50th Kaikoura05

The Organising Committee extends a warm welcome to all delegates and visitors to Kaikoura, where it all began 50 years ago.

Please note that all information in this publication was correct at the time of going to print. However, due to factors beyond our immediate control, such as weather, road conditions and permission for land access, some unexpected late changes in field trip routes and itineraries may be required.

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Field Trip Guides

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Field Trip Guides – Contents

FIELD TRIP 8

FOLLOWING IN MCKAY'S FOOTSTEPS – ICONIC CRETACEOUS TO NEOGENE SUCCESSIONS, HAUMURI BLUFF, MARLBOROUGH

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Introduction

Haumuri Bluff is a classic stratigraphic site, a key to understanding the development of our geological timescale, and yet it is seldom visited by today's geologists. Haumuri Bluff was a tremendously important site for fossil collecting in the late nineteenth century (e.g., Haast 1871; Hector 1874; McKay 1877 & 1886), most notably, for the abundant macrofossils collected and the stories that surrounded these collection trips. From such collections was established the Late Cretaceous Mata Series (Finlay & Marwick 1947), later refined by Harold Wellman at the 1955 New Zealand Geological Survey Conference in Kaikoura (Fig. 1; Wellman 1959). Wellman proposed that the Mata Series should comprise the Piripauan, Haumurian and Teurian stages, though the Teurian was later moved to the Tertiary (Hornibrook 1962). In a twist of fate, Haumuri Bluff is no longer considered suitable as a type section, yet it remains a historically significant site for sedimentary geologists and stratigraphers.

Figure 1. Harold Wellman talking on his classification of NZ Cretaceous Stages at the NZ Geological Survey Conference in Kaikoura 1955.

In the course of this trip we will view the interval stratotype sections for the Piripauan and Haumurian Stages at Haumuri Bluff and Haumuri Bluff railway cutting, as well as some of the Tertiary units of the area (Fig. 2). Emphasis will be placed on the history of research in the area, the stratigraphic concepts that have developed over the last 150 years, as well as our present understanding of the age relationships and depositional setting of the sediments examined. This trip is somewhat of a re-enactment of a field trip on 12 May 1955 to Haumuri Bluff, lead by Horace Fyfe. During that 1955 Kaikoura Conference trip, the party geologised from Claverley to Oaro a distance of 10 km, all in the afternoon, and all by foot!

During the trip we also want to acknowledge and reflect on the great work undertaken by our colleague the late Guyon Warren over a number of years at Haumuri Bluff, and indeed in Marlborough and Canterbury, as reflected in his NZ Geological Survey bulletin (Warren & Speden 1978), and GNS published geological map for this area (Warren 1995).

HEALTH & SAFETY

Travel from State Highway 1 is by 4WD vehicles to Okarahia Stream and out to Haumuri Bluff. Please be aware of certain hazards on today's trip. We will be examining rocks in coastal sections, so there may be loose rocks falling from higher ground, as well as dangers from rising tides, slippery and sharp rocks, negotiating a steep grassy bank, as well as resident seals along the beach. Lowtide today is approximately 1205 hours. In addition, one of our sections is adjacent to the main trunk rail line, and everyone needs to be alert to possible train movements.

HISTORY OF GEOLOGICAL RESEARCH AT HAUMURI BLUFF

Early Studies

The discovery and collection by Hood of fossils at Waipara in 1859, followed by the identification by Owen (1862) of fossil reptile bones, initiated a series of studies on Cretaceous sequences in Marlborough and North Canterbury between 1865 and 1876. Sir James Hector developed a keen interest in the region and, following his instructions, Buchanan (1868) explored the region and published the first geological information on Haumuri Bluff. However, it is probable that fossils were collected earlier from Haumuri Bluff (Hochstetter 1864; see Warren & Speden 1978). Then followed the more detailed stratigraphic studies and collection of fossils by Haast (1871) in 1869, Travers in 1871, Hutton (1874) in 1871, McKay in the summer of 1872-73 (Hector 1874), Hector and Hutton in 1873 (Hector 1874), and McKay (1877) during March to July, 1876.

No further significant mapping or collecting was undertaken for nearly 60 years until the unpublished work of H. E. Fyfe in 1934. However, important paleontological studies were published by Hector on reptiles (1874) and belemnites (1878), Woods (1917) on molluscs, Wilckens (1922) on gastropods, and Marshall (1926) on ammonoids. Information from these studies provided the foundation for the stratigraphic subdivisions (group and stage) of Thomson (1917) and Finlay & Marwick (1940, 1947), who designated Haumuri Bluff as the type section for the Piripauan and Haumurian stages of the Mata Series. Sadly, as identified by Welles & Gregg (1971), many of the collections made during the 1860's and 1870's were not well documented, maintained or accurately located stratigraphically. Also, large vertebrate collections were lost with the disappearance (sinking) of the ship *Matoaka*, which sailed from Canterbury in May 1869. Collections were also sent to the British Museum and to E. D. Cope at the Philadelphia Museum. The latter are apparently lost (Welles & Gregg 1977).

Historical Context of Cretaceous Stratigraphy

The Cretaceous System spans a major transition marking the end of prolonged subduction on the Pacific margin of Gondwanaland, the onset of rifting and, by the end of the Cretaceous, the complete separation of New Zealand from other Gondwana fragments. The Mata Series "cover" rocks are relatively undeformed, non-marine to marine, transgressive successions, widely distributed throughout New Zealand (King et al. 1999; Crampton 2004).

The Mata Series was originally introduced by Finlay & Marwick (1947), with three stages – the Piripauan (Thomson 1917), Teurian (Finlay & Marwick 1947), and Wangaloan (Morgan 1918; Fig. 3). Subsequent work suppressed the Wangaloan (Hornibrook & Harrington (1957), and transferred the Teurian to the Tertiary (Hornibrook 1962). Wellman (1959) recognised three stages in the Mata Series – the Piripauan, Haumurian, and Teurian.

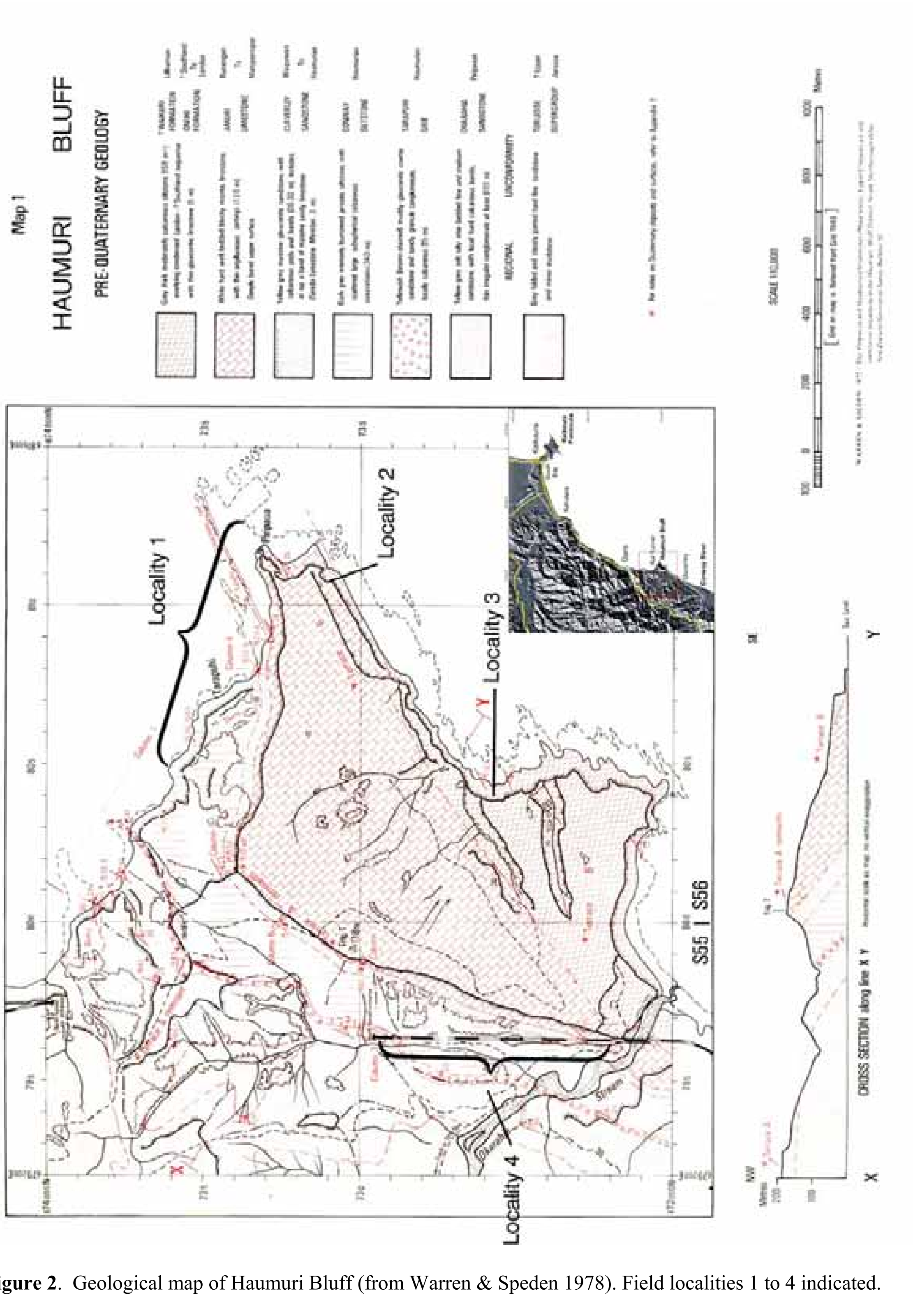

Figure 2. Geological map of Haumuri Bluff (from Warren & Speden 1978). Field localities 1 to 4 indicated.

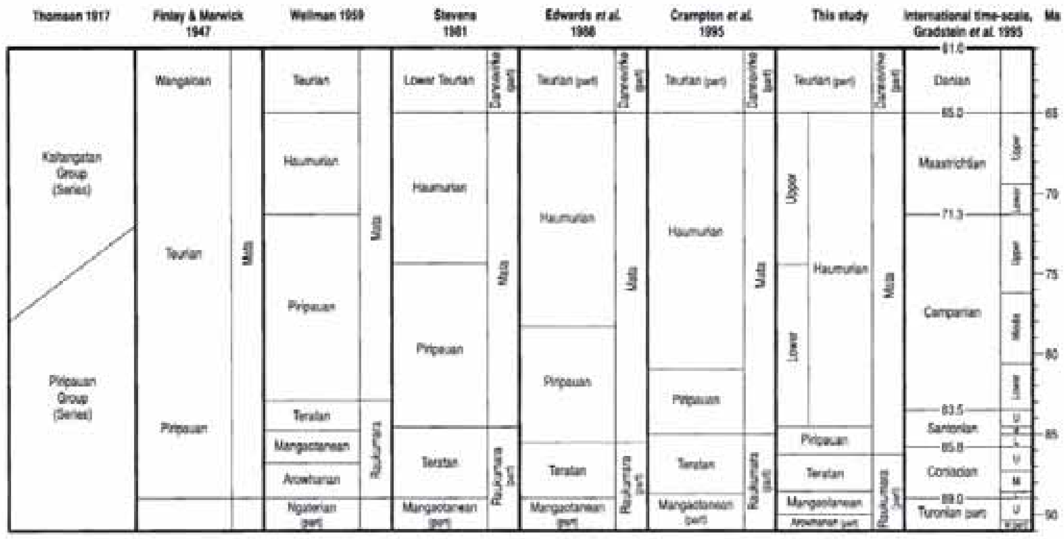

Figure 3. Summary of the historical concepts of the Mata Series and its stages from Crampton et al. (2000). Earlier publications are referenced in Crampton et al. (2000).

The "Piripauan Group" was originally defined to include all strata at Haumuri Bluff (Thomson 1917) from the "*Teredo* Limestone" to the cannon ball sandstone. Subsequent recognition of the Piripauan and Haumurian stages of the Mata Series (after Wellman 1959 and Hornibrook 1962) limited the Piripauan Stage to strata containing *Inoceramus pacificus* and *I. australis*. This definition created numerous problems for subsequent workers (Warren & Speden 1978) as summarised by Crampton et al. (2000).

Haumuri Bluff is no longer considered an appropriate Late Cretaceous stratotype because:

- the base of the section is a major unconformity, so much of Piripauan time might be absent
- the fossil fauna in the Piripauan of Haumuri Bluff is facies controlled and, hence, not typical of coeval taxa elsewhere in New Zealand
- the Haumurian is a glauconitic facies at Haumuri Bluff and thus could represent slow sedimentation
- the upper Haumurian is poorly defined in the Haumuri Bluff section
- much of the Haumurian is devoid of calcareous fossils at Haumuri Bluff
- the polytaxic nature of the index Haumurian fossil *Inoceramus matotorus* and the poorly understood taxonomy of the other index macrofossil, *Ostrea lapillicola.*
- the Piripauan-Haumurian boundary at Haumuri Bluff is a disconformity and at least two dinoflagellate zones are missing (Roncaglia & Schiøler 1997; Roncaglia et al. 1999).

For these reasons, new boundary stratotype sections for the Late Cretaceous were erected by Crampton et al. (2000) in a tributary of Ben More Stream, Marlborough. They also redefined the lower boundary of the Piripauan Stage at the lowest occurrence of *Inoceramus pacificus*, though the lower boundary is apparently not present at Haumuri Bluff. The upper part of the Piripauan Stage is represented by the *I. australis* Taxon-range Zone (Crampton 2004).

The Haumurian Stage was originally defined to include strata containing *Inoceramus matotorus* and *Ostrea lapillicola* (Wellman 1959), and was redefined by Crampton et al. (2000) based on the lowest occurrence of the dinoflagellate *Nelsoniella aceras* in the new stratotype near Ben More Stream, Marlborough.

Wellman's (1959) work on the subdivision of the Cretaceous of New Zealand catalysed major research on the geology of Haumuri Bluff, and many other areas, and fossil groups. Important to the geology, biostratigraphy and correlation of Haumuri Bluff are the publications of Stevens (1965), Henderson (1970), Webb (1971), Welles & Gregg (1971), Warren & Speden (1978), Wilson (1984a, b), Browne & Field (1985), Warren (1995), Crampton (1996), Roncaglia & Schiøler (1997), Roncaglia et al. (1999), Crampton et al. (2000), Cooper (2004), and Wilson et al. (2005). Notable advances are the detailed zonation by dinoflagellate microfossils of the Haumurian Stage into 11 zones and subzones, the refined lithostratigraphy and chronological dating and correlation, and the identification of the duration of the Piripauan and Haumurian stages as 2.5 ± 0.1 m.y. and 19 ± 0.6 m.y. respectively (Cooper 2004: table 1.3), and the formal subdivision of the Haumurian into Lower and Upper substages.

Pleistocene Terraces

Two prominent terraces of marine origin truncate the Cretaceous-Cenozoic sequences at Haumuri Bluff; the Tarapuhi Terrace at c.164 m a.s.l., and the Amuri Bluff Terrace at c.40 m a.s.l. (Ota et al. 1996). The Tarapuhi Terrace has some 2.5 m of shelly marine deposits, capped by loess c.3.5 m thick. The lower surface is underlain by c.3 m of loess and by c.5 m of marine silt and gravel, with an abrasion platform at c.31 m a.s.l. The reworked faunas indicate derivation from a variety of shallow marine environments. Faunas on both surfaces indicate a cold temperate regime, with the geomorphological and amino-acid epimerisation dating indicating deposition during a cold, even glacial, periods (Ota et al. 1996). Based on amino-acid age of 135 ± 35 ka for *Tawera* shells from the Tarapuhi Terrace, as well as geological correlations, Ota et al. (1996) correlated the terrace with oxygen isotope substage 5c (100 ± 3 ka). They correlated the lower Amuri Bluff terrace to oxygen isotope substage 3 (59 ± 3 ka). These ages give uplift estimates of 1.6 ± 0.1 m/ka and 1.1 ± 0.3 m/ka for the Tarapuhi and Amuri Bluff terraces respectively (Ota et al. 1996).

FIELD STOPS

Locality 1 – Piripaua and Tarapuhi – 3 hours
E2551906; N5850420 to E2552445; N5850049

The majority of the trip will be at the classic north side of Piripaua (meaning paua which are hidden or difficult to find) and at Tarapuhi (meaning windy peak?), type section for a number of Late Cretaceous to Tertiary formations, as well as the original interval stratotype for the Piripauan and Haumurian Stages (Figs. 4 & 5). Descent to the coast is by a steep grassy bank. Please exercise care, and one at a time down the hill! Initially we'll walk west, down through the section, from the Amuri Limestone where we arrive at the coast, through the Claverley Sandstone, to the Conway Formation. The strata are described here in the order they will be encountered (opposite to their stratigraphic order). Please give the resident seals a wide berth!

This is the type section of the Amuri Limestone and it consists of centimetre to decimetre-bedded (stylobedded), light cream to green-grey, hard, bioturbated calcilutite (Browne & Field 1985; Fig. 6). The limestone is made up mostly of coccoliths and foraminifera. Burrows include *Thallasinoides* and *Zoophycos.* Softer centimetre-thick micritic mud or marl is interbedded with the harder limestone. Here the formation ranges from Mangaorapan (possibly Waipawan) at the base (Early Eocene) to Runangan at the top (Late Eocene).

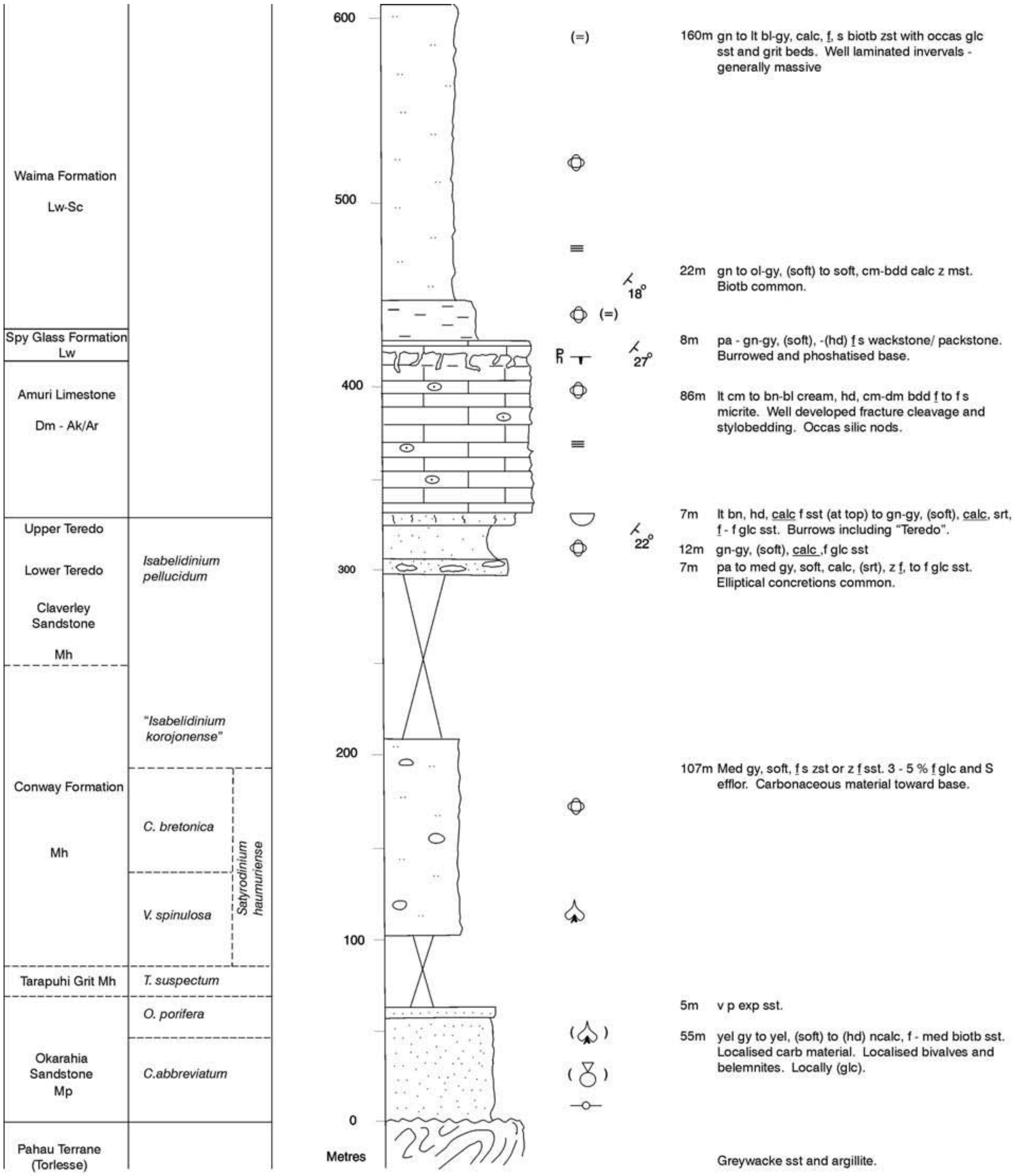

Figure 4. Stratigraphic column, north side of Haumuri Bluff (along beach).

Figure 5. Northern side of Haumuri Bluff from Piripaua (lower right) to Tarapuhi (centre). The base of the section is in the far distance. Stratigraphic units dip toward the viewer and include the type sections for the Amuri Limestone, Claverley Sandstone, and Conway Formations of Eocene-Haumurian age (E2552428; N5850185).

Figure 6. Amuri Limestone exposed at Piripaua, looking up dip toward the contact with the Spy Glass Formation (E2552497; N5850202).

Warren (1995) noted that the environment of deposition of the Amuri Limestone was rather uncertain and cited Morris (1987) and Strong (pers. comm.) in suggesting the unit resulted from pelagic or hemipelagic deposition of calcareous ooze on a soft bottom at bathyal or near bathyal depths. Crampton et al. (2003) inferred the Amuri was deposited on a drowned, bathyal "paleo-platform", based in part on their palinspastic models.

Claverley Sandstone also has its type section at this locality (Warren & Speden 1978), and comprises yellow-brown, poorly sorted, quartzose and glauconitic sandstone, and here is bounded by two prominent reefs, formed of the so-called upper and lower Teredo Limestone members (Fig. 7). The name Teredo Limestone dates back to Hector (1874), while McKay (1877) introduced the lower Teredo Limestone. "Teredo" is usually regarded today as a wood boring bivalve, and the tubes are more probably those of the tube-secreting family Clavagellidae, members of which bore into soft and hard substrates (Warren & Speden 1978). The so-called Lower Teredo Limestone is in fact a series of discontinuous cemented bands or lenses rather than biological structures (Fig. 8). These lenses are up to 1 m thick and 10 m in lateral extent.

Figure 7. Contact between the Upper Teredo Limestone (right) and the Amuri Limestone (left) (E2551071; N5849262).

The Claverley Sandstone represents a considerable time period spanning the Haumurian to Waipawan (latest Cretaceous-Early Eocene). Haumurian dinoflagellates (*Isabelidinium pellucidum* zone) are recorded by Roncaglia et al. (1999) and Wilson et al. (2005) from the formation at beach level, but a sample high on the north face contains an upper Teurian or Waipawan foraminiferal fauna (P. Webb identification in Warren & Speden 1978). Several climatic and carbon cycle perturbations such as the late Paleocene carbon isotope maximum (PCIM, 59-56 Ma), the initial Eocene thermal maximum (IETM, 55.5 Ma), and the early

Eocene climatic optimum (EECO, 53-50 Ma), occurred during deposition of the Claverley Sandstone (e.g., Hollis et al. 2005).

Based on dating available at the time, Warren (1995) concluded the Claverley was probably mainly if not wholly Haumurian and therefore, there was a significant time gap between the Claverley and the overlying Teredo Limestone (upper). This led him to place the Teredo Limestone within the Amuri Limestone Formation, rather than the Claverley. More recent dating (see above) suggests any time gap is much less than was thought, but it seems reasonable to leave the Teredo within the Amuri as both are limestones (or perhaps to give the "upper" Teredo formation rank).

Warren & Speden (1977) and Warren (1995) inferred that the Claverley Sandstone was deposited slowly in a shallow marine setting, with most of its terrigenous detritus transported as wind-blown sand and silt, based on grain size character. The local, occasional deposition of carbonate mud was taken to record low bottom current strengths. The silty nature of the sandstone and a lack of current-derived sedimentary structures were noted as consistent with this, with the proviso that bioturbation could have destroyed some features.

Figure 8. Lower Teredo Limestone comprising a series of cemented lenses within the Claverley Sandstone (E2552149; N5850214).

The north face of Haumuri Bluff is also the type section for the Haumurian Conway Formation (Warren & Speden 1978), a grey massive bioturbated jarositic siltstone or silty sandstone with large spherical concretions. This unit was commonly referred to as the Saurian beds or Saurian sands (Haast 1871; Park 1888), or cannon ball sandstone (Thomson 1917), and has yielded many bone fragments have been recovered. Much of the original fossil collection was sent to Owen in 1869, but was lost at sea en route (Welles & Gregg 1971). Many of the bone fragments are indeterminable but some can confidently be identified as the plesiosaur *Mauisaurus haasti* Hector, and the lectotypes of the two mosasaurs *Tylosaurus* *haumuriensis* (Hector) and *Taniwhasaurus oweni* Hector (Wilson et al. 2005). Dinoflagellate species found in the formation were described recently by Wilson et al. (2005). They recognised three dinoflagellate zones from the formation in this section (cf. Wilson et al. 2005, their fig. 4; see also Roncaglia & Schiøler 1997; Roncaglia et al. 1999).

Bioturbation in the Conway Formation has obscured any depositional sedimentary structures. Warren & Speden (1977) inferred restricted bottom circulation from the fine grain size, benthic fauna and sulphur content of the sediments, and suggested the depositional setting was a low–oxygen, barred submarine depression of wide extent (given that lateral correlatives of the unit). Nevertheless, although the sediment was deposited slowly, quantitative biostratigraphic analysis has recently indicated there were marked changes in sedimentation rate, and probably at least two diastems (Crampton et al., submitted).

The lowest part of the section is not well exposed. The oldest formations, the Tarapuhi Grit and Okarahia Sandstone will be observed at locality 4 this afternoon.

Locality 2 – Piripaua Overview – 30 minutes
E2552445; N5850049

Some clefts south of Piripaua mean that it is difficult to walk through the Amuri Limestone at this stage of the tide. From a grassy overview point, we will observe the upper contact of the Amuri Limestone, into the overlying Spy Glass Formation and Waima Formation. A major phosphatised, burrowed unconformity separates the Amuri Formation from the overlying Spy Glass Formation. This has been referred to variously as the Marshall Unconformity or Marshall Paraconformity, and we will discuss the significance of this horizon in terms of regional geology. Spy Glass Formation was erected by Browne & Field (1985) for centimetre to decimetre bedded green-grey, hard, bioturbated glauconitic sandy wackestone and packstone. Here the Spy Glass Formation is 8 m thick, and of Waitakian age.

Foraminifera from the Spy Glass Formation indicate mid bathyal depths of deposition (>1200 m, C.P. Strong, pers. comm. in Warren 1995).

Locality 3 - Haumuri Bluff – 20 minutes
E 2551815; N5849589

This brief stop is to view the Waima Formation (Waitakian to Middle Miocene) at Haumuri Bluff, especially if people didn't see this formation on the Kaikoura Peninsula field trip. Take care walking down the slippery slope to the coast. The formation comprises light blue-grey, calcareous, very fine sandy mudstone with abundant bioturbation and well bedded laminations of glauconitic sandstone and grit, as well as more massive intervals.

The Waima Formation was probably deposited at bathyal depths (Browne & Field, 1985; Warren, 1995). In some other sections, conglomerates marking initial uplift of the Kaikoura Ranges occur within the Waima Formation.

Locality 4 – Railway Cutting – 1.5 hours
E2551078; N5849862 to E2551071; N5849262

Please be aware of train movements along this section!

The lowest unit at the tunnel portal comprises the Okarahia Sandstone (Fig. 9). The formation is Piripauan in age and consists of yellow-grey, fine to medium sandstone with calcareous concretions, well preserved *Ophiomorpha* burrows, and occasional wood fragments (Fig. 10). Some beds have low-angle cross bedding, and there are also fossiliferous beds containing belemnites. The lower part of the outcrop includes thin pods of phosphatised conglomerate.

Figure 9. Piripauan Okarahia Sandstone (left) overlain by Haumurian Tarapuhi Grit (right – contact arrowed), at the south portal of the railway tunnel (E2551077; N5849772).

Figure 10. Detail of the Okarahia Sandstone with well preserved *Ophiomorpha* burrows and a wood fragment at lower left (E2551078; N5849862). Scale bar displays 10 cm divisions.

Warren & Speden (1977) deduced a generally marine, shallow to medium water depth, moderate energy setting not far from shore for the Okarahia Sandstone, perhaps paralic at the base (and locally non-marine at Mikonui). Roncaglia & Schiøler (1997) inferred a marginal marine, near shore environment for the formation, based on the presence of black/brown wood fragments, the abundance of sporomporphs and low dinoflagellate diversity.

The overlying Tarapuhi Grit consists of green-grey, locally calcareous glauconitic sandstone and fine conglomerate with shell fragments and is Haumurian in age (Fig. 11). The lower portion is distinctly greener and more glauconitic, and includes low angle cross bedding and channelisation. The upper portion of the formation is thicker bedded and more massive.

Warren & Speden (1977) noted that the *Inoceramus-Ostrea-Rotularia* association in the Tarapuhi Grit is analogous to modern mytilid-oyster-annelid associations in intertidal or directly subtidal settings, and that its coarse grain size indicates vigorous current or wave action. They also deduced, from the bimodality of the sediments, that current strengths varied and pointed out that the presence of large burrows and glauconite could be consistent with low-energy periods. They inferred a near shore setting, partly protected by a fringe of offshore shoals that was occasionally breached during storms. The overlying Conway Formation was deposited in slightly deeper water. Based on semiquantitative palynofacies analysis Roncaglia et al. (1999) thought that the Tarapuhi Grit and Conway Siltstone were deposited in "open" marine environments, with influx of terrestrial material from a nearby land area.

Figure 11. Well bedded Tarapuhi Grit, south side of railway portal (E2551073; N5849793). Lower part comprises trough cross bedded sandstone, overlain by thicker bedded and more massive sandstone, with a thin capping of Conway Formation in the upper part of the photo.

A thin Conway Formation interval occurs at the top of the Tarapuhi Grit in Figure 11, and is well exposed mid-way along the train track section (Fig. 12). It is much like the coastal exposures, and we can spend some time here looking for bone fragments within the concretions. For those interested, and if time allows, we can also view the contact of the Claverley Sandstone and the overlying Amuri Limestone a little further down the track (E2551071; N5849262).

Figure 12. Conway Formation with prominent calcareous concretions (E2551084; N5849462).

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