GEOSCIENCES 09

Annual Conference
Oamaru, NZ

FIELD TRIP 3

COASTAL OTAGO – WESTON TO KAKANUI AND OAMARU

Wednesday 25 November 2009

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Introduction

This trip will visit a number of classic fossil localities around Oamaru and Kakanui, and will provide a window into the complex paleoenvironments created by interaction between Late Eocene-Early Oligocene basaltic volcanism and shallow marine sedimentation. We will examine the Oamaru Diatomite, visit several limestone quarries in Ototara Limestone including the working quarry at Parkside, the brachiopod coquina at Everett's Quarry and the diverse bryozoan faunas at McDonald's Quarry. We will then visit coastal sites including the fossiliferous Surtseyan volcaniclastics at Bridge Point, the complex Early Oligocene to Early Miocene hardground sites at All Day Bay and Gee's Point, Awamoa Beach, and Old Rifle Butts where fossiliferous Mount Harris Beds, Gee Greensand, and rhodolith-bearing Ototara Limestone are exposed.

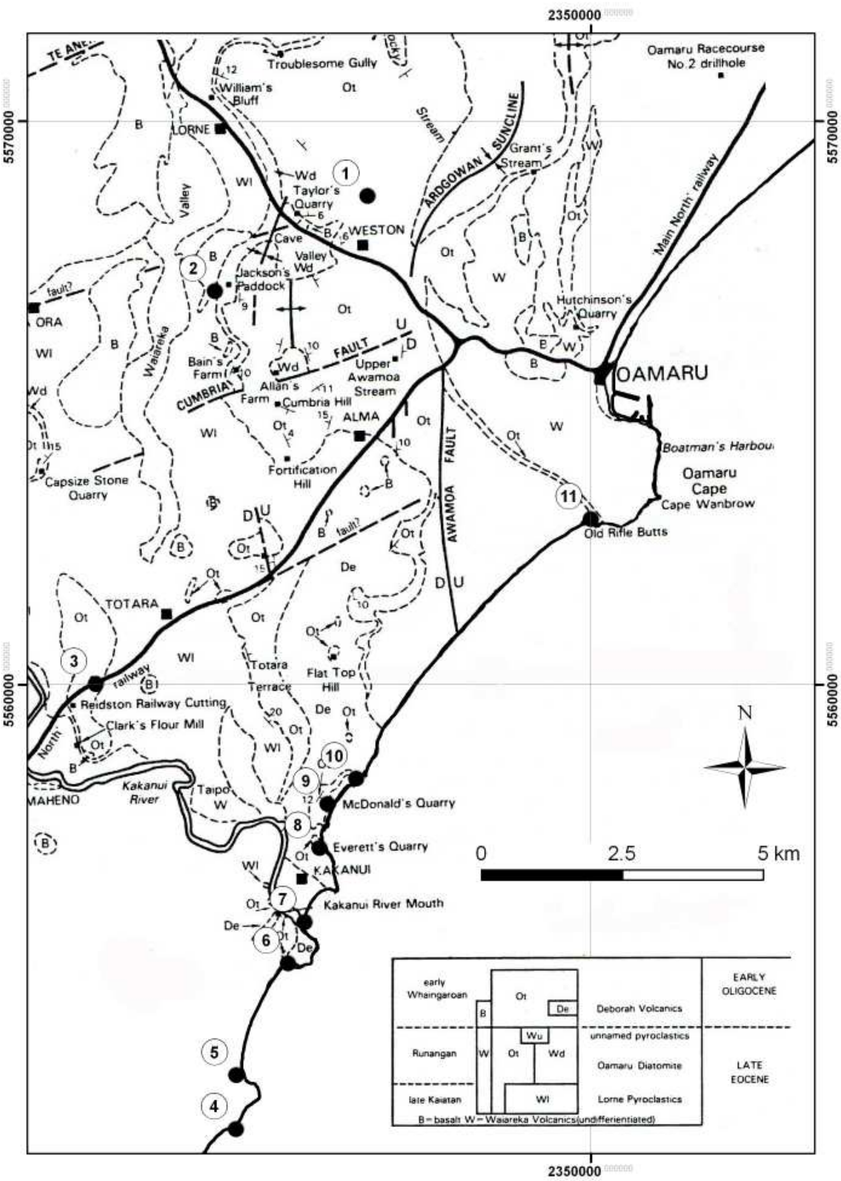
Tide times for Oamaru: Wed 25th Nov 2009: High 9:54 am Low 4:38 pm

Stop 1. Parkside Quarry

The Ototara Limestone (Early Whaingaroan) is a well-sorted bryozoan limestone with little or no volcanic ash, and its creamy colour, uniform texture and strength, as well as its relative softness for cutting and carving has made it a popular building material for both local use and for export. Stone is extracted in massive 2-tonne blocks from the quarry floor at Parkside by a huge cutting saw mounted on the arm of a digger. The limestone is then cut into smaller blocks and treated with a water repellent silicone when used as cladding on buildings. Most of the older historic buildings in Oamaru are constructed of local "Oamaru Stone" quarried from many smaller, now disused sites.

Fig. 3.1. Ototara Limestone has been quarried at Parkside Quarry near Weston since 1906.

Left. One of many buildings in the historic precinct of Oamaru constructed from "Oamaru Stone". The Oamaru courthouse was built in 1882-83 to a classical design reflecting the influence of Palladian architecture. Photo JK Lindqvist.



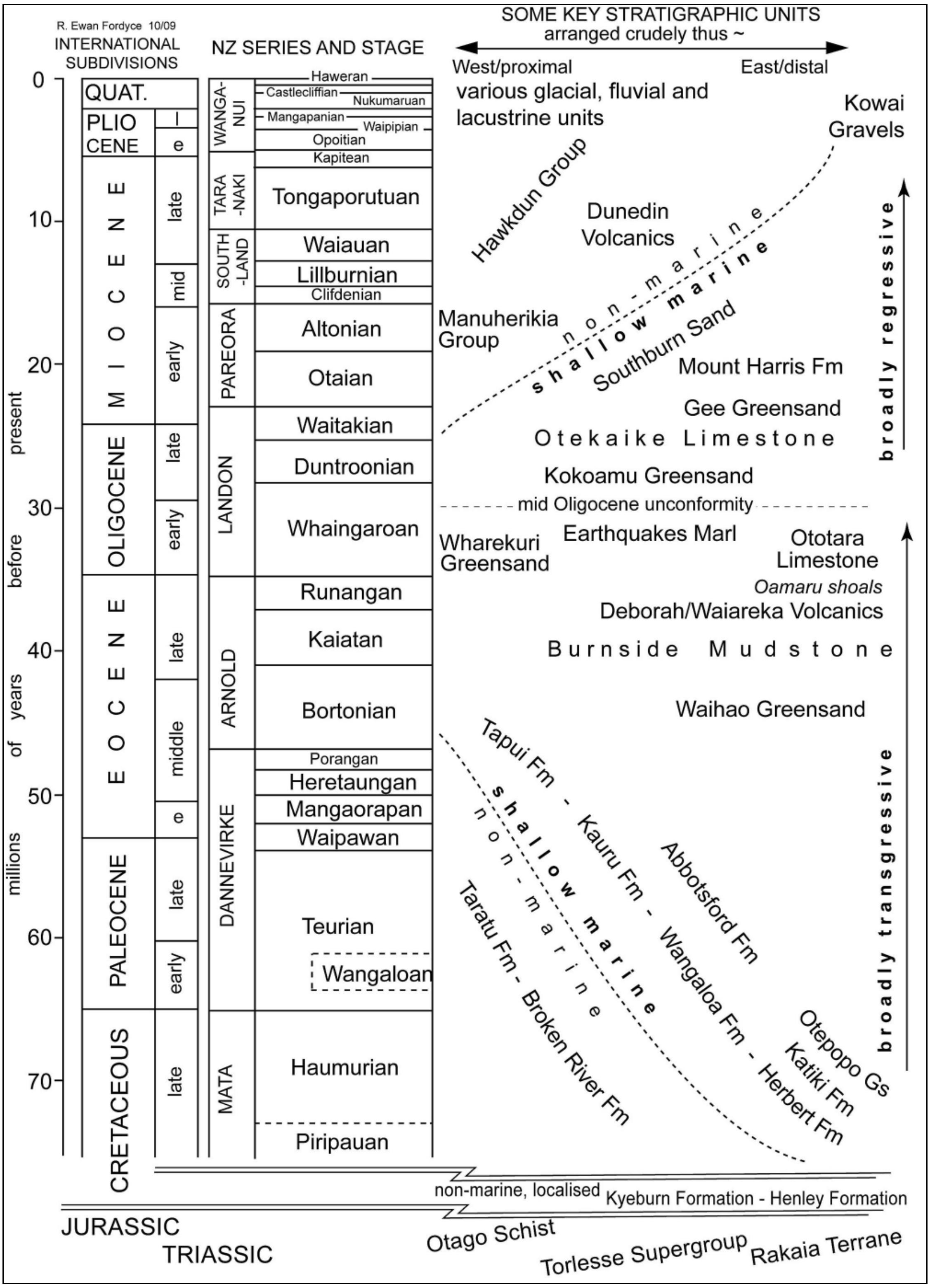


Fig. 3.3. Stratigraphy of Canterbury Basin - South Canterbury to North Otago and Dunedin (RE Fordyce).

Stop 2. Oamaru Diatomite, Jackson's Paddock, Springhill Road

The most detailed account of the Late Eocene (Runangan) Oamaru Diatomite comes from Edwards (1991). The type locality of the Oamaru Diatomite is well exposed in the steep upper slopes of a westward facing escarpment, above Springhill Road. The contact between the diatomite and the underlying Springhill basalt sheet is not visible, but three separate diatomite beds can be recognised on the slopes of the hill below the Ototara Limestone escarpment. The impure diatomite extends over about 25 km^2 and ranges in thickness from about 20 to 40 m. In addition to a very diverse flora of marine diatoms (over 60 genera, and more than 600 species are listed by Desikachary & Sreelatha 1989), there are numerous other microfossils including 50 genera and 127 species of radiolarians (O'Connor 1999), foraminiferans, ostracods, silicoflagellates, sponge spicules, and calcareous nannoplankton (Edwards 1991). In addition a limited fauna of small brachiopods, bivalves, gastropods, and occasional crinoids and cidaroids has been recorded from this unit.

Fig 3.3. The type locality of the Oamaru Diatomite above Springhill Road, and a selection of diatoms from Jackson's Paddock prepared and mounted by A. J. Doig. Diatom photograph by D. Weston.

The diatomite has been renowned for the diversity and richness of exquisitely preserved diatoms since the early days of microscopy. Diatom samples from Oamaru were traded around the world and became the subject of numerous papers in the international literature (Lautour 1889; Schrader 1969; Edwards, 1991). Some are found nowhere else, while others occur in a few late Eocene beds in other parts of the world.

According to Richman & Carter (2007) "The variety of forms present in the Oamaru diatomite is astonishing in comparison with most other sites. Some of the diatoms are triangular (often with various ornamentations), others circular, boat-shaped, hexagonal, pentagonal, square, spindle-shaped, shaped like watches or helmets, and some shapes are difficult to describe at all. Genera include *Cestodiscus*, *Melosira*, *Paralia*, *Stephanopyxis*, *Actinocyclus*, *Brightwellia*, *Coscinodiscus*, *Porodiscus*, *Actinoptychus*, *Aulacodiscus*, *Asterolampra*, *Rutilaria*, *Arachnoidiscus*, *Stictodiscus*, *Chaetoceros*, *Hemiaulus*, *Trinacria*, *Biddulphia*, *Grovea*, *Kittonia*, *Auliscus*, *Triceratium*, *Synedra*, *Cocconeis*, *Amphora*, *Mastogloia*, *Navicula*, *Nitzschia*, *Pinnularia"*

Edwards (1991:3) concluded that "the Oamaru Diatomite was deposited under quiet well-mixed, marginally tropical to warm subtropical waters, at depths of 75 to 150 m in a basin located some 50 km offshore from a low-lying landmass and adjacent to volcanic shoals that from time to time were surmounted by small, short-lived volcanic islands". Deposition of this unusual sediment is attributed to "a widespread phase of explosive volcanism (which) created a basin sufficiently deep and starved of land-derived sediment that, when volcanic activity waned, it could gradually fill with biogenic sediment largely derived from plankton blooms maintained by nutrient-rich waters upwelling near the margins of the basin". Diatomite-sponge-radiolarian deposits occur in a number of other Late Eocene sites around the Pacific rim (Peru, Ecuador, California and Australia). Their more-or-less-simultaneous formation is seen by some authors as evidence for a "silica window" in the Late Eocene resulting from a combination of increased volcanism and warm climate (McGowran et al. (1989).

Alma road cutting (note in passing)

From Jackson's Paddock, we will return to SH1 and drive south to Reidston past a low road-cutting at Alma on SHI (~8km south of Oamaru) which is a somewhat unlikely setting for a highly diverse bryozoan fauna. This locality, of early Runangan age, includes large numbers of angular or subrounded basaltic cobbles and pebbles that are encrusted by coralline algae (probably *Sporolithon* sp.), serpulids, bivalves (*Dimya* sp.) and at least 60 species of well-preserved bryozoans (Lee et al. 1997). The fauna also includes a number of small brachiopods, bivalves and echinoids, and the large foraminiferan *Asterocyclina hornibrooki* which indicates deposition in a shallow, subtropical sea. The bryozoans from this locality include species which persist with little, if any, change into the present-day seas around New Zealand. The pebbles and cobbles have the most diverse encrusting bryozoan fauna of Late Eocene age recorded from anywhere in the world. A very similar occurrence of encrusted volcanic pebbles, including large numbers of subrounded, 10-50mm diameter rhodoliths, is present in another roadcut on Fortification Road, near Kakanui. Many of the basalt cobbles and pebbles are highly vesicular, and the presence of angular boulders up to 130mm in diameter suggests one or more subaerial eruptive vents near to these sites.

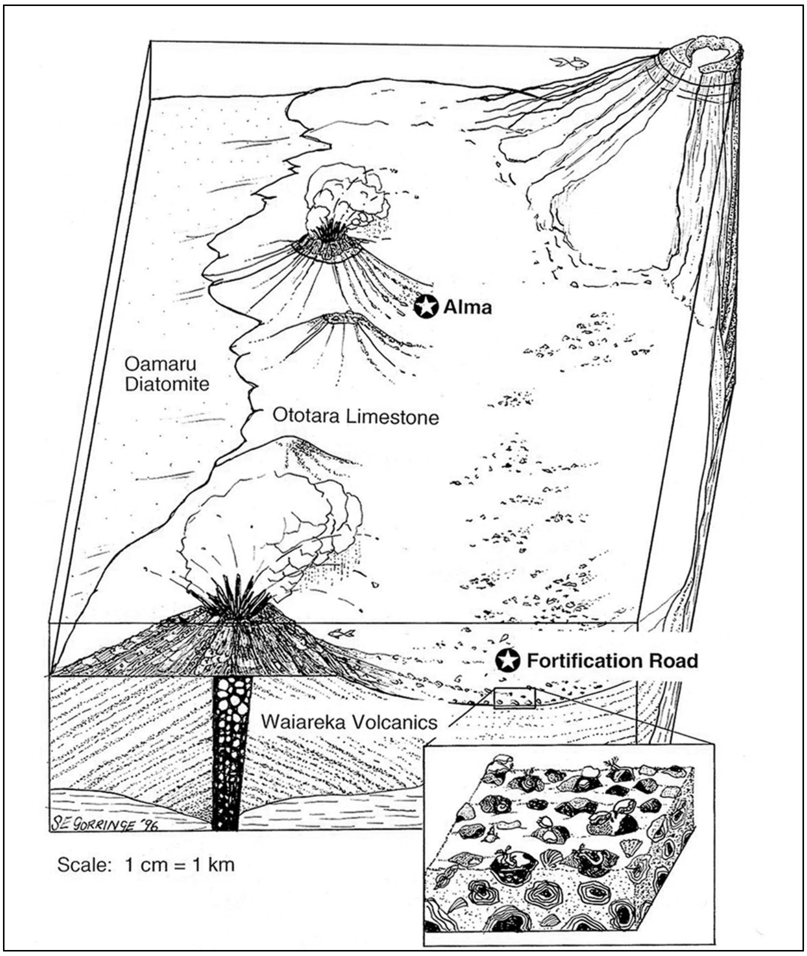


Fig. 3.5 is a reconstruction of part of the Oamaru volcanic field in Early Runangan time, and shows the relative sites of deposition of the contemporaneous pebble and cobble horizons, the Ototara Limestone, the Oamaru Diatomite, and unfossiliferous Waiareka tuffs.

It seems likely that a 10km wide, and perhaps 20km long volcanic high extended in a north-south direction nearly parallel to the present-day coastline. The encrusted pebbles and cobbles seem to have been deposited in a channel adjacent to submarine and subaerial vents. During periods of quiescence Ototara Limestone accumulated on the volcanic highs, and Oamaru Diatomite was deposited in a somewhat deeper basin to the west. Figure drawn by the late SE Gorringe.

Stop 3. Reidston, contact between limestone and tuffs

At Reidston we will make a brief stop above a railway cutting which exposes the contact between the Ototara Limestone and underlying bedded volcanic tuffs of the Waiareka Volcanic Formation.

Note Clark's Flour Mill to the left, before we cross the railway line just south of Reidston. Built around 1865 of Ototara Limestone cut from the hill behind the mill, this is the only surviving water-powered flour mill with early machinery substantially intact (see NZ Historic Places Trust web site for further information).

We will cross the Kakanui River at Maheno where we may make a brief stop at St Andrew's Anglican Church, if time permits. The church was constructed in 1938 of rust-coloured quartz sandstone (Taratu Formation) quarried from the Kuriheka Estate, a few km to the west. A few km past the small township of Herbert, note the flat-topped Mount Charles above the railway line where a basalt sill of Late Eocene age intrudes glauconitic mudstones of Eocene age. To the southwest, across the Waianakarua River, Quaternary gravels rest with angular unconformity on Late Cretaceous and Paleocene greensands and mudstones. Marine fossils of Late Cretaceous age including bivalves and gastropods (Aitcheson et al. 1993) and ammonites such as *Kossmaticeras* occur in concretions in the river

We will turn east at Waianakarua, beside the Mill House, just before crossing the oldest bridge on SH1 still in use. The masonry bridge built of local limestone in 1874 was strengthened and widened in 2005, and carries an IPENZ 1990 plaque recognising its engineering heritage status.

Stop 4. Bridge Point (tide dependent)

Bridge Point is the site of a small, monogenetic, continental-shelf Surtseyan volcano of late Eocene (Runangan) age. The lower part of the sequence is unfossiliferous, and may represent a short-lived eruption (active for days or weeks at most) (Cas et al., 1989). The upper part of the exposure consists of about 25m of epiclastic, redeposited volcanic clasts and tuff, lime mud, some glauconite, and a wide assortment of invertebrate fossils, many of which may have colonised the wave-planed upper surface of the volcano. The fauna at Bridge Point is well preserved and highly diverse, although because most specimens are small, and scattered through the outcrop, the diversity may not at first be apparent. Fossils include at least 50 species of molluscs, brachiopods, bryozoans, serpulids (including large coiled *Glomerula* attached to basalt cobbles), octocoral holdfasts, cidaroids, foraminifera (including *Bolivina pontis* Finlay, a Runangan indicator which has its type locality at Bridge Point), and a wide array of trace fossils. Brachiopods occur as small double valved, hollow shells, now infilled with sparry secondary calcite that obscures internal structures. *Aetheia gualteri*, *Liothyrella* and *Magella carinata* are quite common at Bridge Point, as are scattered valves of *Novocrania*, *Tegulorhynchia* and *Terebratulina.* Molluscs are locally common, particularly in the bands with pink tuff. They include the bivalves *Limatula*, *Limea*, *Marama, Quadrilatera, Serripecten venosus* (Hutton), the gastropods *Anatoma*, *Argalista*, *Conus, Cypraea*, *Emarginula*, *Trivia*, a pteropod *Limacina,* and a nautiloid, *Aturia* (Beu and Maxwell 1990). The probable habitat was on the flanks of a volcanic seamount, with mixing of shallow and deeper-water biotopes, and the abundance of pteropods may have resulted from upwelling. Several genera, including *Arca, Conus, Cypraea* and *Quadrilatera* indicate subtropical conditions.

Stop 5. All Day Bay Lagoon Wetland

Near the coast at All Day Bay is a brackish water lagoon with swampy rush, sedge and succulent herbs margins. The lagoon supports a wide variety of waterfowl including paradise shelduck, New Zealand shoveller, grey teal, grey duck, oyster catcher, pied and black stilt, mallard, black swan, white-faced heron. Protected by a QRII National Trust Open Space Covenant since 1993, the 10ha reserve is also visited by royal spoonbills, glossy ibis and white heron.

Stop 6. Campbell’s Beach, Kakanui

The sequence at Campbell’s Beach has attracted much debate from stratigraphers interested in the limestones (Gage 1957; Fordyce et al. 1985). There are two limestones in succession, each truncated by an unconformity. The lower limestone is the Ototara, characteristic of the Oamaru region of North Otago, while the upper limestone is the Otekaike, better developed inland and to the north. Most of the Tertiary sequences thicken to the east (basin-ward) but here the Otekaike Limestone has thinned to the east, indicating a nearby high late in the Oligocene (Field & Browne 1989). At Campbell’s Beach, the basaltic volcanics are closely associated with 5+ m of bryozoan-rich bioclastic Ototara Limestone, which is muddy and tuffaceous in the base and cemented toward the top. This is also the type locality (and type horizon) for the key zonal planktic foraminiferan *Subbotina angiporoides*. Also of note are the zonal *Globigerina brevis*, and shallow water benthics such as *Amphistegina*. The Ototara is overlain unconformably by 50cm m of hard, cemented, glauconitic Otekaike Limestone (Waitakian; Late Oligocene) with a conspicuous macroinvertebrate fauna including scleractinian corals, octocorals, molluscan moulds, and worn vertebrate bones. Further inland the Otekaike Limestone thickens rapidly to more than 30 m. The overlying thin Gee Greensand, which infills pockets in the limestone, includes little terrigenous debris, and is rich in phosphatic nodules, bone fragments, and shark teeth. Foraminifera include relatively common *Globoquadrina dehiscens*, a zonal fossil for the local Waitakian stage. The Gee Greensand rapidly becomes more muddy upwards, and within a few m produces foraminifera characteristic of the early Miocene Otaian stage. The greensand grades up into grey massive calcareous mudstone of the Mount Harris Formation, which yields the age-diagnostic benthic *Haeuslerella pukeuriensis*, and planktics including *Globorotalia incognita* – both characteristic of the warm Altonian stage (later early Miocene) (Fordyce et al. 1985).

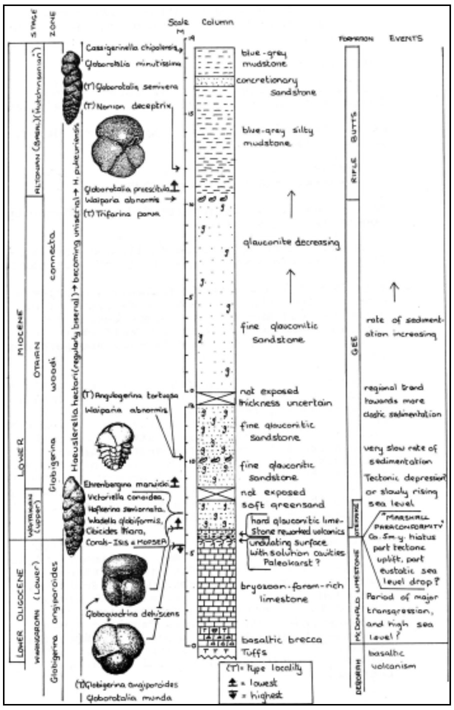


Fig. 3.6. Sequence at Campbell's Beach, Kakanui (Figure from Hornibrook 1982). McDonald Limestone now = Ototara Limestone; Rifle Butts Formation = Mt Harris Formation

Stop 7. Kakanui Mineral Breccia, north bank Kakanui River

Crystalline tuffs (Kakanui Mineral Breccia) (KMB) of the Waiareka-Deborah Volcanics (sensu Coombs et al. 1986) form the two headlands north and south of the Kakanui River. The Kakanui Mineral Breccia is a shallow-water volcaniclastic sediment, usually well sorted, and cemented by calcite and phillipsite. It is characterized by an abundance of exotic xenoliths of presumed upper-mantle derivation (80 to 90 km depth). Xenoliths include spinel lherzolites, garnet pyroxenites, amphibolites, granulites, schists, sediments, and polished rounded megacrysts up to 20 cm across. The commonest is a black amphibole, kaersutite. In decreasing order of abundance are augite, yellowish-white anorthoclase, reddish garnet, brown mica, ilmenite, green chrome diopside, and apatite. The KMB was erupted around 34 Ma, close to the Eocene-Oligocene boundary (Hoernle et al. 2006).

Stop 8. Everett's Quarry (private property)

About 2 m of nearly flat-lying bioclastic coquina limestone is exposed in this long-disused quarry, about 1km north of Kakanui. Everett's Quarry contains a diverse fauna of exquisitely preserved brachiopods of Early Whaingaroan age. At least a dozen brachiopod genera, including the small cemented forms *Kakanuiella hedleyi* and *Novocrania chathamensis,* the rhynchonellids *Aetheia gualteri* and *Tegulorhynchia sublaevis* and thousands of juvenile and adult *Terebratulina suessi* are present at this locality. The bryozoans are similarly diverse and well-preserved, especially those encrusting larger brachiopod shells, or living on the micritic geopetal infillings of the large smooth brachiopod, *Liothyrella.* The presence of many large foraminifera, including *Amphistegina* and *Wadella,* and the diverse brachiopod fauna, together with barnacles and serpulids indicate deposition in shallow, warm water on a volcanic high.

Stop 9. McDonald's Quarry (private property)

A large limestone quarry about 700 m northwest of Everett's Quarry was the type locality for the McDonald Limestone of Gage (1957) which is now regarded as the upper unit of the Ototara Limestone. The limestone is a well-cemented to friable, massive, creamy-white bryozoan calcarenite, with occasional yellowish-brown tuffaceous lenses. Brachiopods such as the large, smooth *Liothyrella* are abundant, as are foraminifera, but the fauna is dominated by dozens, possibly hundreds of species of bryozoans. McDonalds Quarry is the type locality for 22 species described by Brown (1952) in a major monograph. Genera include *Adeona, Aspidostoma, Cellaria, Celleporina, Chaperia, Exochella, Foveolaria, Porina,* and *Smittina*. There is a marked difference between the fauna here which was considered by Brown to have been deposited in deep sheltered waters, and that at nearby Everett's Quarry.

Note that the quarry is currently being used to supply large boulders to counteract rapid coastal erosion between Kakanui and Oamaru

Stop 10. Gee's Bay (tide dependent; steep slippery access)

An interesting and complex Early Oligocene to Early Miocene hardground paleoenvironment is exposed along the coastal section south of Gee's Point, about 500m north of Everett's Quarry. About 4 metres of bryozoan-dominated Ototara Limestone grades up from calcareous tuffs with scattered fossils. The upper metre of the Whaingaroan limestone becomes progressively more phosphatised and the common occurrence of *in situ* octocoral holdfasts on the dark brown, highly phosphatic upper surface suggests that this represents a submarine hardground. A second, much younger lithified glauconitic limestone, the Otekaike Limestone of Waitakian (Early Miocene) age infills burrows, borings and cavities in the upper Ototara Limestone, and incorporates pebbles and cobbles of the older brown phosphatic limestone. The Duntroonian Stage is missing in this section, although inland from Oamaru it is represented by the widespread fossiliferous Kokoamu Greensand. A younger greensand unit, the Gee Greensand, blankets the highly irregular hardground surface, and the lower 30-50cm includes numerous octocorals and reworked Waitakian foraminifera. A few brachiopods, decalcified molluscs, and bryozoans are scattered through the upper Gee Greensand which is of Otaian (Early Miocene) age.

Fig. 3.7. In the foreground is the corroded, burrowed and bored phosphatised top of the Lower Oligocene Ototara Limestone which is overlain by a thin veneer of unphosphatised glauconitic Upper Oligocene Otekaike Limestone containing poorly rounded clasts of the Ototara Limestone. Early Miocene Gee Greensand rests paraconformably on the irregular contact with the cemented older limestones.

Stop 11. Old Rifle Butts (tide dependent)

This is reached by walking north along the coast below the Oamaru golf course, then along the beach to the cliff section. Watch for falling debris! The first exposure is the blue-grey Rifle Butts Formation or Mount Harris Beds, a poorly-bedded deep water siltstone of Altonian age which has scattered molluscan fossils and occasional corals. Lower in the section is the "*Turritella*" shellbed, made up of numerous internal moulds of a large turritellid gastropod. The silts grade down into more glauconitic and sandy Gee Greensand of Otaian age. The basal 1.5m of Gee Greensand is crowded with the large, mostly double-valved, smooth terebratellid *"Pachymagas"*. The Gee Greensand rests on the bored and corroded, phosphatised upper surface of the Ototara Limestone which here comprises about 1.5m of spheroidal or ovoid rhodoIiths of calcareous algae (possibly *Lithothamnium sp.)*, which encrust small basalt pebbles or brachiopod fragments. The matrix between the rhodoliths is a hard, white, bryozoan limestone, of probable Whaingaroan age, or a glauconitic limestone which is the equivalent in coastal sections of the Waitakian Otekaike Limestone. As at Gee's Bay and Campbell's Beach, the Kokoamu Greensand is missing from this section.

Beneath the rhodolith bed are several metres of fossiliferous greenish-grey calcareous tuffs, and then a bed of massive bryozoan limestone which is the type locality for the Ototara Limestone (Gage, 1957). Further down in the section are volcaniclastic limestones, fine grained tuffaceous beds which weather back into narrow fissures, another rhodolith bed, and numerous calcareous, fossiliferous and unfossiliferous tuff units.

A conspicuous raised beach deposit which slopes gently to the south is perched on the cliff above the mid Cenozoic sedimentary strata. It contains large rounded blocks of the "rhodolith member" of the Ototara Limestone, rounded cobbles, and molluscs. This raised beach marks the actual position of the 125,000 year old shoreline as is apparent from the sea cave which cuts back into the dipping Gee Greensand and other units.

Fig. 3.8. The succession of dipping beds of the Ototara Limestone (the upper few metres of which are tuffaceous), overlain by a 1-5 m thick rhodolith bed and the brachiopod-rich Gee Greensand. Note the 125,000 year old sea cave about 5 m above the present day beach. Closeup of the packed rhodoliths (left), and the smooth monospecific terebratellid brachiopods embedded in the Gee Greensand.

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