# GEOSCIENCES 09

Annual Conference
Oamaru, NZ

FIELD TRIP 13

# DEEPEST FIORDLAND

Friday 27 November - Friday 4 December
2009

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Turnbull, I.M. (2009). Deepest Fiordland. *In:* Turnbull, I.M. (ed.). Field Trip Guides, Geosciences 09 Conference, Oamaru, New Zealand. Geological Society of New Zealand Miscellaneous Publication 128B. 12 p.

# Deepest Fiordland

"There seems to be no escape from strenuous work if the mapping of further areas of Fiordland is undertaken"
J.H. Miller, 1951

Wet Jacket Arm from Resolution Island, on a good day (A. Allibone, photo).

## Introduction

This post-conference field trip into Fiordland has been designed to show participants some of the more interesting, as well as some of the more controversial, aspects of Fiordland geology which have emerged from the recently completed QMAP 1:250 000 geological map of Fiordland. The part of Fiordland we are visiting (Fig. 1) – from Doubtful Sound south to Dusky Sound via the outer coast – is remote, rugged and spectacular. It is also notorious for rough seas, bad weather, thick bush, and sandflies. We are unlikely to be able to visit all the locations we have on the itinerary, through either inclement conditions or time constraints. The vessel we have chartered, the 25m yatch "*Breaksea Girl*", is very seaworthy and comfortable, with a highly experienced crew who will do their best to make the trip a success. There are also opportunities to see some rare and endangered wildlife, and some of New Zealand's most historic places.

The itinerary has been constrained by having to utilise affordable and easy transport: much of the really interesting geology in Fiordland is hard to get at without taking more time, effort and helicopters. This guide provides only an outline of the geology, and for details, participants will have access to an on-board library of relevant papers which have been published on much of the geology we will see. Copies of the draft Fiordland geological map will also be provided.

Because of the complexity of the geology and the difficulties of access, we can only look at a very small part of the region, but nevertheless should see many of the rock types Fiordland has to offer, as well as some of the key geological relationships in southwest Fiordland. For most of the trip we will be within the inboard part of the Median Batholith, which comprises Paleozoic and Cretaceous plutons that intrude

Paleozoic Western Province metasediments (Fig. 2). Rock units we will see include some Early Cretaceous granulite facies Western Fiordland Orthogneiss (WFO) plutons and their intrusive and tectonic contacts. One WFO pluton is the granulitic to eclogitic Breaksea Gneiss, the most deeply buried WFO unit in Fiordland. Other stops will be on Paleozoic paragneisses and orthogneisses; the Cretaceous Doubtful Sound, Resolution Island and Straight River shear zones; Buller and Takaka terrane sandstones, mudstones and quartzites (Fig. 2); Paleozoic and Cretaceous granites; and Pliocene fossiliferous sediments. We will also look at raised marine terraces, landslides, and evidence of recent tsunami and earthquakes in this tectonically active region.

## Itinerary

We leave Oamaru as soon as possible (ca. 2:30 pm) after the Conference finishes on Friday 27th November. We will travel by Mini-van to Manapouri, via Dunedin and Gore; this will take around 5 hours with fuel stops. Accommodation for the evening is at the Manapouri Motel, where we have one large communal room and a double cabin or two. Meals are in the local pub: breakfast the next morning will be self-service in the motel. A pre-trip briefing from the Breaksea Girl operators will be held in the evening. At the same time, we will need to check and de-contaminate all shore-going field gear for weed seeds (and mice) before landing on Breaksea Island.

Because most of the planned stops are totally dependant on tide, sea, wind and weather conditions, we may not be able to visit them in the order they are listed and we may have to re-schedule some landings on our return voyage from Dusky. Some stops we may not get to at all. Stops are identified, but not numbered consecutively (Fig. 1). Grid references are based on the (old) NZMS 260 sheets B43, B44 and A44 and are approximate only, as exact landing points will be subject to conditions at the time.

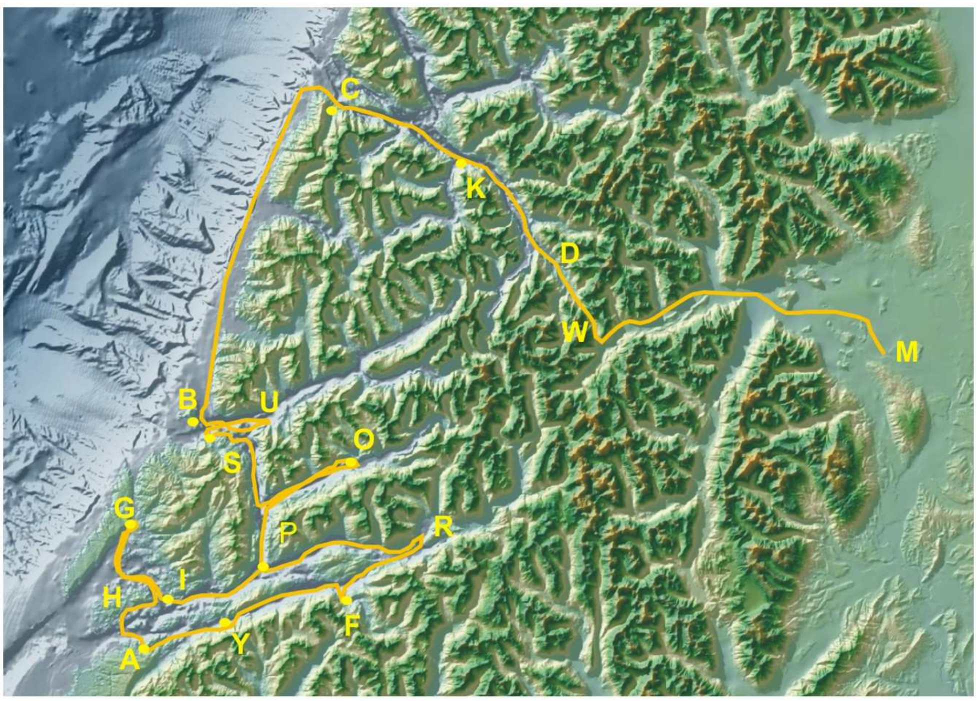


Figure 1: Planned route and landing sites.

## *Saturday 28th November*

An 0800 start from the wharf at Pearl Harbour, Lake Manapouri. Any surplus gear can be left with the Breaksea Girl operators. We will take the regular tourist boat across the lake to West Arm, meet the bus, and hop over Wilmot Pass to meet the Breaksea Girl at Deep Cove. We may visit the West Arm power station either on the way to Deep Cove, or on the way back on the 3rd.

***En route…***Lake Manapouri has been a target for "safari geologists" and radiometric raiders since the days of Turner (1937), but the raiders have recently been suppressed by Scott (2008), and by mapping away from the shoreline into the bush and up the hills. Eastern Manapouri is overlain by Eocene sediments down-faulted along Late Cenozoic faults. Further west, the Lake Manapouri shoreline and the surrounding mountains are dominated by Jurassic to Cretaceous mafic and felsic plutons which are cut by the Early Cretaceous Grebe Mylonite Zone. This large intra-batholithic fault separates inboard and outboard parts of the Median Batholith in some parts of Fiordland (Scott et al. 2009; Allibone et al. 2009a; see Fig. 2). The area from West Arm across Wilmot Pass to Deep Cove was mapped in detail by Gibson (1982) and consists largely of Paleozoic metasediments intruded by Carboniferous to Cretaceous mafic and granitic plutons. Deep Cove itself is the type area for the Cambro-Ordovician Deep Cove Gneiss (DCG), a complex unit of amphibolite, quartzofeldspathic gneisses, marble and calc-silicate. We will see a lot more of the DCG during the trip.

We board the *Breaksea Girl* at Deep Cove, and head out into Doubtful Sound. Watch for dolphins, and fur seals. The spectacular and rugged country south of Doubtful Sound was the subject of another PhD, by Oliver (1976, 1980); key outcrops along the shoreline have since been investigated by numerous enthusiastic Australian geologists (Klepeis, Clarke, Daczko and their students). Doubtful Sound follows the Wilmot Fault (Gibson 1990), a major Late Cretaceous fault separating different plutons of the Western Fiordland Orthogneiss (WFO), as well as different metasedimentary units. To the north, WFO plutons intrude the metasediments (Allibone et al. 2009 in press); to the south, the contact has been significantly disrupted by the north-dipping Doubtful Sound Shear Zone (DSSZ).

### **Kellard Point** (B43/431224)

This is the place to see the DSSZ. The landing will be splashy if the tide and wind are not in our favour, and we may just have to cruise past. At the point, the highly sheared and amphibolitised upper margin of the Cretaceous Malaspina Pluton of the WFO is in tectonic contact with marble mylonites and amphibolites of the Deep Cove Gneiss, which are themselves intruded by Early Paleozoic orthogneisses dated (here) by Gibson & Ireland (1996) at 481.4±8 Ma. These orthogneisses have now been found in several other places within the Paleozoic metasediments (Jongens, this conference). The shear sense determined for the DSSZ here (and elsewhere south of Doubtful Sound) is top down to the NE (Gibson & Ireland 1996; Klepeis et al. 2007) with possibly several km of movement.

Deep Cove Gneiss in the hanging wall of the DSSZ preserves mid amphibolite facies assemblages. Garnet granulite facies assemblages in Malaspina Pluton (WFO) have been largely replaced by amphibolite facies during movement on the shear zone. Isolated lenses of DCG within the shear zone record higher pressures, similar to those in the Malaspina Pluton. These lenses are interpreted as the remnants of a narrow thermal aureole around the Malaspina Pluton, through which the DSSZ developed (Hollis et al. 2004). Elsewhere in the DCG, metastable amphibolite facies assemblages survived emplacement of the Malaspina Pluton (Daczko et al. 2009).

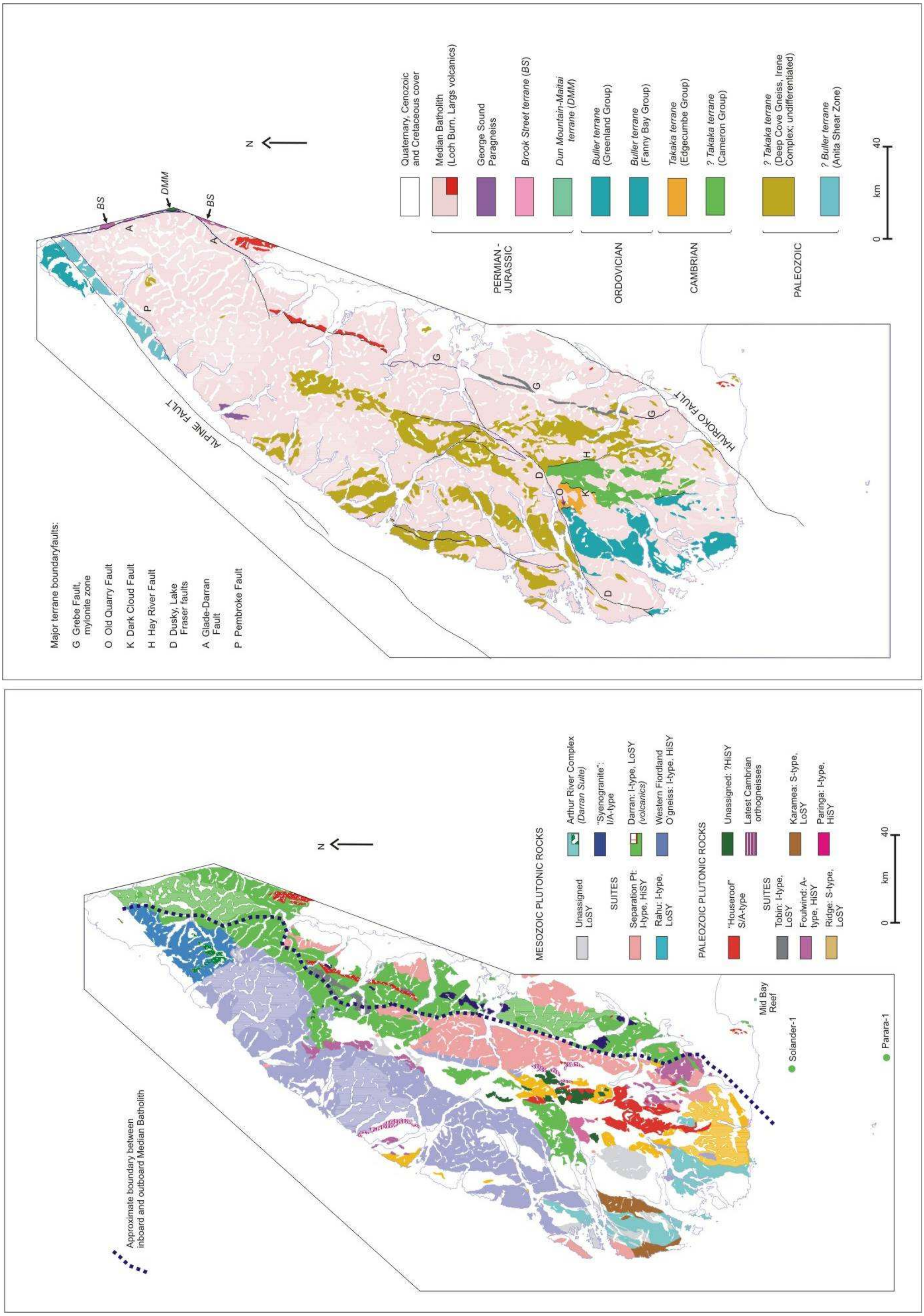

Figure 2: Summary geology of Fiordland: the Median Batholith (l) and Paleozoic terranes (r).

**Cascada Cove** (B43/295283)

Further out along the south wall of Doubtful Sound, Cascada Cove is the last bay before the open sea, opposite Secretary Island. This stop may also be very splashy if there is a swell running, and landing may not be feasible. Cascada Cove is significant for several reasons. Firstly, it was named in 1793 during the little-known Spanish expedition lead by Don Felipe Bauza, the first European exploration of Doubtful Sound. Secondly, it marks the position of the Straight River Fault, a sub-vertical mylonitic fault mapped by Oliver (1980), separating WFO (Malaspina Pluton) from Deep Cove Gneiss metasediments to the west. Steeply dipping mylonite fabrics are the youngest features and mark the main focus of movement within the SRSZ, a zone of deformation which overprints older fabrics within both the Malaspina and Deep Cove gneisses (King et al. 2007). This shear zone is either truncated by the Wilmot Fault, or grades northward into a broad zone of distributed deformation.

Cascada Cove also contains elevated platforms cut into the gneisses and mylonites of the SRSZ. Five platforms have been recognised (Downes et al. 2005), from sea level up to 8.5 m above sea level. These platforms, as well as others on the islets to the north, could be interpreted to as the result of progressive uplift of the coast due to ongoing seismic activity.

***En route…***From Cascada Cove we head out from Doubtful Sound, past the Hares Ears, and south along the outer coast past Dagg Sound and Coal River. This is the longest (3-4 hours) and potentially the roughest leg of the voyage, and takes us to Breaksea Sound. There will be abundant marine bird life (mollymawks, petrels, prions, gulls), probably fur seals, and possibly more dolphins. The coast is all within Deep Cove Gneiss until just north of Coal River Bay, where a contact with another WFO pluton, the Breaksea Orthogneiss, is exposed (but has never been landed on). If the weather is calm we may sail close by; if not, we will be well offshore. The numerous fresh landslides date from the July 2009 Dusky Sound earthquake (Wilson et al. 2009)

**Breaksea Island** (B44/146947)

Breaksea Island at the entrance to Breaksea Sound is a special area within the park, and requires a separate access permit. Predators (rats, mice, stoats) were removed from the island in the 1980's and it is now home to several endangered species, including Saddleback (Tieke) and Fiordland skink. We will land on the (relatively) sheltered eastern shore.

**CHECK ALL GEAR BEFORE LANDING: NO RODENTS: NO PLANTS: NO SEEDS**

Breaksea Island is also the type locality of the Breaksea Orthogneiss, comprising interbanded eclogite and granulite facies gabbro, diorite and rare ultramafic rocks (De Paoli et al., in press and this conference' Allibone et al. 2009b). These rocks have been buried to ca. 80 km and are part of the Western Fiordland Orthogneiss suite. They are probably Early Cretaceous in age. Assemblages include plagioclase-rich omphacite granulite, and omphacite-poor, garnet-rich and plagioclase-poor eclogite (De Paoli et al. in press). Some banding (foliation) is probably inherited from original cumulate layering. The high pressure metamorphic fabrics are cut by amphibolite facies shear zones.

***En route…***We expect to be back on board by late evening, and will probably anchor overnight in Sunday Cove, just inside the entrance to Breaksea Sound. Ships moored in Breaksea and several other fiords were used as floating bases for helicopters flying venison recovery missions. Recommended reading is Grant (1998).

***Sunday 29th September***

As usual, today's itinerary will depend on sea, wind, tide and weather. Several stops are planned on northern Resolution Island. Resolution Island is rat-free. It is currently being cleansed of other predators, with an extensive stoat trapping programme, all the deer will be removed and it will become another island haven for endangered species.

## **Disappointment Cove area** (B44/169929)

The first stop is in or near Disappointment Cove; this site is exposed to the NW and may be inaccessible if the swell is too great. The tiny **Stevens Cove** east of the main bay is an alternative, as is the eastern shore of the **Gilbert Islands**. At these localities the Resolution Orthogneiss, another WFO intrusion (De Paoli et al. in press, and Allibone et al. 2009b), has a gently dipping fabric which is probably related to the overlying Resolution Island Shear Zone. The parent lithology is medium to coarse equigranular hornblende metagabbro and metadiorite. Metamorphic grade is hornblende granulite; Resolution Orthogneiss includes locally hosts xenolithic blocks of Breaksea Orthogneiss.

## **Opposite Entry Island** (B44/186922)

Sea conditions and weather permitting, we will land further east on the northern shore of Resolution Island to look at the Resolution Island Shear Zone (Klepeis et al. 2007). This zone of ductile strain consists of branching amphibolite facies mylonites cutting both underlying WFO gneisses and overlying metasediments of the Deep Cove Gneiss. It has been only partly unravelled, and more work needs to be done. The zone has a general SE dip, but is probably folded (along with overlying metasediments) and it has also been re-activated, with brittle faults and soft pug in some exposures. Marble mylonites similar to those of the DSSZ are present further west. Movement sense is toward the NE, similar to the DSSZ; but there may be more to it than that.

About 1 km east of the RISZ at B44/192917, and truncating it, lies the southern extension of the Straight River Fault, marked here by mylonitised Straight River Granite (perhaps Paleozoic in age). The mylonite fabric is itself folded in places. East of the Straight River Fault lies the Malaspina Pluton, another WFO intrusion. The SRSZ trends southward into Resolution Island, but there it does not mark the Malaspina contact, which is intrusive into Deep Cove Gneiss (Allibone et al. 2009b) If landing here is impossible, an alternative stop is on the north shore of Breaksea Sound at B44/213956. Breaksea Orthogneiss and strongly foliated Straight River Granite are juxtaposed across a ca. 40m wide zone of both ductile and brittle faulting marking the Straight River Shear Zone.

***En route…***From Resolution Island we will head south along Acheron Passage and into Wet Jacket Arm, home of the elusive population of Fiordland moose. It can rain for 50 days on end in this arm, but in compensation there is normally little swell to contend with. The surrounding hills are predominantly granulite facies Malaspina Pluton, with Deep Cove Gneiss occupying synformal inliers.

## **Wet Jacket Arm: several stops around Oke Island**

On the south shore of Wet Jacket opposite Oke Island at B44/315892, an intrusive contact between Malaspina Pluton and Paleozoic metasediment has been described in detail (Allibone et al. 2009b). The contact between massive to weakly foliated diorite with disseminated garnet, and metasediment (psammite and amphibolite) is intrusive, although locally overprinted by foliation in the diorite. Later brittle faults also disrupt the outcrop. A ca. 500 m wide zone of locally garnetiferous migmatites is developed in metasediments and Supper Cove Orthogneiss adjacent to the contact. The migmatites are interpreted as the result of dehydration melting in a narrow thermal aureole around the Malaspina Pluton. Note the lack of marble and marble mylonite at the contact.

More typical amphibolite facies Paleozoic metasediments are well exposed on Oke Island (B44/305898) and will be seen *en route* to the next stop. On the north side of Wet Jacket Arm opposite Oke Island, we will make a brief landing on a stream delta at B44/316907. Of particular interest here are the sandflies, and boulders of quartzose sandstone with rare black mudstone. The sandstone contains fine-grained metamorphic mica and rare garnet and may be Buller terrane. These sediments are infaulted into the surrounding granulite facies WFO and amphibolite facies Deep Cove Gneiss along a major NE-trending brittle fault of probable Cenozoic age.

***En route…***From Oke Island we will head back along Wet Jacket Arm, passing another outcrop of the intrusive WFO-DCG contact at B44/285891on the northern shoreline en route (it is not possible to land here). Depending on time and tide, we may stop at another WFO-DCG intrusive contact at the southern shore (B44/265870). From Wet Jacket we head further south along Acheron Passage.

### **Passage Point** (B44/223793)

At the southeastern corner of Acheron Passage, a sheltered cove retains some of the very scant evidence of the local tsunami which occurred following the July 2009 Dusky Sound earthquake. Look very hard! A cod, several starfish, and gravel and shell material from the bottom of a small bay were washed about 6 m into the bush during this event (Wilson et al. 2009). The rock outcrops at this bay are Paleozoic metasediment within the Deep Cove Gneiss.

***En route…***From Passage Point we will head along Bowen Channel to Duck Cove. Depending on time, we may anchor here, or in Sportsmans Cove, or in Luncheon Cove on Anchor Island. Anchor Island is now predator-free and home to saddleback and kakapo, but we are unlikely to see any. The Dusky Sound earthquake was felt most emphatically by those aboard vessels anchored at Luncheon Cove. This cove is also one of the few sandfly-free parts of Fiordland and was named by Captain Cook who dined there on crayfish.

### ***Monday 30th November***

### **Goose Cove and Five Fingers, western Resolution Island**

The first stop is on the eastern side of Goose Cove around A44/081835. Depending on swell and tide, we will land either north or south of the Shag River mouth to look at relationships between Breaksea and Resolution Orthogneisses in beach side outcrops. Outcrops of the Resolution Orthogneiss lie south of the Shag River mouth, here a relatively mafic variant with early foliation and later almost mylonitic cross-cutting shear zones. Breaksea Orthogneiss blocks occur within the Resolution Orthogneiss. The contact with the Anchor Island Intrusives is not exposed, and may be the southern limit of the RISZ. The orthogneiss is truncated to the west by the Late Cenozoic Two Fingers Fault.

The second planned stop, very much subject to swell conditions, is on the western side of Goose Cove at A44/065826 to look at fossiliferous Pliocene sediments, discovered by the New Golden Hind expedition in 1948. It is a slightly longer excursion to look at new exposures in a July 2009 landslide. If this site is inaccessible, B44/068828 to the north may be an alternative landing. The sediments, faulted against schist across the Five Fingers Fault to the west, consists of basal conglomerate grading upward into carbonaceous mud, lignite, then clean fine sand and finally into macrofossiliferous siltstone (Turnbull et al. 1985).

A brief stop on the Goose Cove gravel barrier, swell permitting, will give a glimpse into Goose Cove itself. The barrier includes many cobbles of schistose sandstone and mudstone, derived from Five Fingers Peninsula to the west. Sediments within the cove have been cored, and may contain evidence of a tsunami dated at 1428-1484 AD, the date of a major earthquake on the Alpine Fault (Downes et al. 2005). The barrier may have been affected by tsunami during the July 2009 event.

***En route….***From Goose Cove we head south back into the maze of islands in outer Dusky Sound. A brief stop may be made at Richard Henry's old house site on Pigeon Island. Richard Henry was the first "caretaker" of Resolution Island, placing many kakapo and other birds there to give them protection against predators which were over-running Fiordland in the late 1800's. Stoats eventually reached Resolution Island, and it is only now being reclaimed, thanks to an enormous effort by DoC.

**Indian Island** (B44/126734)

Country rock throughout much of outer Dusky Sound is the Anchor Island Intrusives, a complex of Paleozoic to Cretaceous dioritic to granitic rocks with rafts of metasediments. The Intrusives have not yet been broken down into map units and only scattered radiometric ages have been obtained. They are intruded by the Cretaceous Indian Island Pluton, a biotite granodiorite which grades into muscovite-garnet granite in more leucocratic parts (Allibone et al. 2007). It is locally K-feldspar megacrystic, and accessory tourmaline is prominent on Thrum Cap. Indian Island Granite intruded metasediments in southwest Fiordland ca. 10 Ma prior to emplacement of the Malaspina Pluton into the same rocks. Local fabric development in the Indian Island pluton may reflect syn- to post-WFO emplacement deformation. We will land at the eastern end of the island, at another historic site where Captain Cook encountered the local "Indians" (Begg & Begg 1966).

We will probably anchor in Luncheon Cove this evening.

***Tuesday 1^st^ December***

**Astronomers Point** (B44/108708)

From Luncheon Cove we will head across outer Dusky Sound. Views to the north, of Five Fingers Peninsula, and to the south above Fannin Bay, are of spectacular raised marine erosion surfaces. The prominent bench to the south at 65 m ASL has been dated at ca. 120 Ka (Kim & Sutherland 2004). It is offset by around 10 m (west side up) by an active fault trace (see Wilson *et al*. 2009, fig. 14).

We will land at Astronomers Point, beside Crayfish Island on the southern shore of Dusky. This site is where Captain James Cook anchored the Endeavour in March 1773, taking astronomical observations, exploring Dusky Sound, meeting the locals and making beer. The tree to which he tied his ship, illustrated in Hodge's paintings, is still visible. A plaque commemorates this historic site (Begg & Begg 1966). The outcrops at the end of the point and on Crayfish Island are Paleozoic amphibolite facies metasediment, migmatitic in places, and invaded by Anchor Island Intrusives and Indian Island Granite. The metasediments are higher grade than those to the southeast across the Dusky and Lake Fraser faults. Together with Indian Island Pluton and Anchor Island Intrusives, they have been traced across outer Dusky Sound and show that the Dusky Fault does not pass straight out to the Tasman Sea. From Astronomers Point we head east, past Cascade Cove into Cook Channel.

**Cook Channel** (B44/150715 and 154717)

If we can find the right place, we will make two stops close together on the south shore of Cook Channel opposite Long Island. Long Island consists of mid amphibolite facies metasediments: garnet biotite quartzofeldspathic gneiss, amphibolite, and minor pelite, calc-silicate and marble. The southern shore is lower grade, greenschist to lower amphibolite facies Buller terrane (Fanny Bay Group) metasandstone and metamudstone. Fanny Bay Group is intruded by the Mt Evans Pluton, a Paleozoic granite with staurolite in its metamorphic aureole. Although the contact is not clearly exposed, representative outcrops of these contrasting rocks will be briefly examined. The Fanny Bay Group rocks have P=4-4.5kb, T=580$^{o}$C; Long Island metasediments to the north have P=7.5kb, T=650$^{o}$C (Daczko et al. 2009).

***En route…*** We head east along Cook Channel, following the Dusky Fault separating higher grade metasedimentary gneisses and orthogneisses from lower grade Buller (and Takaka) terrane rocks to the south, and turn onto Fanny Bay.

**Fanny Bay** (B44/310757 and B44/317747)

The region adjacent to Dusky Sound was the subject of another PhD by Ward (1984). Ward mapped and subdivided the Fanny Bay Group (of the Buller terrane) into several formations, distinguished by various proportions of quartzite, sandstone and graphitic or non-graphitic mudstone. The sequence is folded, and metamorphic grade is mid amphibolite facies. Some higher pressure (kyanite) overprinting has been recognised. We will land first on Fanny Formation at the entrance to the bay, and on Burnett Formation outcrops further into the bay, to look at folding, metamorphic grade, and preserved sedimentary structures in these units. Graptolites occur within this group in Chalky and Preservation inlets to the south but have not yet been found here.

Along the southern shore of Nine Fathom Passage east from Fanny Bay lies the Dusky Sound marble quarry at B44/333777, which was worked in a small way in the 1880s. The marble is infaulted along a strand of the Dusky Fault, and is part of the Edgecumbe Group (Takaka terrane) which is in inferred fault contact (across the Old Quarry Fault) with Buller terrane. Edgecumbe Group outcrops in Nine Fathoms Passage consist of quartzofeldspathic sandstone, mafic volcanic rocks and conglomerate.

If anyone wishes to walk home via the Dusky Track, we can run into Supper Cove at the head of Dusky Sound to drop them off at the start of the track. Supper Cove Orthogneiss, which forms much of the northern Dusky Sound shoreline, is a Cretaceous dioritic orthogneiss of the Darran Suite, far inside the inboard Median Batholith. The Dusky Fault zone trends inland through Shark Cove, has some active traces (Kilcoy, Vincent faults; Powell 2006) and merges into the Spey-Mica Burn Fault System we crossed on the Wilmot Pass road.

We may anchor in Supper Cove for the evening, or head north to another anchorage, depending on the weather forecast.

### *Wednesday 2$^{nd}$ December*

***En route…*** We will head north from Dusky on the return voyage to Doubtful Sound today. If swell and wind are against us it will be a long slog. No stops are planned during this leg of the trip, unless we have been unable to land at some sites on the way south and have time in hand to pick up these missed stops on the way north.

### *Thursday 3$^{rd}$ December.*

We are due to catch the bus back over Wilmot Pass after lunch, so may have the morning free. Options are to walk back up the road and across to the spoil heap from the Manapouri tailrace tunnel, to see a magnificent (but randomly oriented) set of samples from a 7 km long drill hole under the Fiordland mountains; or climb a (steep) bush track above Deep Cove into a hanging valley with Lake Troup in the glacial cirque at the head.

From West Arm we take the boat back across Lake Manapouri to Pearl Harbour and civilisation. The return trip to Dunedin may be this evening, or on the morning of the 4$^{th}$ December.

"The best view of Fiordland is from the back of the boat heading home across the lake"

(anonymous QMAP fieldie, after a month in the scrub)

## References

A library of papers relevant to the Doubtful-Dusky area will be aboard the "Breaksea Girl", along with pre-press copies of the Fiordland QMAP sheet. We will also have bound on board, copies of the Oamaru Conference abstracts (including several relevant papers); and their presenters. The following reference list is not comprehensive.


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(Breaksea Orthogneiss at Coal River, on a bad day)