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ZEALANDIA IN SPACE AND TIME

Victoria University of Wellington
25th-27th November 2015

FIELD TRIP GUIDES

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Field Guides

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FIELD TRIP 1

Following in Cotton's footsteps (tyre tracks): Origin and evolution of the Wellington K Surface by mountain bike

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Kevin Norton

Victoria University of Wellington

Itinerary: (Refer to Figure 1)

	Mountain bikers	Walkers
Stop 1	Makara Peak mountain bike carpark (9.20 am)	Mill Creek wind turbines (9.45 am)
Stop 2	Makara Peak (10.00 am)	Makara Village (12.00 pm)
Stop 3	Wrights Hill (12.00 pm lunch)	Owhiro Bay (2.00 pm)
Stop 4	Red Rocks meet up with the walkers (3 pm)	Red Rocks meet up with the bikers (3.00 pm)

We aim to be back at the University by 5 pm.

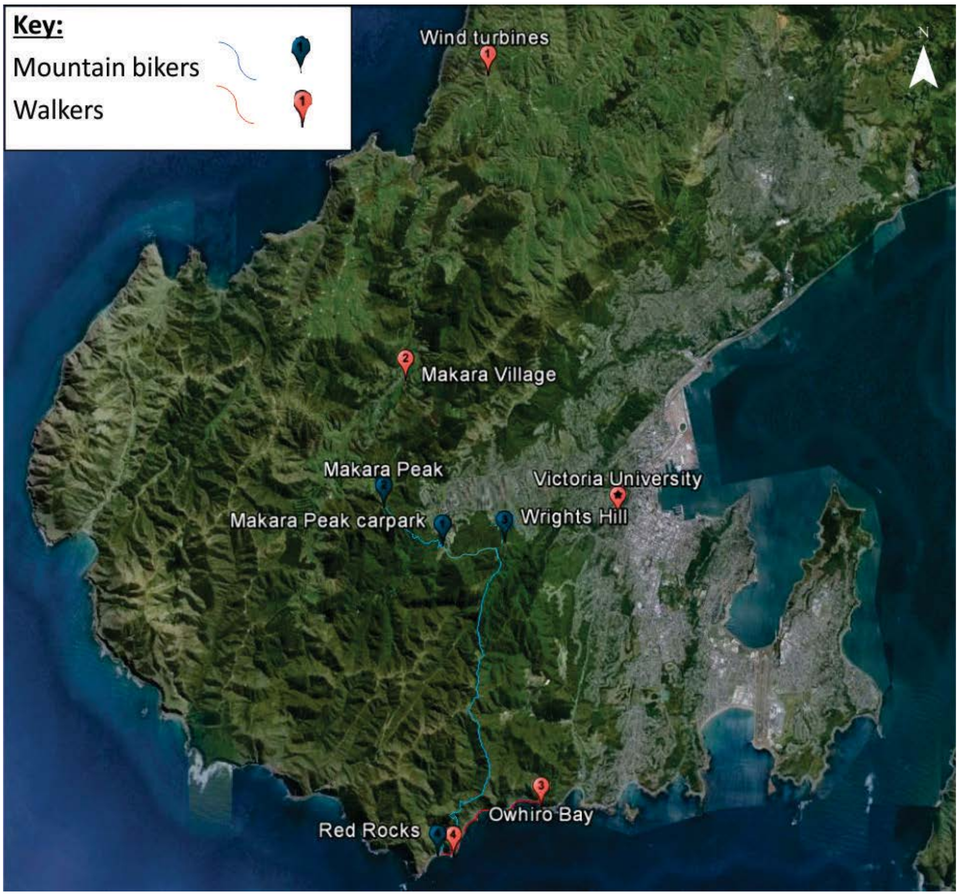

Figure 1: Aerial view of Wellington. Locations of stops shown in red for mountain bikers, and in blue for walkers. (Google Earth)

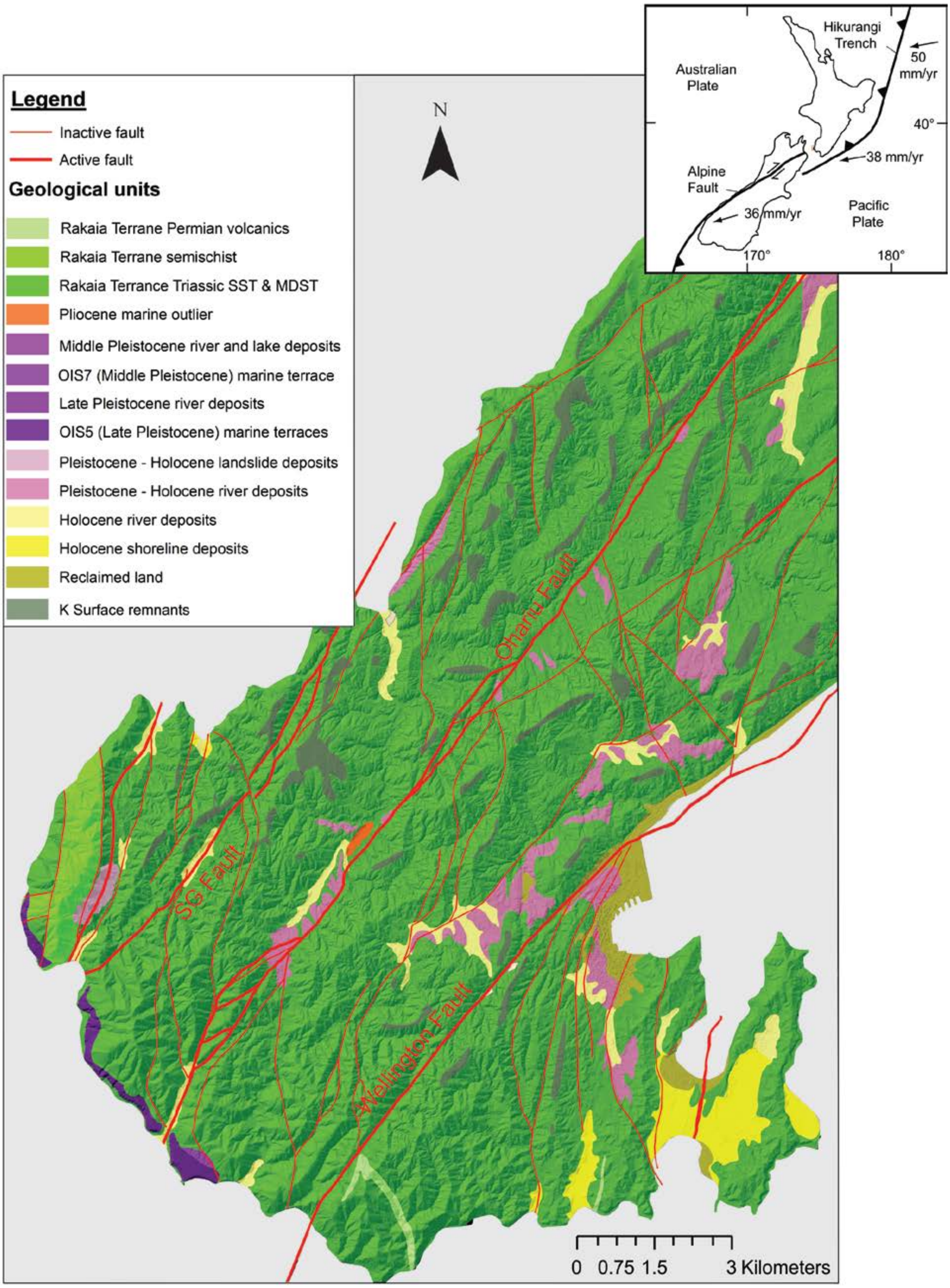

Figure 2: Top right: Overview of New Zealand's tectonic setting, altered from Rodgers and Little (2006). Centre: Geological map of the lower western North Island. (Data compiled from GNS QMAP, Active Faults Database and high resolution LiDAR data provided by the GWRC and Landcare)

Introduction

The K Surface is a regional erosional surface that dominates the landscape of western Wellington from Makara in the south, to Paraparaumu in the north (Figure 2). Sir Charles Cotton was the first to describe this physiographic feature that has subsequently been deformed vertically and horizontally by faults and eroded by hillslope processes. The K Surface remnants we can see in Wellington today vary in altitude. For example, Mount Kaukau has an altitude of 442 m whereas other areas are as low as 200 m such as Emerald Hill and Trentham Memorial Park.

The age of the K Surface is not well constrained; currently it is thought to be between 0.4 and 4 Ma (Begg and Mazengarb, 1996). Figure 3 displays the broad tectonic history of the Wellington area over the past ~11 Ma. The important question relating to the K Surface is whether it initiated: (1) during the uplift events following the deposition of Pliocene marine sediments, today observed in a marine outlier near Makara (Stop 2 for walkers), (2) during the uplift events of the Late Miocene, or (3), an older uplift event (i.e. after Oligocene submergence of Zealandia) (Landis et al., 2008).

A significant aspect to note is that if the K Surface was initiated in the Late Miocene (or earlier), then it probably would have been further eroded and altered during Pliocene – Pleistocene uplift.

Sir Charles Cotton and the K Surface

Sir Charles Cotton (1885 – 1970) (Figure 4a) was Professor of Geology at Victoria University between 1921 and 1953, and one of New Zealand's pioneering geologists (Grapes, 2008). He has made enormous contributions to understanding the evolution of New Zealand's landforms through his talented use of field observations, sketches (Figure 4b), and simple block diagrams describing landscape processes.

The peneplain concept was first termed in 1889 by America's "Father of Geography" William Morris Davis, who believed it to be the third and final stage of his geomorphic cycle of landform evolution, later termed, the "Davisian Cycle" (now largely superseded) (Chorley et al., 1973). Davis' idea was that, over the course of geological time, fluvial erosion would lower the land until there was such a small gradient that no erosion could occur (Chorley et al., 1973).

In 1912, Cotton described the geomorphic evolution of Wellington in terms of Davis' three erosion cycles, while emphasising the importance of tectonics and climate change (Grapes, 2008). He recognised the oldest erosion feature in the landscape as remnants of a "post mature", or even "senile" surface he termed the K Surface (K because of its "key" character in the landscape) (Cotton, 1912; Cotton, 1957). However, today, the K also refers to the surface's highest point: Mount Kaukau (Cotton, 1957). Cotton determined the K Surface to be result of the oldest erosion cycle in the landscape (termed the *Kaukau cycle*) (Cotton, 1957). He attributed the height differences to later deformation in between the NNE trending faults (Cotton, 1957).

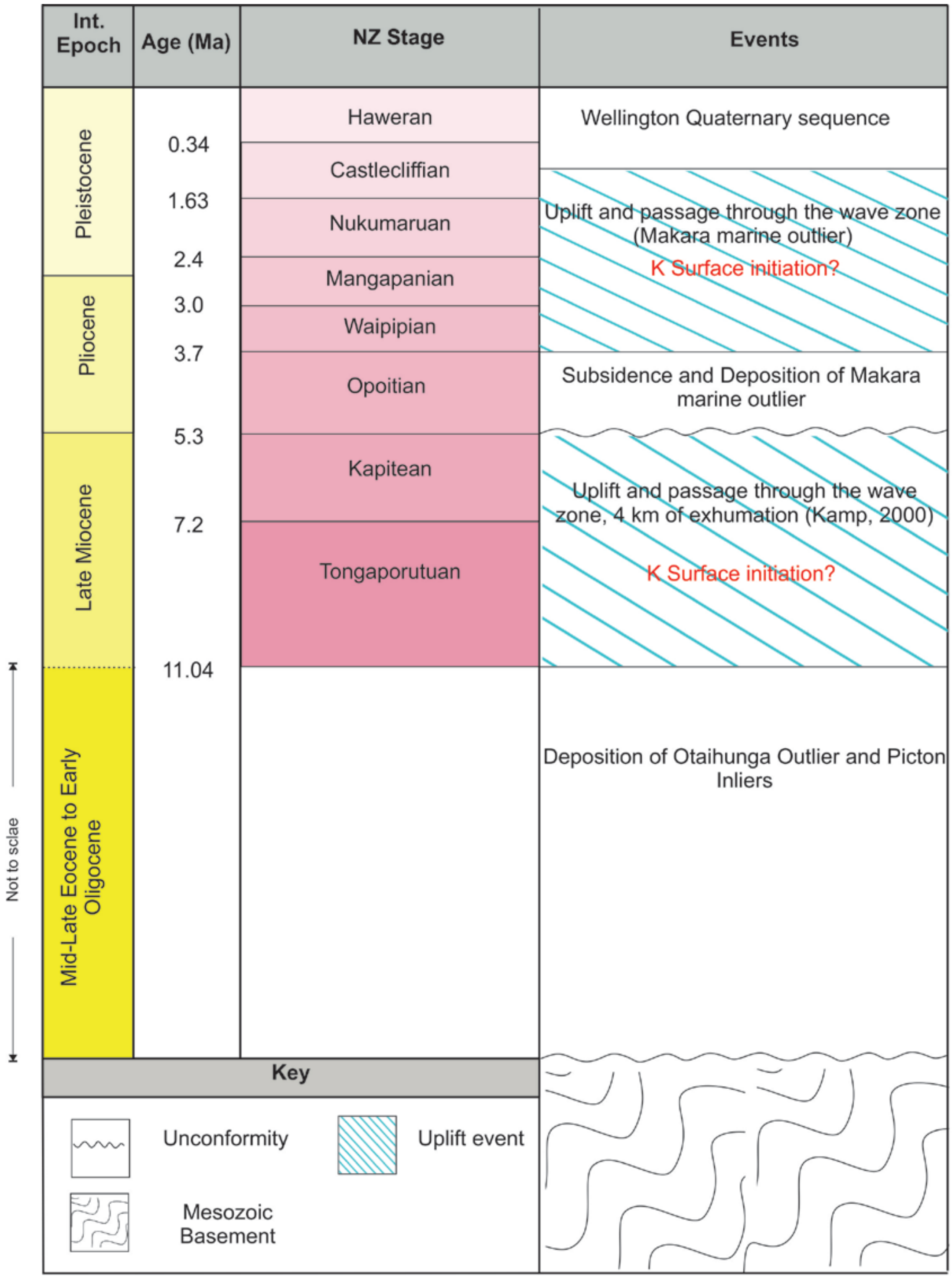

Figure 3: Stratigraphic column of geological events relating to K Surface formation

The next erosion cycle proposed by Cotton (1912); the *Intermediate cycle* was the most noticeable marine terrace on Wellington's south coast at Tongue Point. Today, it is understood that this marine terrace is related to the Last Interglacial highstand in sea level, approximately 125,000 years ago (Grapes, 2008). Cotton termed the processes which created the youngest geomorphic features in the landscape the *Present cycle* of erosion, characterised by steep gorges cut into greywacke by streams (Cotton, 1912; Grapes, 2008).

Today, the peneplain concept is not without debate, due to an absence of present-day examples, and controversy over relict examples (Grapes, 2008). In his 1957 paper, Cotton revisited the K Surface, stating:

"Whether the surface was produced originally by peneplanation (downwearing of the land), by pediplanation (backwearing of scarps), or even by some other process such as marine erosion scarcely matters for the present purpose, which is to make use of it as a key … to the original tectonic form of the landscape" (Cotton, 1957, p. 776)

The abundant marine platforms around Wellington suggest that the K Surface could be a wave cut platform. Additionally, the approximately uniform ridge heights of the K Surface could be the result of uniform fault spacing. In a landscape with approximately uniform uplift and rock erodibility (i.e. all the rocks are heavily fractured) hillslope lengths will tend to be equal. If that is the case, trunk river spacing (i.e. fault spacing) controls relief. In this way, something approaching the K-surface could be generated without need of a peneplain.

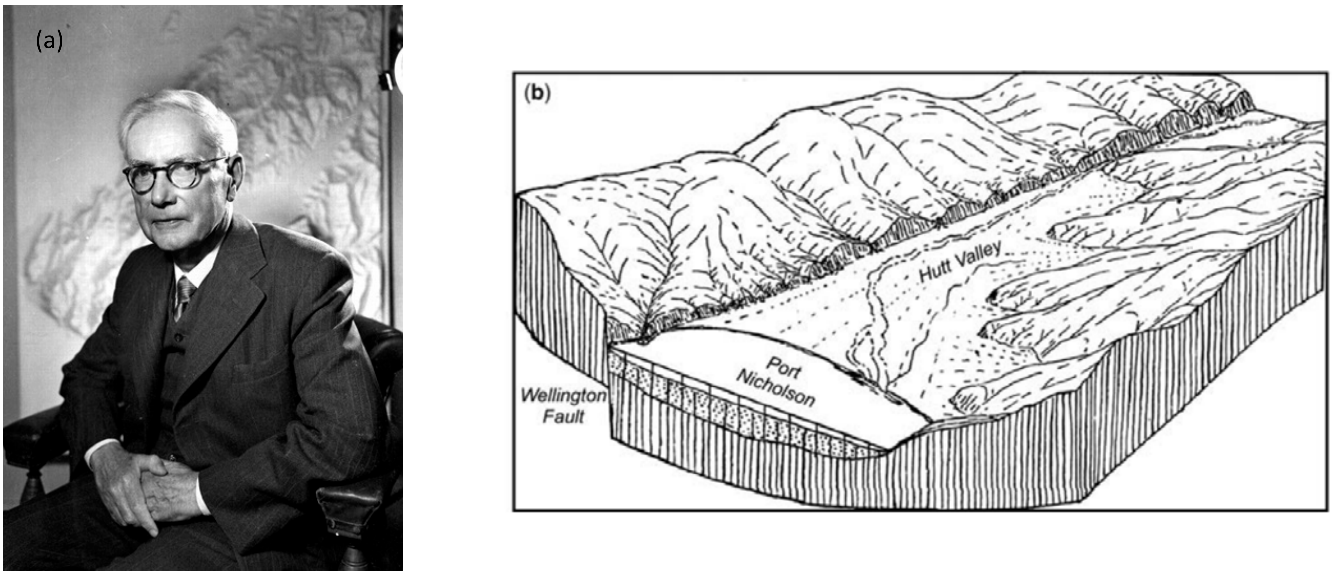

Figure 4: (a) Sir Charles Cotton. Photograph taken on the occasion of his retirement in 1953 as Professor of Geology, Victoria University of Wellington, New Zealand (No. VUW100032 Photographer's Proof Series, held in the J. C. Beaglehole Room. Victoria University of Wellington Library). (b) A sketch by Cotton of the Hutt Valley and the western hills separated by the southern part of the Wellington Fault.

Geological background

The tectonic setting of North Island of New Zealand is characterised by oblique subduction of the Pacific plate underneath the Australian plate at 38 mm/yr at an azimuth of approximately 260° (Begg et al., 2008; Gross et al., 2004; Rodgers and Little, 2006). The subduction interface is shallowly dipping to the northwest at a depth of 25 – 30 km below the surface (Begg et al., 2008).

Active faults within the area all strike approximately NE-SW (Figure 2). All inactive faults strike approximately either NE or NW and as a result they appear to chop the K Surface into blocks (Figure 2). The main active faults in the area of interest are the Ohariu, Shepherds Gully and Wellington faults, which are all right-lateral strike-slip and have slip rates ranging from 1 – 10 mm/yr (Van Dissen and Berryman, 1996). Slip rates are variable along different parts of each fault (Langridge et al., 2005). In Te Marua, near Upper Hutt, the Wellington Fault displays an apparent 5 km dextral offset of the Mesozoic aged Esk Head Mélange (Nicol et al., 2007). There is potentially an additional 3 km of lateral displacement of the Mélange north of the fault, producing a total strike-slip of approximately 5 – 8 km (Begg and Mazengarb, 1996).

There are limited data available on the geometry of the active faults, specifically in terms of accurate dips. Nevertheless, through ground-penetrating radar (GPR) techniques, Gross et al. (2004) deduced that at two field sites in the Hutt Valley, the Wellington fault's dip and dip direction is approximately 55 - 75°SE and 72 - 84°SE. Furthermore, it was found through trenching on Ohariu Valley Road that the Ohariu Fault dips steeply to the northwest (~80 °) and exhibits apparent reverse displacement (Van Dissen et al., 2010).

Sand dunes on top of the K Surface

On the top of the K Surface, at Stop 1 for the walkers, the stratigraphy consists of Torlesse greywacke, overlain by a discontinuous mud layer, which is then overlain by well sorted, quartz-bearing sands up to ~8 m thick (Figure 5). The Torlesse greywacke at this location is oxidised and heavily weathered and deformed. The contact between the Torlesse greywacke and the overlying muds is hard to pinpoint, due to the highly weathered nature of the outcrop. The ~1.5 m thick muds are oxidised in the lower part of the unit and reduced in the upper part, and exhibit organic matter throughout. The well sorted sands stratigraphically above the muds are unevenly draped over the landscape, and have been determined to be 10 – 12 ka through optically stimulated luminescence dating done at Victoria University of Wellington (unpublished). The sands have subsequently been deduced as being windblown as evidenced by: 1) large scale cross bedding observed in the strata; 2) well sorted with positive graded bedding (possibly due to sand streams at high wind); 3) spherical grains under the microscope (Figure 6); and 4) lack of pebbles and gravels present (therefore, not fluvial) (S. Lamb, personal communication, April, 2014).

Figure 5: The stratigraphy on top of the K Surface at approximately 41°14’S, 174°40’E (Photo by Cam Watson)

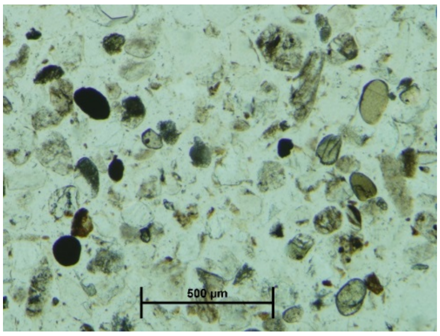

Figure 6: Thin section of sand dune sand collected from Mill Creek Wind Farm, western Wellington. Note the roundness of the grains. (Location: 41°12'S 174°44'E Elevation: ~215 m)

Makara Pliocene marine outlier

Stop 2 for the walkers is Makara Village where there is a sequence of Early Pliocene (Opoitian) marine rocks preserved as a marine outlier between two splays of the Ohariu Fault (Figure 2) (Begg and Johnston, 2000; Grant-Taylor and Hornibrook, 1964). These sediments represent the only known onshore Pliocene sediments of the South Wanganui Basin (Begg and Johnston, 2000). The best exposure of the sequence is located behind the house at 474a Makara Road. Other small exposures can be found in parts of Makara Stream and in road cuts near the cemetery.

The deposit was drilled and a core obtained in 1988 near the green of Hole 1 at Makara Public golf course (Figure 7). It is weakly indurated, and unconformably overlies greywacke basement (Figure 7). The deposit is poorly bedded and generally grades upwards from sandstone into calcareous mudstone. The lower part of the deposit is defined by unconformities in the form of conglomerate and grit horizons, and there are shellbeds present. The upper part of the deposit is generally finer-grained with higher dispersion of shells compared to the lower part, and has concretions scattered throughout. The sequence is interpreted to have been deposited in a marine environment shifting over time from inner shelf to outer shelf (Begg and Johnston, 2000).

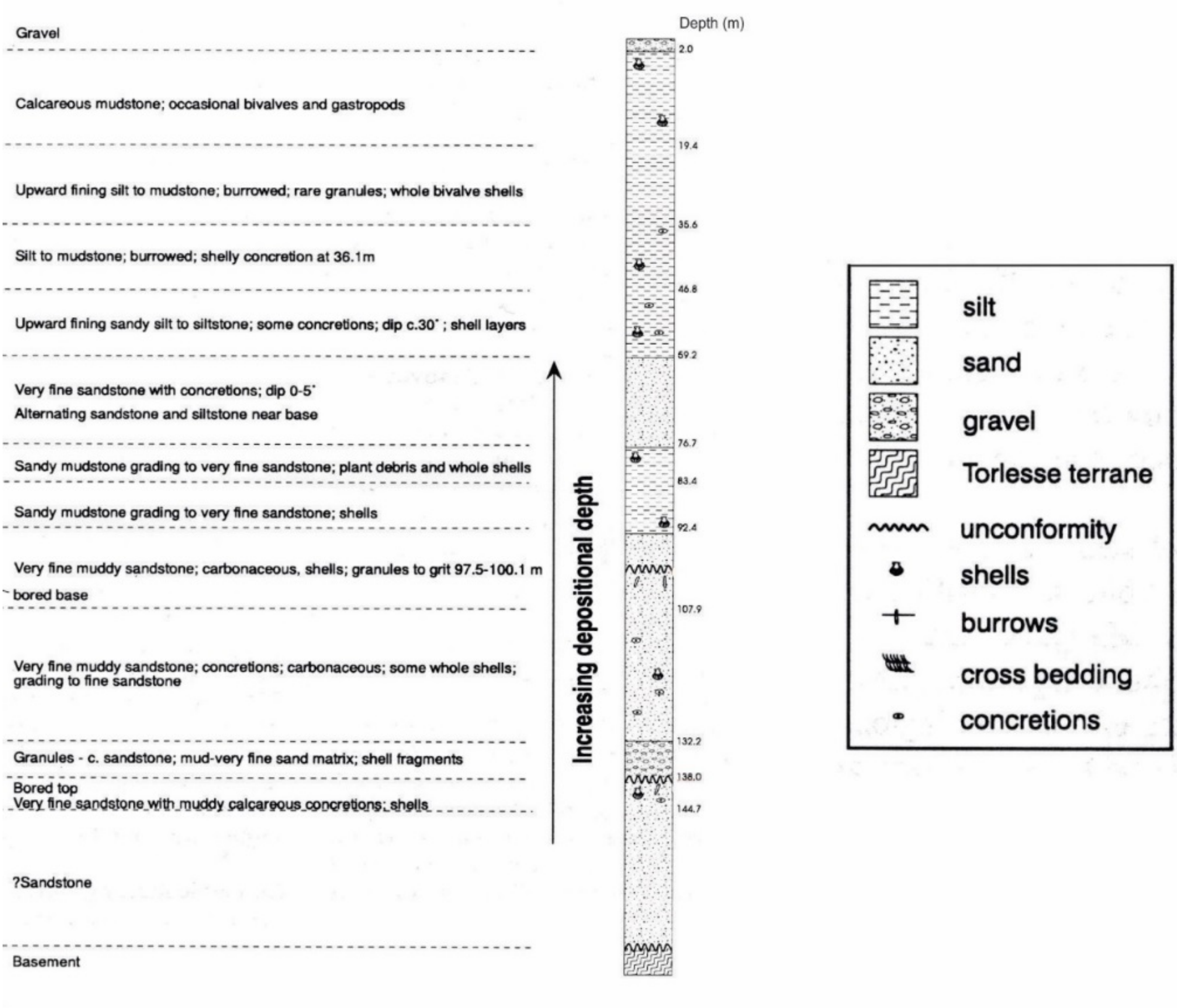

Figure 7: A stratigraphic column from the Printers Flat core, drilled near the first hole of Makara Public Golf Course in 1988. Figure adapted from Begg and Mazengarb (1996)

Seismic data was obtained via two lines at Makara in January 2015 (Figure 8a). Figure 8b displays a (maximum) velocity model with depth for the marine sediments underlying the village. According to Stagpoole's velocity/depth calculations for Pliocene aged sediments in Taranaki, Northland and the West Coast, these sediments of maximum ~3.2 km/s P-wave velocity were buried to a depth of ~2000 ± 500 m before being uplifted to where they are today (Stagpoole, 1997). These results are comparable with burial depths of ~4 km and ~2 km for Pliocene sediment in the Wanganui and Wairarapa Basins respectively (Tozer, 2013).

Figure 8c displays the depth to the top of the 2.5 – 3.2 km/s marine sediment for the red seismic line. The ~2 m deep depression near the NW end of the line may be due to tectonic activity on the Ohariu Fault.

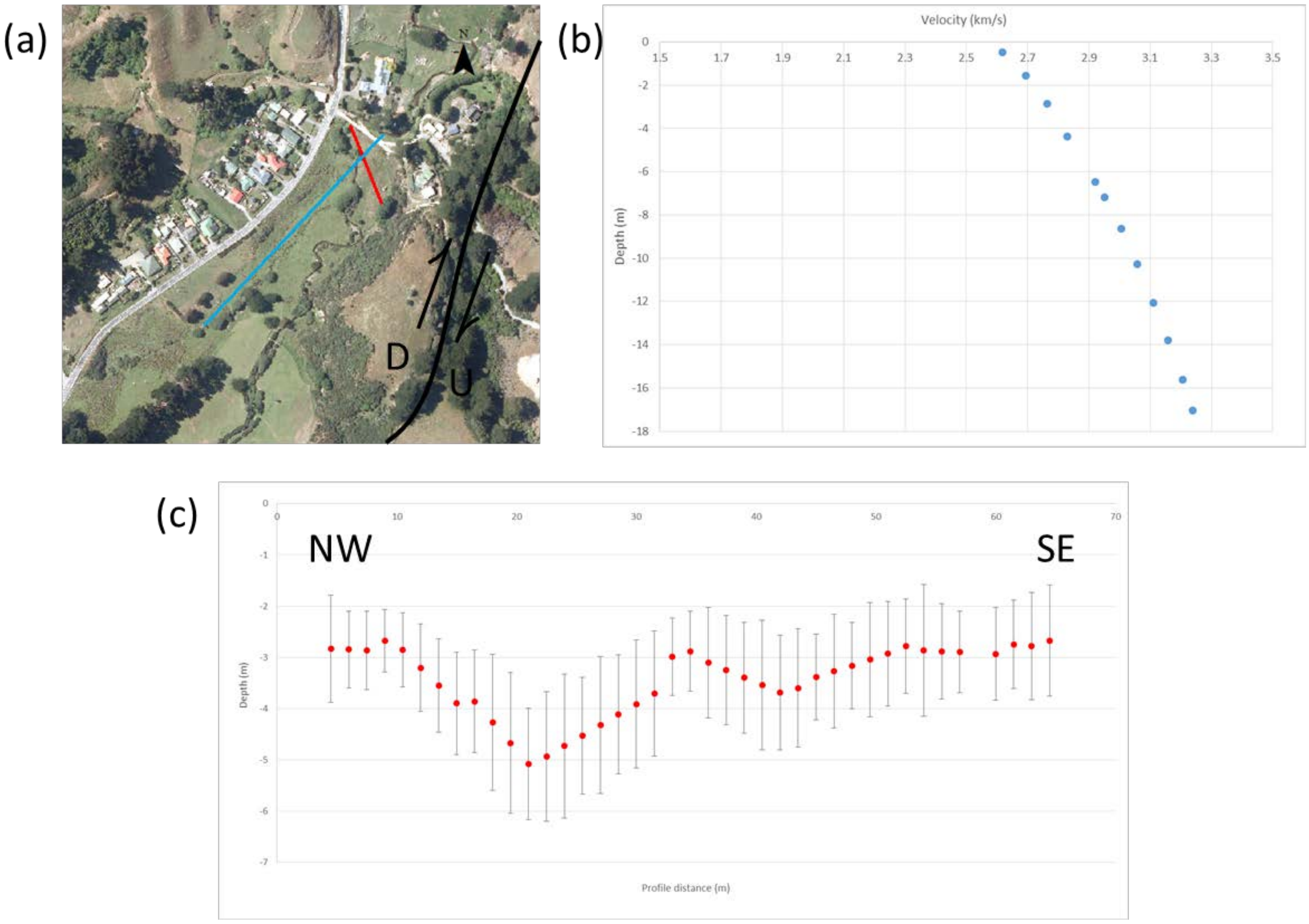

Figure 8: (a) Locations of seismic lines shot in January 2015 at Makara Village, with the Ohariu Fault to the east (b) Velocity model with depth for the Pliocene marine sediments for the blue seismic line, calculated using the WHB inversion for travel-times, (c) The depth to the top of the marine sediment (2.5 – 3.2 km/s) for the red seismic line, obtained using the plus-minus method.

Vertical tectonic movements of western Wellington

Vertical tectonic movements are important as they provide insights into crustal and upper mantle dynamics. They are difficult to document, especially in a region such as Wellington, as it is tectonically active and dominated by bedrock (i.e. no marker beds), with unknown erosion rates.

As previously mentioned, the age of the K Surface is not well constrained, although we are currently waiting on cosmogenic nuclide exposure ages for the greywacke at the top of the K Surface, which will hopefully provide us with a minimum age and an erosion rate. However, regardless of what age the K Surface is, we can use the remnants to infer mechanisms for the vertical tectonic movements of western Wellington.

Figure 9a displays interpolated heights for the K Surface that will be used constrain the amplitude and wavelength of uplift, and thus provide us with insight into the roles of in-plane stress and lithospheric plate flexure in the plate boundary zone of the southern North Island. Indeed, initial 2D profiles (Figure 9b&c) suggest that the K Surface exhibits broad scale NW-SE doming.

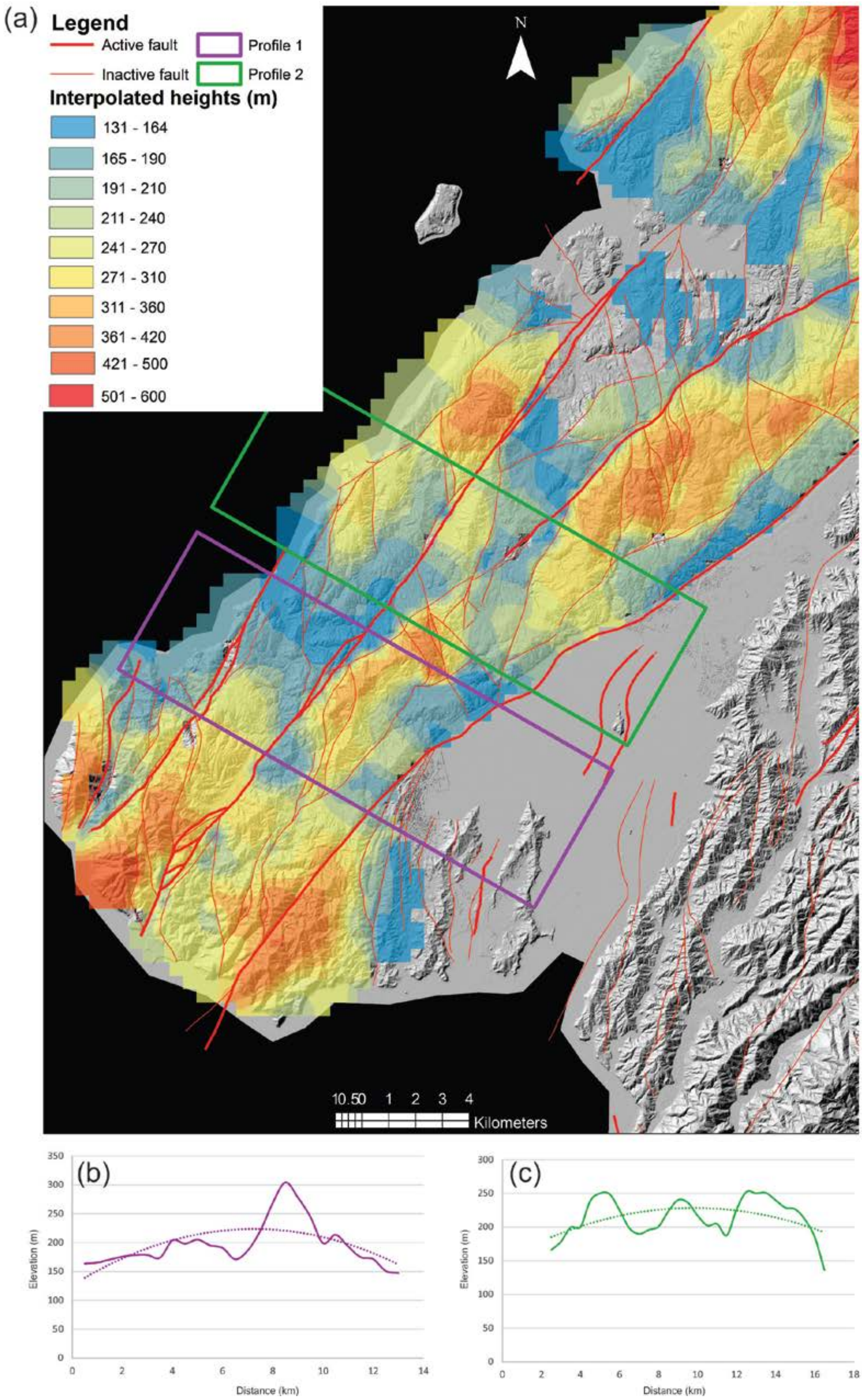

Figure 9: (a) Interpolated heights for the K Surface, active and inactive faults were input into the interpolator as barriers, (b) 2D mean K Surface elevation profile with order 2 polynomial trendline for Profile 1, (c) 2D mean K Surface elevation profile with order 2 polynomial trendline for Profile 2. (DEM used for analyses obtained from GWRC and Landcare)

Red Rocks

At Red Rocks, the sequence is almost vertical and is summarised in Figure 10. The rocks young towards the west and are steeply dipping, meaning that this sequence has been rotated from its original horizontal position (Grapes and Campbell, 1994). The sequence consists of Late Permian basalt, chert and red to green coloured siltstones sandwiched between Triassic aged greywackes and light grey-red siltstone (Grapes and Campbell, 1994).

The relative positioning of these rocks can be explained by the inferred fault represented by the contact between the base of the Late Permian green siltstone and the Late Triassic grey/red siltstone (Figure 10) (Grapes and Campbell, 1994).

Citing evidence from the geochemistry of the rocks, Grapes and Campbell (1994) suggest that the Late Permian sediments signify part of a seamount that collided with greywacke sediments being deposited in a trench along the Gondwana continent in Late Triassic times.

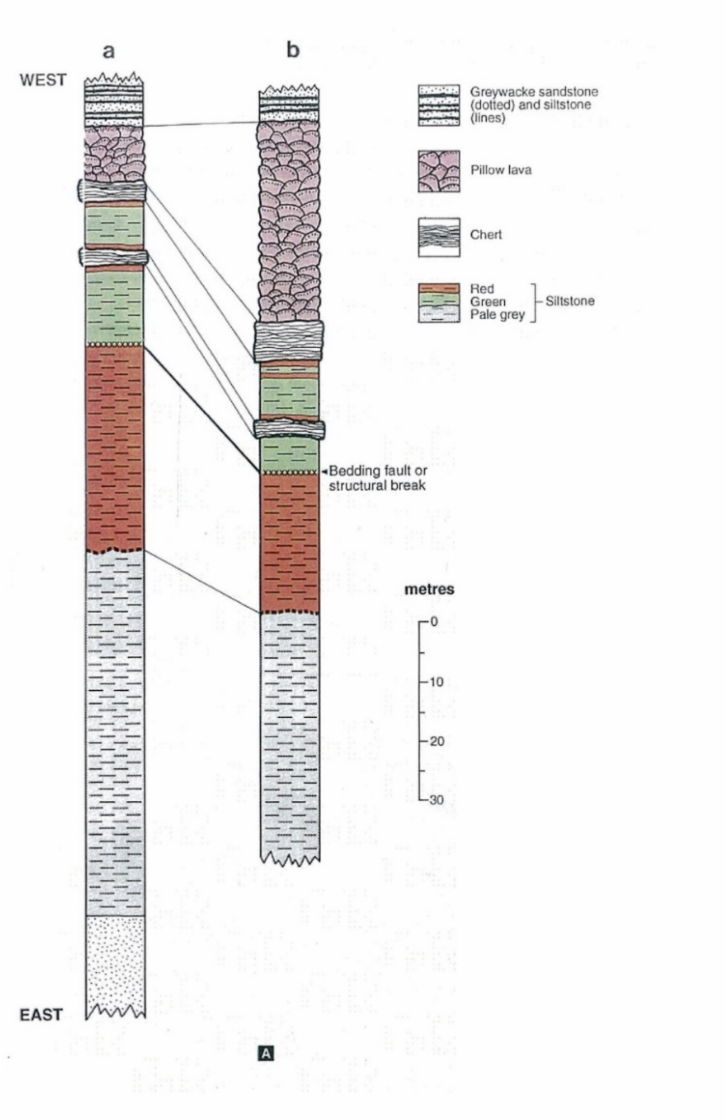

Figure 10: Sections of the rock sequence at Red Rocks (a = shore platform, b = cliff section at the back of the shore platform). Note that the sequence has been rotated so that the rocks are horizontal, i.e. in their assumed initial attitude with younging towards the west. (Grapes and Campbell, 1994)

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