suggested Duration – 20 minutes

Watch for traffic!

During the Taupo ignimbrite eruption the catchments of the central North Island were choked with a variety of pyroclastic debris. A recent paper by Segschneider et al. (2002) describes a series of depositional phases associated with the 1.8 ka eruptive episode. In a regional sense, an initial period of laharic remobilisation was followed by two phases of fluvial remobilisation. At this locality, the Taupo ignimbrite deposit is some 2 m thick and approximately 20 m topographically above the present-day Ngaruroro River level. Grading, planar lamination, cross-bedding, and abundant charred fragments of vegetation (up to log size) are evident and indicate fluvial reworking of the pyroclastic debris. This gives an idea of the volume of sediment involved (Kuripapango is approximately 70 km from the eruptive centre at Horomatangi Reef), as well as the extreme consequences that the eruption had in the catchments of the central North Island. Similar deposits, also 20-30 m above present-day river levels will be seen in the Taruarau River (Locality L) where the pumice was locally ponded before exiting through a narrow greywacke gorge.

Locality J – Gentle Annie Rd, Kuripapango (U20/961953)

Suggested Duration – 20 minutes

Watch for traffic!

Observations - The youngest marine sediments in the area are a mixture of sandstones, siltstones, gravels, and shell hash comprising the Sentry Box Formation (Fig. 10). Similar facies occur at Mt. Miroroa and the western side of Mt. Kohinga (Beu et al. 1981). On the Gentle Annie, the topographically lower exposure comprises a small fault bounded block on the roadside. The topographically higher outcrop comprises coarse-grained clastics overlain by sandstone and siltstone onlapping a greywacke paleo-high or sea stack (now poorly exposed). These rocks extend west over the summit area of the Gentle Annie, and down the western side of the road, which is bounded to the north by the Kaweka Fault (Browne 1981). Hill (1889) was the first to describe limestone from the Gentle Annie Hill, and it is assumed that the outcrops he observed were also of the Sentry Box Formation.

Significance - These sediments represent the youngest marine deposition in the region.

Locality K – Kaweka Fault Overview (U20/957957)

Suggested Duration – 15 minutes

Watch for traffic!

A brief stop to observe the topographic expression of the Kaweka Fault as a series of active fault traces, and the general Kuripapango landscape. Several splays of the Kaweka Fault pass near the summit of the Gentle Annie Road (above us), and several active traces are visible in the valley immediately to the north. The Kaweka Fault is thought to be dextral, although the most recent movement was likely to be sinistral, based on offset of a small stream east of Kuripapango Hill across the Kaweka Fault. The Lakes (two small lakes east of Kuripapango Hill) were created from damming of a large landslide associated with movement of the Kaweka Fault (Fig. 2). The dramatic topographic step east of Kuripapango Hill (elevation 1250 m) marks the northward continuation of the fault. The elevation change from the top of the hill to the Blowhard Plateau is 750 m. A gravity profile east of the fault to Locality A, indicates approximately 1 km of Mangatoro Formation immediately east of the Kaweka Fault (Browne 1981). This suggests the total vertical displacement on the Kaweka Fault in the Kuripapango area of at least 2 km.

Locality L - Taruarau River (U20/874917)

Suggested Duration – 15 minutes

A brief stop to observe coarse-clastics on the left bank of the Taruarau River. They include abundant carbonaceous debris, channellised bedforms, cross bedding, and multiple stacked cycles. What are these units and how would you interpret their depositional setting based on what you've seen over the past two days?

Locality M - Ngamatea Station Limestone Escarpment (U20/833906)

Suggested Duration – 30 minutes

Observations - Adjacent to the Taihape-Napier Road is a 10-15 m high escarpment of Kapitean grainstone of the Blowhard Formation. It forms a flat-lying escarpment west of the Taruarau River.

Significance - Unlike the Kuripapango region, at Ngamatea Station the Blowhard Formation comprises mostly limestone (this stop) and sandstone lithofacies (locality N) with little in the way of conglomerate. A large, previously unmapped fault, the Taruarau Fault, separates this locality from adjacent Torlesse Terrane sediments exposed further east, and can be traced over a 50 km length to the north and south.

Locality N - Ngamatea Station Sandstone Bluff (U20/779924)

Suggested Duration – 60 minutes

Observations –The geology of Ngamatea Station is dominated by the Torlesse Terrane and a cover sequence of Blowhard Formation limestones (Locality M) and sandstones (this stop). Conglomeratic facies within the Blowhard Formation (ie. Spiral Conglomerate) as observed at Kuripapango seem to be absent, though are exposed further south in Otupae Station and along the Taihape-Napier Rd west of the Taruarau River. Erosion-resistant sandstone bluffs are common at Ngamatea, forming a distinctive Wyoming-like topography (Fig. 18). At this location the lithology consists of well sorted, very fine to fine-grained massive, cross-bedded and planar laminated sandstone. Beds are often erosive into underlying sandstones, commonly with channels sometimes filled with mudstone rip-up and greywacke clasts (Fig. 18B). Thin-bedded siltstone laminae occur in places.

Significance – The well sorted nature, together with cross bedding and channels indicates a high-energy depositional environment, likely in an inner to mid-shelf setting. Sands were deposited in lower shoreface or mid-shelf settings by both fair- weather and storm currents. This is similar to the interpretations of the Blowhard Formation from the Kuripapango region. During deposition the Kuripapango Strait extended across the top of the ranges, and these sediments mark the initial depositional succession characterised by high energy currents in this interior seaway. The bulk of the Pliocene succession observed at Kuripapango is not evident at Ngamatea, albeit for as yet poorly dated conglomerates, sandstones, and siltstones possibly comparable to the Sentry Box Formation. Quaternary uplift has presumably stripped the bulk of these Pliocene sediments from the Ngamatea region (cf. Kamp et al. 2002 for uplift rates based on fission track studies).

A B

Figure 18. A. Bluff-forming topography consisting of Blowhard Formation sandstone (U20/756953). The abundance of cross-bedding, channels, and the shelf faunas suggests deposition in shallow marine seas dominated by high energy fair-weather and storm currents. B. Detail of well sorted pebbly sandstone within channel of the Blowhard Formation at U20/779924 (50 cm scale with 10 cm divisions).

Locality O - Rangitikei Bridge (U19/709863)

Suggested Duration – 15 minutes

A brief stop will be made at the old Rangitikei Bridge, the last remaining structure from the stage coaching days of the nineteenth century (Fig. 19). Quaternary gravels in the river banks rest on Torlesse Terrane outcrops at river level.

Figure 19. The single lane suspension bridge over the Rangitikei River, the last remaining road structure from the historic inland Patea Road.

Locality P -Rangitikei Unconformity (T21/689849)

Suggested Duration – 10 minutes

Watch for traffic!

A brief stop to view an angular unconformity between steeply dipping Torlesse Terrane (below), and gently south-dipping Neogene sediments (above the farm track).

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