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FIELD TRIP 4

THE WAIHEMO FAULT SYSTEM, NORTH OTAGO

Wednesday 25 November 2009

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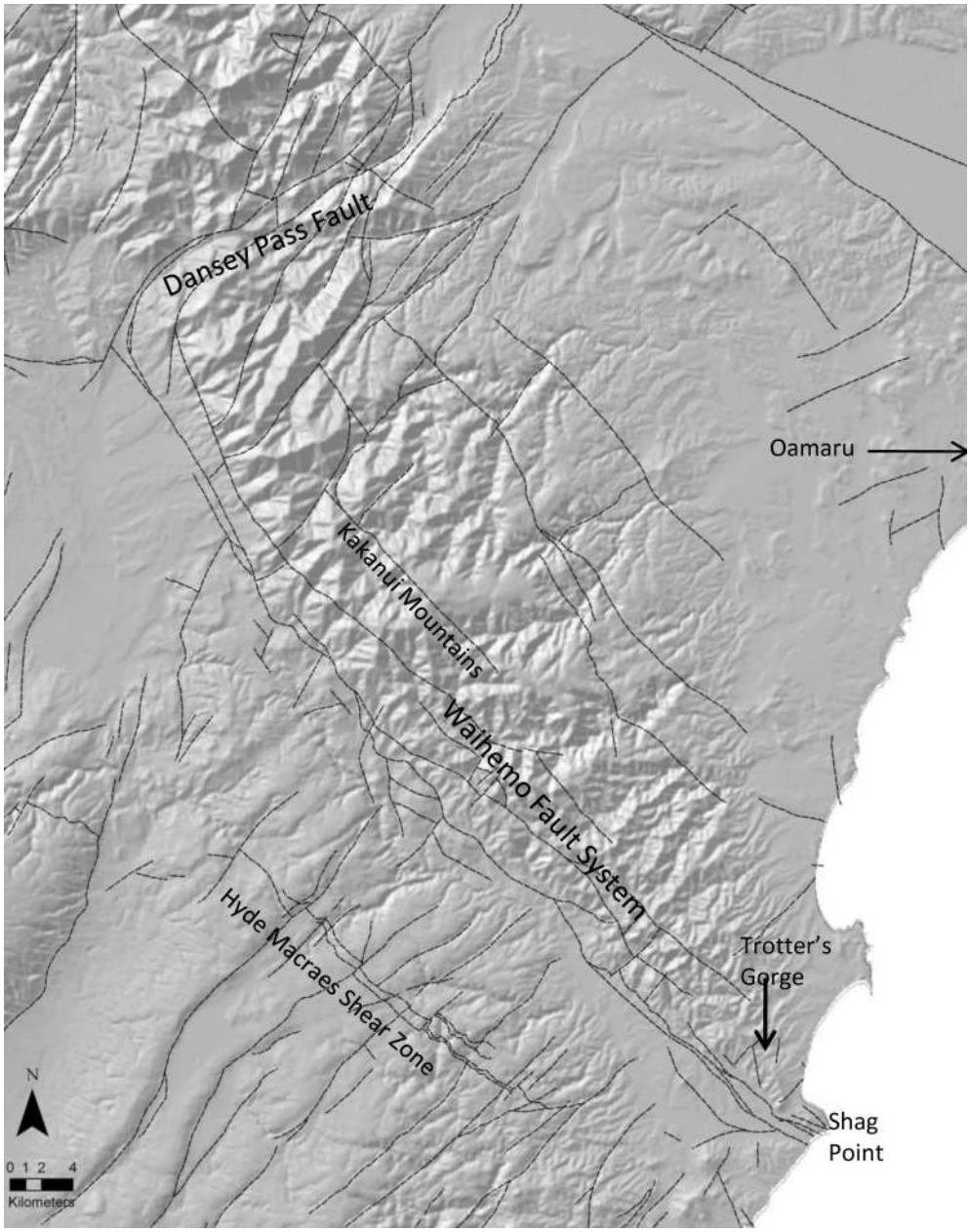
LEADERS: CLAUDINE CURRAN, RICHARD NORRIS (University of Otago)



Digital elevation model of the field area, illustrating the extent of the lower half of the Waihemo Fault System (GNS).

Introduction

The Waihemo Fault System is a major NW trending structural feature in the north Otago landscape. It lies at the base of the Kakanui Ranges, which are the result of an inversion regime, reactivating mid-late Cretaceous normal faulting in the Late Cenozoic. It consists of numerous laterally continuous strands, some of which extend for many kilometres, suggesting that this is a major crustal structure. The fault system merges with the Hawkdun Fault System at its northern flank, runs offshore at Shag Point, and is aligned with the southern edge of the Bounty Trough. Its relationship with similar parallel-trending faults in the Otago Schist, such as the Hyde-Macraes Shear Zone, the Rise-and-Shine Shear Zone and the Cromwell Gorge Shear Zone, is poorly understood, but it is considered to be associated with the extensional exhumation of the schist ~110 Ma.

This major crustal structure forms the main structural divide between the greenschist facies of the Central Otago Schist and the prehnite-pumpellyite facies of the Kakanui Ranges. Its lateral continuity belies the fact that it is a complex structure, made up of many segments, with varying degrees of reactivation along the different strands. The greatest movement has occurred along the northern strands, whereas the amount of reverse thrusting diminishes with proximity to the coast.

This fieldtrip will encompass some of the most interesting features of this fault system. The emphasis is on the southern section of the fault, from Shag Point in the SE, to Dansey Pass in the NW, where the fault system runs into the Dansey Pass Fault. We will see the preservation of Cretaceous sediments, the Kyeburn and Horse Range Formations, which have subsequently been uplifted into the hanging wall of the current tectonic regime. We will go to the coast, at Shag Point, where the amount of reverse movement has diminished, and where late Tertiary sediments are preserved in the hanging wall of the fault. Here there will also be a brief demonstration of offshore seismic acquisition, which may give an indication of the structure of the fault system offshore. A photo stop along the Macraes Road will show the scarps of the range front forming the Kakanui Mountains, and where the Otago peneplain (somewhat concordant with the Waipounamu Erosion Surface) can be seen dipping to the NE towards the mountains. At the Makareao Limeworks we will explore the prehnite-pumpellyite (TZ IIA) schist in the hanging wall, and the repeated stacks of limestone formed within it. At Pigroot Creek we will see one of the strands of the Waihemo Fault System in outcrop, before driving through Dansey Pass along the Dansey Pass fault, and down the long sloping backslope of the Kakanui Mountains.

Route Map:

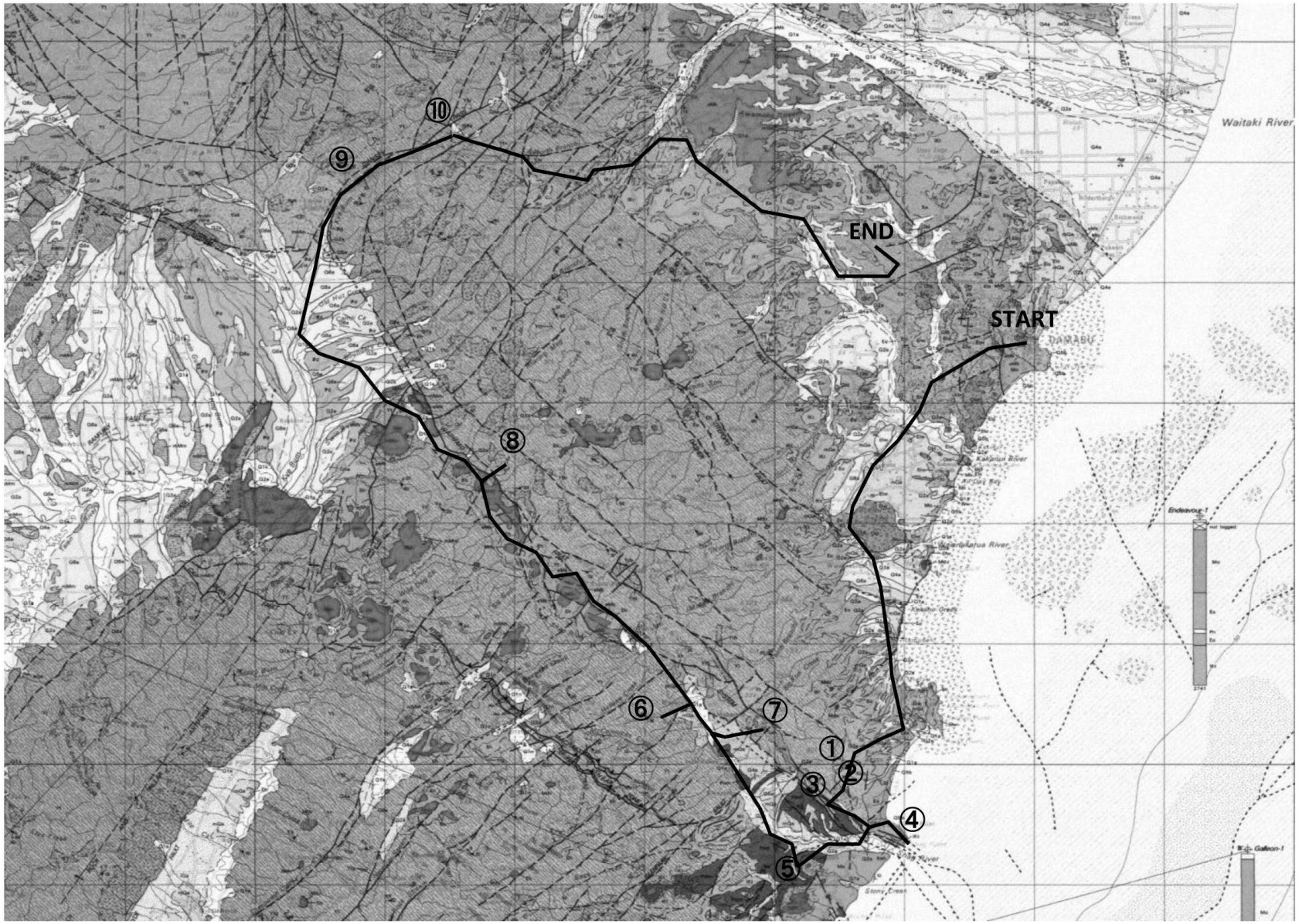
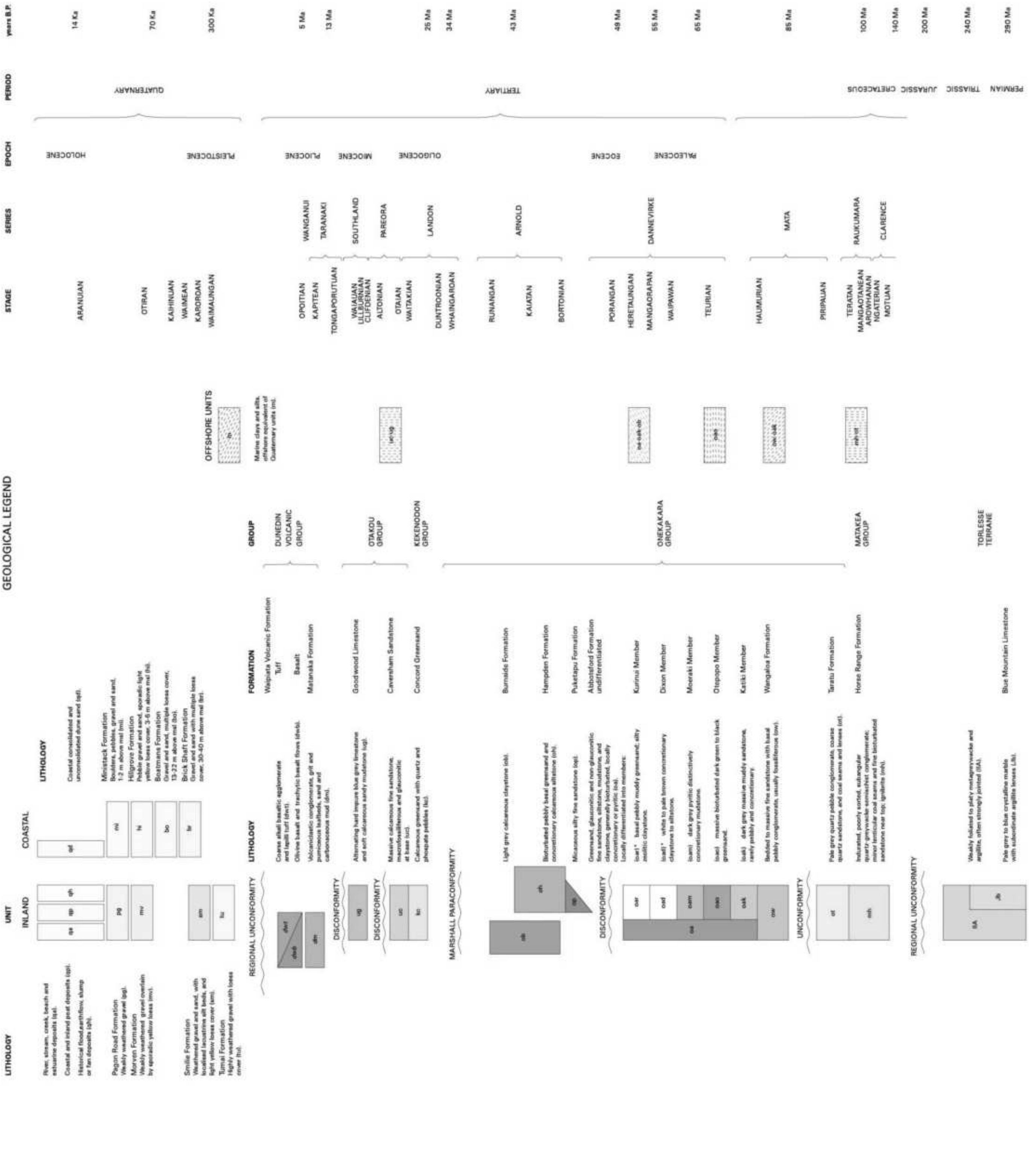


Fig 1: Waitaki Qmap & legend below: Numbers denote stops along route.



Legend taken from McMillan, 1999.

ITINERARY

8.00 am Minibuses leave Oamaru Opera House. Proceed along State Highway 1 south from Oamaru.

~10 km Sign on left for "Historic Place". Just past sign is the entrance to Totara Estate. Totara Estate was one of the "Great Estates" of the Waitaki district established in the 1850s and it was from here in 1882 that the first shipment of frozen meat from New Zealand was sent to Britain on the SS Dunedin, the first New Zealand vessel to be fitted with chillers. The estate has been restored in recent years and tours of the old buildings can be undertaken. Many of the original buildings were close to the Waiareka Creek and were destroyed in the "Great Storm" of 1876. During the storm, two ships in Oamaru harbour were wrecked with the loss of three lives and the Waireka Creek flooded, destroying houses at Totara with the loss of five lives.

Views to the right of the road are towards the dip slope of the Kakanui Mountains. The Kakanui Range is uplifted on its southwestern side along the Waihemo Fault System, and the unconformity between the Otago Schist and the overlying late Cretaceous/Tertiary strata (the "Otago Peneplain" or Waipunamu Erosion Surface) forms a dissected surface dipping gently to the northeast, as seen from the road. The foreground is underlain by late Cretaceous – Tertiary strata including prominent hills of limestone ("Oamaru Stone").

2 km south of Totara Estate is a sign for Clark's Flour Mill. This old mill (off to the left of the road) was built in 1865 as part of the Totara Estate. Originally powered by running water, it was later converted to electricity in the 1930s and operated as a mill until 1976. It is now owned by the NZ Historic Places Trust and is one of the few NZ water-powered mills remaining with its original machinery essentially intact.

~14 km Maheno

~22 km Herbert

~27 km Wainakarua – note the old Mill House and bridge

~33 km Hampden. To the south of Hampden, we pass the sign for the Moeraki Boulders. These are large carbonate septarian concretions within late Cretaceous mudstones which have been washed out of the cliffs and left scattered along the beach. In Maori legend, they represented gourds left behind when the great canoe Araiteuru founded on the Otago coast at nearby Shag Point. The turnoff to the settlement of Moeraki is about 5 km from Hampden, clearly indicated by the mounted fishing boat. It was an ancient Maori settlement and at one stage, was hoped to rival Oamaru as a port for north Otago produce. A railway line was constructed to the wharf but slope stability problems meant that maintenance was an ongoing problem. Moeraki remains a small fishing and holiday village and is the site of the renowned Fleur's Place seafood restaurant, founded by Fleur Sullivan, where the fish literally come straight from the wharf to the table!

~38 km Turn off to right along the Trotters Gorge road. The road winds down into Trotters Gorge and passes high cliffs at the side of the road composed of Horse Range Formation. These are mid-Cretaceous sandstones, breccias and conglomerates resting unconformably on schist basement. Together with the similar age Kyeburn Formation found at the north end of the Waihemo Fault, these sediments represent accumulation of detritus in a fault-angle depression formed by normal, down-to-the-northeast, movement on the Waihemo Fault during mid-Cretaceous. The sediments are only found on the hanging-wall of the fault which today is uplifted by late Cenozoic reverse movement. The detritus consists of angular schist clasts and rounded low-grade schist/greywacke clasts. Paleocurrent directions suggest a dominance of river systems flowing parallel to the fault scarp mainly carrying low grade detritus from areas to the northwest, rather than very local alluvial fans being fed directly from the fault scarp (Mitchell, 1990; see accompanying discussion under STOP 2).

~45 km **STOP 1: Viewpoint near crest of Horse Range** **10 mins**

We will pull off the road into a parking area near the top of the Horse Ranges for a view to the northeast down the gorge. From our viewpoint, which is on schist basement close to the unconformity, the conglomerate beds of the Horse Range Formation may be seen extending back down the hill.

~47 km **STOP 2: Basal Horse Range beds** **15 mins**

We will pull off the road onto a parking area and examine outcrops of basal Horse Range Formation. Schist outcrops just the other side of the fence, so we are virtually standing on the unconformity. The basal Horse Range Formation here consists of quartz sands, conglomerates and carbonaceous silts. A prominent light-coloured band of silt and clay contains well-preserved stems and leaves (see detailed notes for STOP 2).

~48 km **STOP 3: Shag Valley Ignimbrite** **45 mins**

On the way down the hill from STOP 2, note outcrops of conglomerates of the Horse Range Formation in the side of the road. The junction with Walsh Road marks a major strand of the Waihemo Fault System.

At Stop 3, we will pull off the road by a gate, disembark and proceed through the gate over the small creek and turn right onto a rough farm track that runs parallel to the creek. A frontal strand of the Waihemo Fault System runs through this spot and forms the prominent gully running away to the northwest. It separates quartz sands of the late Cretaceous-early Tertiary sequence from near basal mid-Cretaceous Horse Range Formation. The section through the Horse Range Formation along the farm track extends through the Shag Valley Ignimbrite, recently dated at 112 Ma (Tulloch et al., 2009), which occurs interbedded with basal Horse Range Formation sands and conglomerates (see detailed notes for STOP 3).

On returning to the vans, we will backtrack about 500m to Walsh Road (note ignimbrite outcrops in roadside) where we turn right onto Walsh Road. Several strands of the Waihemo Fault System run parallel to Walsh Road. Steeply dipping beds of the Horse Range Formation may be seen to the left of the road in the hangingwall of a major strand of the fault.

~53 km Junction with State Highway 1. As we approach the SH1 intersection (and cross the railway line), the view in front to the southeast is down the line of the Waihemo Fault System, with Shag Point forming the uplifted headland in the hangingwall to the left of the view.

~54 km Turn-off to Shag Point. The view to the north at the turnoff is along Katiki beach. The unit exposed along cliffs behind the beach and forming the low rocky platforms is the Katiki Member of the Abbotsford Formation. This is a Late Cretaceous muddy sandstone with calcareous concretions and containing marine fossils. It overlies the Wangaloa and Taratu Formations exposed on Shag Point itself. The road passes holiday houses and a small community of Shag Point before entering the DoC reserve. We will drive to the carpark at the end of the road.

~58 km **STOP 4: Shag Point** **30 mins**

We will disembark from the vehicles and walk to the headland. The rocks are part of the late Cretaceous Taratu Formation that passes upward (and northward) into the marine Wangaloa Formation. It is easy to scramble down onto the rocks here. The rocks at Shag Point are in the hangingwall of the Waihemo Fault system and are cut in places by Cretaceous normal faults downthrowing to the northeast. The rocks are warped into a gentle anticline that defines the hangingwall structure. Here, the hangingwall is composed of the later Cretaceous sequence, at STOP 3 it was the mid Cretaceous Horse Range Formation and further to the northwest it the hangingwall is formed of schist. This change in hangingwall stratigraphic unit with the lowering of the height of the uplifted block attests to the diminution of reverse reactivation towards the present coastline (see detailed notes for STOP 4). We will also examine a proposed tsunami deposit on the headland (Kennedy et al., 2007).

After returning to the vehicles, we will retrace our route back on to State Highway 1 and head south to Palmerston. The route takes us across the Waihemo Fault and along the valley of the Shag River.

~60 km **STOP 5: Palmerston** **15 mins**

Palmerston was founded in 1862 and named after Lord Palmerston, several years before Palmerston North in the North Island. Despite the latter growing to a much greater population, Palmerston, Otago, retains its right of priority in the naming stakes!

The high hill to the east of the town with the monument on top is Puketapu, a Miocene volcanic centre and part of the broader Dunedin Volcanic Group. The monument is to Sir John McKenzie, a 19th Century runholder and politician.

This is the last stop with toilet facilities and coffee or other refreshments until late afternoon!! Please take advantage of the opportunity.

We will leave Palmerston on State Highway 85, commonly known as the Pigroot. This was an original miners' route to the goldfields of the Maniototo. To the right are the Kakanui Mountains formed by uplift along the Waihemo Fault System that runs at the foot of the scarp. To the left, the Cretaceous "peneplain" surface cut into schist, slopes down towards the road and is overlain by late Cretaceous and Tertiary sediments. Outcrops of Tertiary sediments in road cuts give way to outcrops of TZ4 Otago Schist as we continue along the road. In general, the schist forming the

basement on the southwest (footwall) of the fault is TZ4 whereas that in the northeast (hangingwall) is TZ2/3, indicating that late Tertiary reversal of movement has not been sufficient to eradicate the juxtaposition of schist zones caused by Cretaceous normal movement.

You may also note the line of an old railway running parallel to the road. This railway operated until the 1980s and was used to haul limestone from the Dunback quarry (STOP 7) to the Burnside cement works in Dunedin.

~74 km Dunback

From Dunback we travel about 1.5 km further along SH85 and then turn left onto Macraes Road and pull into a large parking area on the right at the crest of the hill.

~76 km **STOP 6: View of Waihemo Fault line** **15 mins**

From our vantage point, we get an excellent view of the line of the Waihemo Fault System and the scarp of the Kakanui Mountains. Far to the right (SE), Shag Point is visible where the fault runs out to sea. The mountains and scarp increase in height as they strike inland and continue to the left horizon (see notes and panorama for STOP 6).

From STOP 6, we will retrace our route back through Dunback to the junction on the left with Limekiln Road about 1 km south of Dunback. We drive along Limekiln Road to the lime quarry, crossing the Waihemo Fault System near the quarry entrance.

~82 km **STOP 7: Makareao Lime Works** **c. 1 hour**

We will need to stop at the quarry office for health and safety formalities before proceeding on to the (non-working) old quarry at the base of the main hill. The site is within the uplifted schist of the hangingwall of the fault system. Here, the normal TZ2/3 quartzofeldspathic schist contains large lenticular bodies of limestone. The structure of the schist is complex and the limestone layers are stacked above each other at the quarry site. They are also cut by normal faults, possibly Cretaceous faults of the Waihemo system that have not been inverted (see detailed notes for STOP 7). The limestones have been quarried since the late 19th century, mainly for lime, but for a long period during the 20th century for cement manufacture at the Milburn cement works in Dunedin. Cement manufacture in Dunedin ceased in the 1980s and the quarries have been reopened as a source of agricultural lime.

Weather permitting, we will have lunch here before continuing.

~85 km Junction with State Highway 85.

We will continue along the Pigroot highway following the line of the fault system northwestwards. The road north of Dunback cuts in towards the scarp and follows close to the fault line. Outcrops of late Cretaceous Hogburn Formation (equivalent to the Taratu at the coast) may be seen in road cuts, along with schist.

~102 km Green Valley. Outcrops of Oligocene Green Valley Limestone may be seen to the left of the road. Flat-topped hills west of the fault line are capped with volcanic flows, sills and intrusions of the Waipiata Volcanic Group (Miocene, the outlying equivalents of the Dunedin Volcanic Group of the coastal tract).

~113 km As we descend a steep decline with views of the sloping peneplain to the left, there is a sign indicating a "Goldfields Plaque". Outcrops on the right of the road are of Hogburn Formation quartz sands. The plaque, sited on top of this roadcut, refers to the hill down which we have just travelled. This location was known in the goldfields days as "Dead Horse Clinch", due to the narrowing of the track and the steep, muddy gradient which led to exciting times with horse-drawn vehicles! From the plaque looking to the SE, old ruts formed by the wagon wheels can still be seen in the grassy slope.

~118 km **STOP 8: Pigroot Creek** **1.5 hours**

We will leave the vehicles in the picnic area and cross the road to the gate and enter the paddock on the north side of the road.

Pigroot Creek exposes a section through the late Cretaceous/Tertiary sediments to one of the main strands of the fault system. It is one of the few places where the fault plane is clearly exposed separating Tertiary sediment from hangingwall schist. It is also the only place we are aware of where evidence for late Quaternary displacement on the fault can be seen unequivocally. We have investigated this site in some detail including gravity and seismic surveys across the fault and OSL dating of late Quaternary sediments affected by fault displacement (see detailed notes for STOP 8).

Depending on time and weather, we will walk up the creek looking at the section through the sedimentary formations as far as the fault exposure.We will return to the vehicles via the terrace top.

The route from Pigroot Creek climbs upwards, crossing the upper reaches of the Shag River and the highest point on the road at Red Cutting. Outcrops of white Hogburn Formation sands and grey Swinburn Formation marine silts may be seen along the creek banks and in road cuttings. Just past Pigroot Creek, a long roadcut exposes basaltic surge deposits of the Waipiata Volcanics (Miocene).

~128 km Swinburn

The road crosses the nose of an anticline cored by schist. Outcrops of the Tertiary sedimentary sequence and volcanics may be seen on the roadside dipping in opposite directions either side of prominent outcrops of strongly lineated schist. The Waihemo Fault outcrops some distance up the Swinburn to the right of the road.

~134 km Kyeburn. Junction on left with Hyde–Middlemarch road. Bridge over Kyeburn. Orange–brown weathering outcrops along the Kyeburn are of Maniototo Conglomerate (earlier known as Maori Bottom Formation). The Pliocene Maniototo Conglomerate (Youngson, J. H. et al., 1998) is composed of rounded clasts of lowgrade schist and greywacke derived from the Kakanui and Hawkdun Ranges deposited in an extensive braid plain across most of central Otago. It dates the timing of uplift of the ranges and commencement of reverse movement on the Waihemo Fault System. The Maniototo Conglomerate is extensively deformed along the range-fronts and over the northeast trending ranges to the southwest, suggesting uplift of these was later than the northwest trending ranges. To the left can be seen the northeastward plunging nose of the Rock-and-Pillar Range, a large anticlinal uplift bounded by the Hyde Fault on the eastern side.

~135 km Turn right onto Kyeburn River Road

The road runs along Quaternary terrace surfaces on the flanks of the Kyeburn. The outcrops of brown weathering Maniototo Conlomerate along the far side of the river eventually give way to Quaternary gravels.

~147 km Junction with Naseby–Danseys Pass Road

The Waihemo Fault System is offset by about 3 km across the Danseys Pass Fault which strikes NE–SW. In front, the Hawkdun Ranges can be seen, bounded on their left by the continuation of the Waihemo Fault System in the form of the Stranraer, Blue Lake and Hawkdun Faults (Bishop, 1974). The whole fault system is segmented on a large scale, with one range diminishing as another rises (see fig. 2).

Within the corner defined by the Hawkdun–Stranraer Faults and Danseys Pass Fault, Kyeburn Formation fanglomerates, composed of non-marine schist-derived conglomerates, breccias and sands, are preserved on the hangingwall (Bishop and Laird, 1976). These are of similar age and facies to the Horse Range Formation and likewise record the Cretaceous normal displacement on this fault system. The Kyeburn Formation also contains a tuff deposit (Eweburn Tuff of Tulloch et al., 2009), dated at a similar age of 112 Ma as the Shag Valley Ignimbrite.

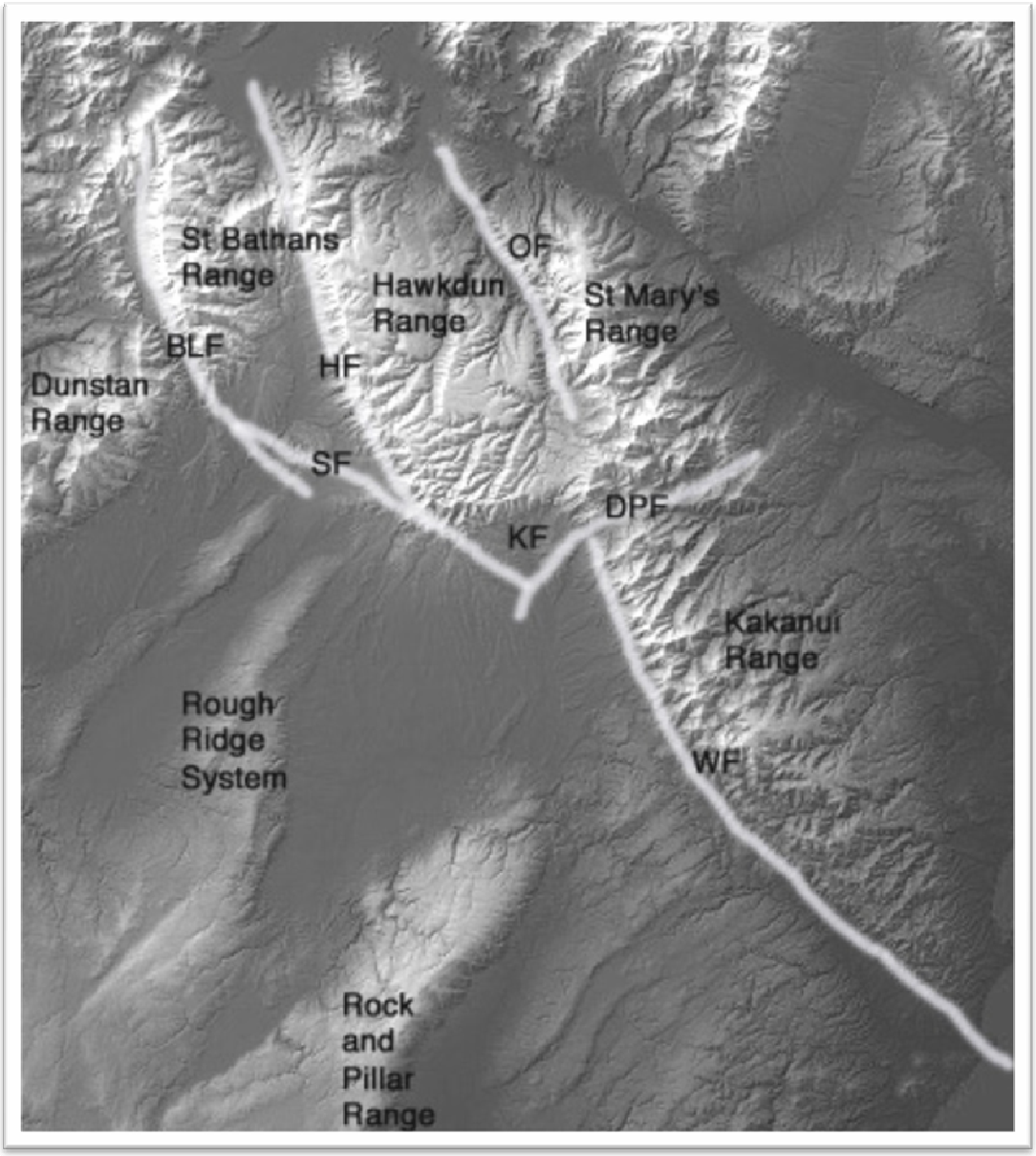


Fig. 2: Topographic model of the Maniototo area showing the main uplifted ranges and the major faults (note that many of these are composite). BLF: Blue Lake Fault; DPF: Danseys Pass Fault; HF: Hawkdun Fault; KF: area underlain by Kyeburn Formation; OF: Otematata Fault; SF: Stranraer Fault; WF: Waihemo Fault.

We turn right towards Danseys Pass. The slopes up to the left are underlain by Kyeburn Formation. Outcrops by the side of the road are mainly of Maniototo Conglomerate. Further along the road, outcrops of Kyeburn Formation are apparent to the left as the road follows the line of the Danseys Pass Fault. White-cream coloured exposures of Hogburn Formation are separated from the Kyeburn by the fault. As we approach STOP 9, old gold workings of the Kyeburn Diggings may be seen along the road and across the river.

~155 km **STOP 9: Danseys Pass Coach Inn** **20 mins**

Refreshment stop. Hot and cold drinks and nibbles are available from the bar.

Danseys Pass Coach Inn is one of the few remaining old coach inns in central Otago dating back to the pioneering days. It was first built in 1862 and has been sensitively maintained and refurbished since then. After refreshments, etc., we will continue following the line of the Danseys Pass Fault as we climb up towards the pass. Danseys Pass is the only drivable road across the northwest trending ranges of the Waihemo Fault System between the Lindis Pass and the coast. The road is fairly rough and windy on this stretch so you may need car sickness medication!

~163 km Danseys Pass summit

~165 km **STOP 10: Viewpoint** **10 mins**

Depending on time and weather, we will stop briefly at a pull-in by the side of the road for people to stretch their legs and admire/photograph the view to the north down the dip-slope of the Kakanui Mountains.

From here, we continue down Danseys Pass Road. Many outcrops of schist may be observed around the road. This side of the Kakanui Mountains slopes much less steeply on average than the scarp slop that we ascended, so the road is long and winding! Views of the Waitaki Valley may be seen in the distance. We cross the Maerewhenua River and follow it down to the north. Large cliffs of the overlying Cretaceous –Tertiary sequence may be seen. Downriver from the Danseys Pass Holiday Park, the lower beds of the Papakaio Formation rest unconformably on schist. As we approach the Waitaki Valley, large quarry faces in the sedimentary succession may be seen to the right. These areas were sluiced for gold until the late 20th century.

~188 km Turn off to right on Tokarahi-Tapui road.

~192 km Tokorahi

At Tokorahi there is a restored Victorian mansion that was the original homestead of one of the great Victorian estates of the region. The hills to the right are capped by the Tokorahi Sill, a basalt intrusion that forms part of the late Eocene Waiareka Volcanic Formation.

~200 km Tapui

~203 km Bear left onto Post Office Gully Road

~206 km Bear right onto Burnside Road

~213 km Entrance to Burnside Homestead on right of road. Turn into gateway, follow drive around to sign for carpark and park in grassy area indicated.

STOP 11: BURNSIDE HOMESTEAD AND BBQ

Those not attending the BBQ will be able to obtain transport from here back to Oamaru. You must exit the vehicles, however, as these vehicles will not be returning directly to Oamaru.

John Reid settled here in 1864 and developed Burnside as an estate. The great homestead at nearby Elderslie was built in 1874 and became the estate centre with Burnside as the working farm of the estate. John Forrester-Reid, the eldest son, built the present Burnside homestead in the mid 1890s and lived there with his family and an entourage of servants until 1928. In 1930, the estate was bought by the Hudson family of Dunedin who owned it until 1974. The present owners and our hosts for the BBQ, Bruce and Alison Albiston, have owned it since then and have carefully restored it to its original glory. It is currently run as a high-class Victorian bed and breakfast.

The Great Hall, Burnside homestead.

DETAILED DESCRIPTION OF STOPS:

STOP 1: HORSE RANGE SUMMIT

At this location we look back across Trotter's Gorge to the north, to see the prominent Horse Range conglomerate cliffs in the distance (fig. 3). The Horse Range Formation is approximately 400 m in this area (Mitchell et al., 2009). They were deposited along the NW trending Waihemo Fault System during a period of normal faulting in the mid Cretaceous (see more info at stop 2).

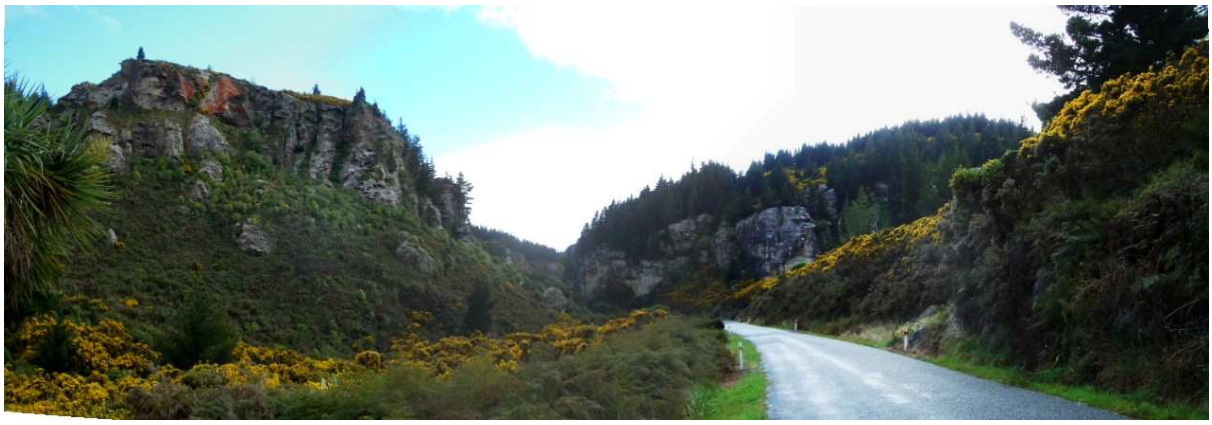


Fig. 3: View towards Trotter's Gorge, with prominent Horse Range conglomerate exposed.

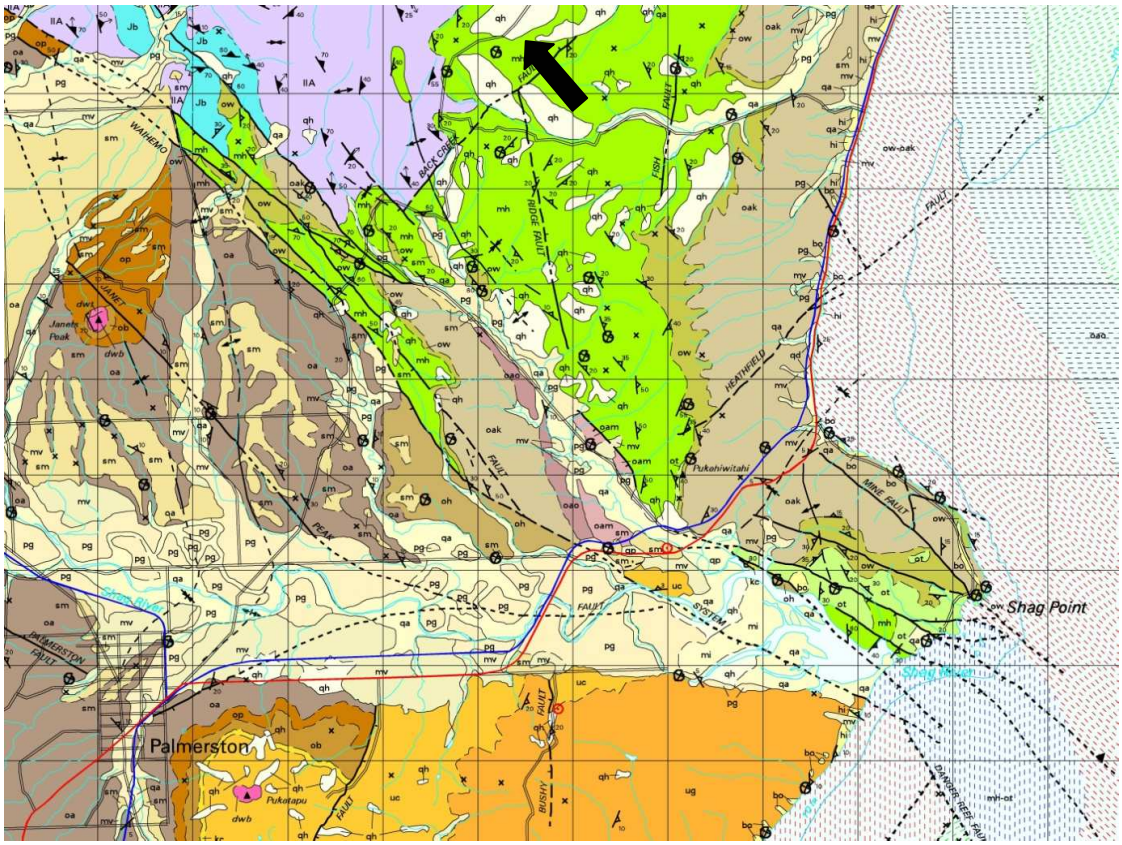


Fig. 4: McMillan's (1999) geological map of Shag Point and Horse Range Mountains. Arrow indicates stop location.